3100 3200 3300 3500

COMPUTER SYSTEMS

COMPASS

PROGRAMMING TRAINING MANUAL

CONTROL DATA CORPORATION

INSTRUCTION INDEX

BY OCTAL OPERATION CODE

OCTAL OPERATION CODE	MNEMONIC OPERATION CODE	SECTION NUMBER
00.0	HLT	3.5.5
00.1	~~SJ1~~	3.5.6
00.2	~~SJ2~~	3.5.6
00.3	~~SJ3~~	3.5.6
00.4	~~SJ4~~	3.5.6
00.5	~~SJ5~~	3.5.6
00.6	~~SJ6~~	3.5.6
00.7	RTJ	3.5.4
01	UJP,I	3.5.1
02.0	No Operation	
02.1-3	IJI	3.5.7
02.4	No Operation	
02.5-7	IJD	3.5.7
03.0	AZJ,EQ	3.5.2
03.1	AZJ,NE	3.5.2
03.2	AZJ,GE	3.5.2
03.3	AZJ,LT	3.5.2
03.4	AQJ,EQ	3.5.3
03.5	AQJ,NE	3.5.3
03.6	AQJ,GE	3.5.3
03.7	AQJ,LT	3.5.3
04.0	ISE	3.6.1
04.1-3	ISE	3.6.1
04.4	ASE,S	3.6.1
04.5	QSE,S	3.6.1
04.6	ASE	3.6.1
04.7	QSE	3.6.1
05.0	ISG	3.6.2
05.1-3	ISG	3.6.2
05.4	ASG,S	3.6.2
05.5	QSG,S	3.6.2
05.6	ASG	3.6.2
05.7	QSG	3.6.2
06.0-7	MEQ	11.1
07.0-7	MTH	11.2
10.0	SSH	11.3
10.1-3	ISI	3.6.3
10.4	ISD	3.6.3
10.5-7	ISD	3.6.3
11.0	ECHA	8.2.6
11.4	ECHA,S	8.2.6
12.0-3	SHA	3.8.2
12.4-7	SHQ	3.8.2
13.0-3	SHAQ	5.3
13.4-7	SCAQ	13.5
14.0	NOP	
14.1-3	ENI	3.4.4
14.4	ENA,S	3.4.4
14.5	ENQ,S	3.4.4
14.6	ENA	3.4.4
14.7	ENQ	3.4.4
15.0	No Operation	
15.1-3	INI	3.4.3
15.4	INA,S	3.4.1
15.5	INQ,S	3.4.2
15.6	INA	3.4.1
15.7	INQ	3.4.2
16.0	No Operation	
16.1-3	XOI	7.5.4
16.4	XOA,S	7.5.2
16.5	XOQ,S	7.5.3
16.6	XOA	7.5.2
16.7	XOQ	7.5.3
17.0	No Operation	
17.1-3	ANI	7.4.4
17.4	ANA,S	7.4.2
17.5	ANQ,S	7.4.3
17.6	ANA	7.4.2
17.7	ANQ	7.4.3
20	LDA,I	3.1.1
21	LDQ,I	3.1.2
22	LACH	8.2.1
23	LQCH	8.2.2
24	LCA,I	7.3.1
25	LDAQ,I	5.1
26	LCAQ,I	7.3.2
27	LDL,I	7.2
30	ADA,I	3.3.1
31	SBA,I	3.3.2
32	ADAQ,I	6.1
33	SBAQ,I	6.2
34	RAD,I	3.3.5
35	SSA,I	7.6
36	SCA,I	7.5.1
37	LPA,I	7.4.1
40	STA,I	3.2.1
41	STQ,I	3.2.2
42	SACH	8.2.3
43	SQCH	8.2.4
44	SWA,I	3.7
45	STAQ,I	5.2
46	SCHA,I	8.2.5
47	STI,I	3.2.3
50	MUA,I	3.3.3
51	DVA,I	3.3.4
52	CPR,I	11.4
53.01	TMQ	9.3.1
53.02	TMA	9.2.1
53.04	AQA	9.5.1
53.(0+b)0	TIA	9.1.1
53.(0+b)3	TMI	9.4.1
53.(0+b)4	AIA	9.5.2
53.41	TQM	9.3.2
53.42	TAM	9.2.2
53.(4+b)0	TAI	9.1.2
53.(4+b)3	TIM	9.4.2
53.(4+b)4	IAI	9.5.3
54	LDI,I	3.1.3
55.0	No Operation	
55.1	ELQ	13.3.1
55.2	EUA	13.2.1
55.3	EAQ	13.4.1
55.4	No Operation	
55.5	QEL	13.3.2
55.6	AEU	13.2.2
55.7	AQE	13.4.2
56	MUAQ,I	6.3
57	DVAQ,I	6.4
60	FAD,I	12.3.1
61	FSB,I	12.3.2
62	FMU,I	12.3.3
63	FDV,I	12.3.4
64	~~LDE~~	14.2.6
65	STE	14.2.7
66	ADE	14.2.8
67	SBE	14.2.9
70.0-3	SFE	14.2.1
70.4	~~EZJ,EQ~~	14.2.2
70.5	~~EZJ,LT~~	14.2.3
70.6	EOJ	14.2.4
70.7	SET	14.2.5
71	SRCE,INT	10.2.1
71	SRCN,INT	10.2.2
72	MOVE,INT	10.3
73	INPC,INT, B,H	20.6
73	INAC,INT	20.8.1
74	INPW,INT, B,N	20.4
74	INAW,INT	20.8.2
75	OUTC,INT, B,H	20.7
75	OTAC,INT	20.8.3
76	OUTW,INT, B,N	20.5
76	OTAW,INT	20.8.4
77.0	CON	20.2
77.1	SEL	20.3
77.2	EXS	20.9.1
77.2	COPY	20.9.2
77.3	INS	20.9.4
77.3	CINS	20.9.5
77.4	INTS	20.9.3
77.50	INCL	21.2
77.51	IOCL	
77.52	SSIM	21.1
77.53	SCIM	
77.54-56	No Operation	
77.57	IAPR	
77.6	PAUS	10.4 & 20.10.5.3
77.70	SLS	
77.71	SFPF	
77.72	SBCD	
77.73	DINT	
77.74	~~EINT~~	21.1-2
77.75	CTI	20.10.5.1
77.76	CTO	20.10.5.2
77.77	~~UCS~~	

BY MNEMONIC OPERATION CODE

MNEMONIC OPERATION CODE	SECTION NUMBER
ADA,I	3.3.1
ADAQ,I	6.1
ADE	14.2.8
AEU	13.2.2
AIA	9.5.2
ANA	7.4.2
ANA,S	7.4.2
ANI	7.4.4
ANQ	7.4.3
ANQ,S	7.4.3
AQA	9.5.1
AQE	13.4.2
AQJ,EQ	3.5.3
AQJ,GE	3.5.3
AQJ,LT	3.5.3
AQJ,NE	3.5.3
ASE	3.6.1
ASE,S	3.6.1
ASG	3.6.2
ASG,S	3.6.2
AZJ,EQ	3.5.2
AZJ,GE	3.5.2
AZJ,LT	3.5.2
AZJ,NE	3.5.2
CINS	20.9.5
CON	20.2
COPY	20.9.2
CPR,I	11.4
CTI	20.10.5.1
CTO	20.10.5.2
DINT	
DVA,I	3.3.4
DVAQ,I	6.4
EAQ	13.4.1
ECHA	8.2.6
ECHA,S	8.2.6
EINT	21.1-2
ELQ	13.3.1
ENA	3.4.4
ENA,S	3.4.4
ENI	3.4.4
ENQ	3.4.4
ENQ,S	3.4.4
EOJ	14.2.4
EUA	13.2.1
EXS	20.9.1
EZJ,EQ	14.2.2
EZJ,LT	14.2.3
FAD,I	12.3.1
FDV,I	12.3.4
FMU,I	12.3.3
FSB,I	12.3.2
HLT	3.5.5
IAI	9.5.3
IAPR	
IJD	3.5.7
IJI	3.5.7
INA	3.4.1
INA,S	3.4.1
INAC,INT	20.8.1
INAW,INT	20.8.2
INCL	21.2
INI	3.4.3
INPC,INT, B,H	20.6
INPW,INT, B,N	20.4
INQ	3.4.2
INQ,S	3.4.2
INS	20.9.4
INTS	20.9.3
IOCL	
ISD	3.6.3
ISE	3.6.1
ISG	3.6.2
ISI	3.6.3
LACH	8.2.1
LCA,I	7.3.1
LCAQ,I	7.3.2
LDA,I	3.1.1
LDAQ,I	5.1
LDE	14.2.6
LDI,I	3.1.3
LDL,I	7.2
LDQ,I	3.1.2
LPA,I	7.4.1
LQCH	8.2.2
MEQ	11.1
MOVE,INT	10.3
MTH	11.2
MUA,I	3.3.3
MUAQ,I	6.3
NOP	
OTAC,INT	20.8.3
OTAW,INT	20.8.4
OUTC,INT, B,H	20.7
OUTW,INT, B,H	20.5
PAUS	10.4 & 20.10.5.3
QEL	13.3.2
QSE	3.6.1
QSE,S	3.6.1
QSG	3.6.2
QSG,S	3.6.2
RAD,I	3.3.5
RTJ	3.5.4
SACH	8.2.3
SBA,I	3.3.2
SBAQ,I	6.2
SBCD	
SBE	14.2.9
SCA,I	7.5.1
SCAQ	13.5
SCHA,I	8.2.5
SCIM	
SEL	20.3
SET	14.2.5
SFE	14.2.1
SFPF	
SHA	3.8.2
SHAQ	5.3
SHQ	3.8.2
SJ1	3.5.6
SJ2	3.5.6
SJ3	3.5.6
SJ4	3.5.6
SJ5	3.5.6
SJ6	3.5.6
SLS	
SQCH	8.2.4
SRCE,INT	10.2.1
SRCN,INT	10.2.2
SSA,I	7.6
SSH	11.3
SSIM	21.1
STA,I	3.2.1
STAQ,I	5.2
STE	14.2.7
STI,I	3.2.3
STQ,I	3.2.2
SWA,I	3.7
TAI	9.1.2
TAM	9.2.2
TIA	9.1.1
TIM	9.4.2
TMA	9.2.1
TMI	9.4.1
TMQ	9.3.1
TQM	9.3.2
UCS	
UJP,I	3.5.1
XOA	7.5.2
XOA,S	7.5.2
XOI	7.5.4
XOQ	7.5.3
XOQ,S	7.5.3

3100
3200
3300
3500

COMPASS PROGRAMMING TRAINING MANUAL

May 1967
Pub. No. 60184200

Aknowledgement

With the exception of an index, three appendices, two additional chapters, a few new sections and extensive editting, the very excellent programming training manual that follows has been written by Mr. H. D. Pridmore and his staff at Commonwealth Bureau of Census and Statistics in Australia. We are grateful to Mr. Pridmore and the Bureau for permission to modify and print their manual so that all 3100/3200/3300/3500 users may benefit from their efforts.

EDP Education Services Department
Corporate Marketing
Control Data Corporation
May 8, 1967

CONTENTS

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

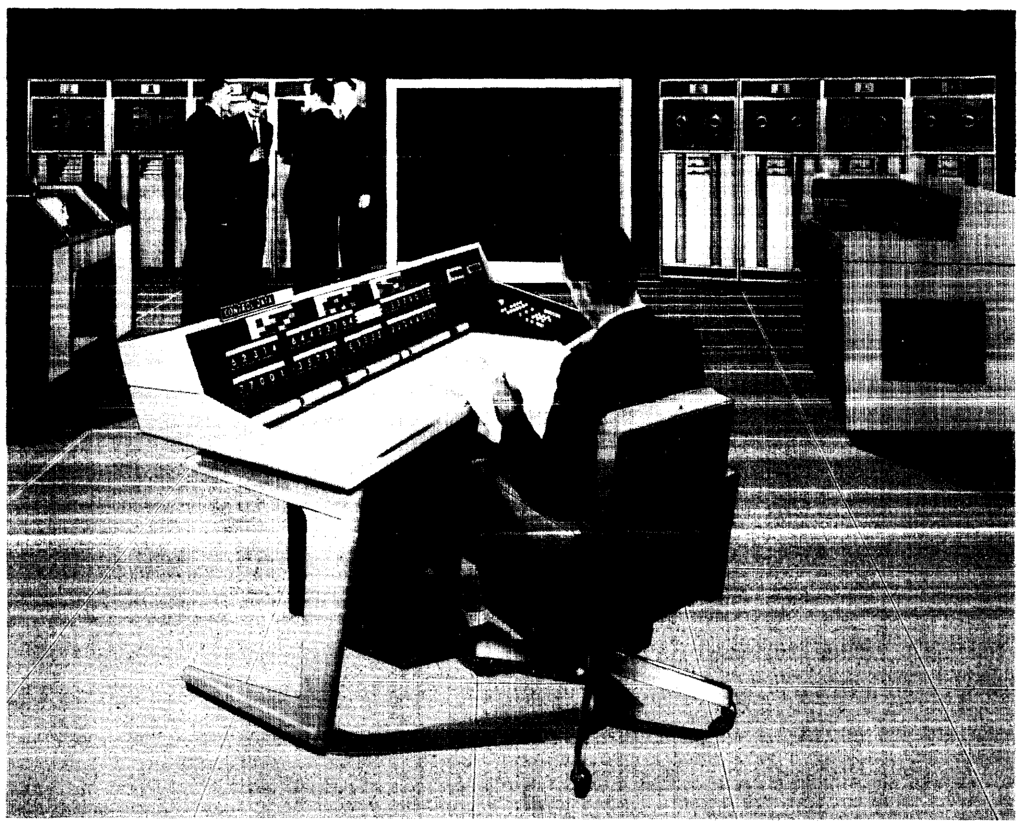
CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

INTRODUCTION TO 3100/3200/3300/3500 COMPUTER HARDWARE

The majority of the programming that will be done for the 3100/3200/3300/3500 computers will be done with a subset of the total instruction repertoire for the particular machine. The subset chosen for this manual applies primarily to the 3100/3200 computers because of the BCD instructions chosen. If this chapter were eliminated, what remains applies equally to all computers in the series. The 3300/3500 computers in addition to having different BCD instructions, have some additional features and instructions. These will not be discussed here. The student is referred to the appropriate machine reference manual for a description of those additions. The timing information included in this manual applies to the 3200/3300 computers. 3100 times are about forty percent higher; 3500 times are at least forty percent lower. Other then in the case of timing information and the BCD instructions, the manual points out those areas that are specifically 3200, which was the machine chosen as representative of those in the series.

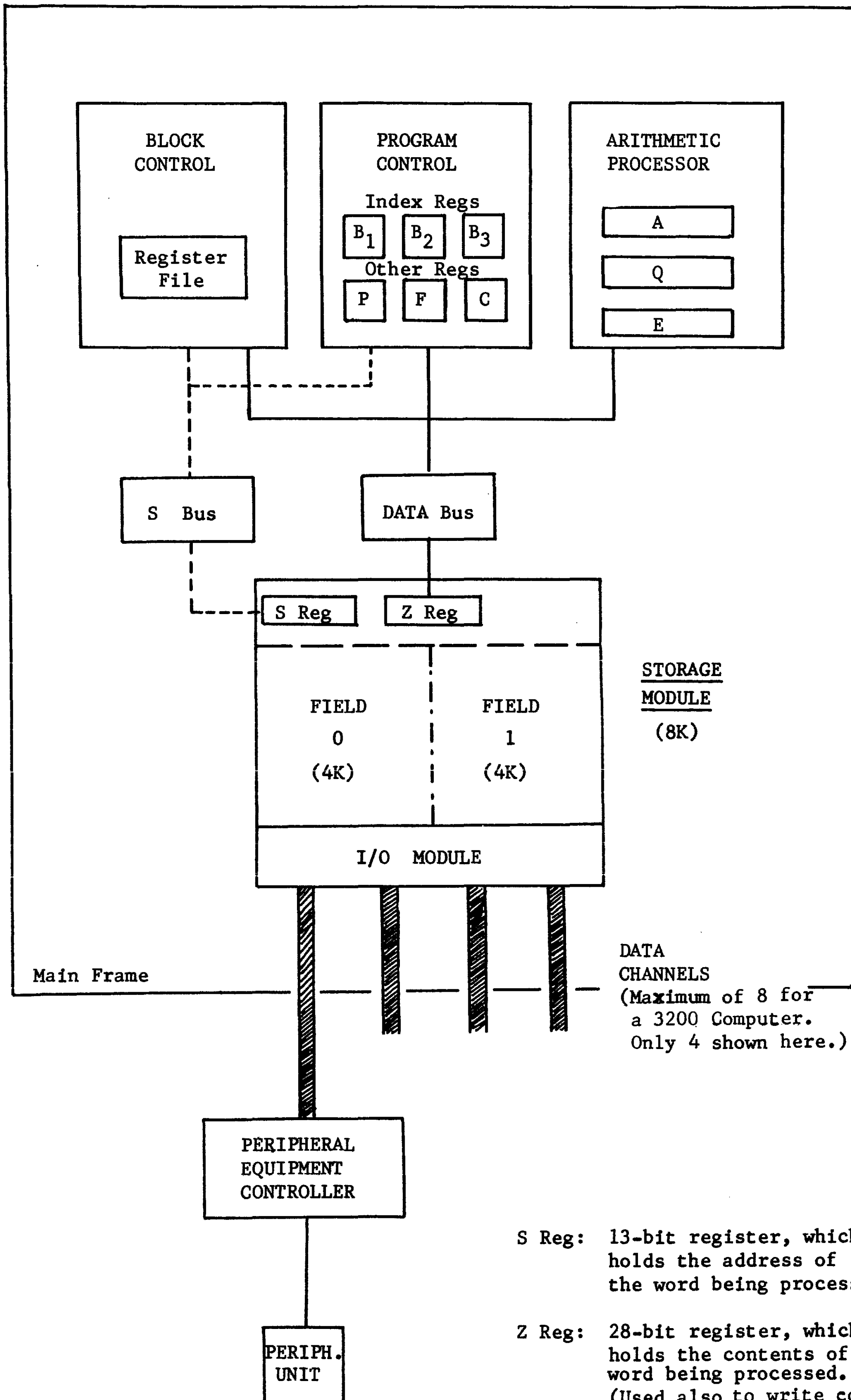


3200 COMPUTER SYSTEM

STUDENT NOTES

1.1 3200 HARDWARE

1.1.1 Diagram of 3200 computer



S Reg: 13-bit register, which holds the address of the word being processed.

Z Reg: 28-bit register, which holds the contents of the word being processed. (Used also to write contents of word back into store.)

1.1.2 Data Bus

The data bus is the path along which data flows between the various sections of the computer. The sections (storage, the arithmetic unit, the console typewriter, and the input/output section) are connected in parallel to the data bus. During execution of each instruction, program control determines which unique path is to be enabled so that the function called for in the program instruction can be carried out.

The data bus contains a 24-bit register called the Data Bus Register (DBR) which is used to hold data temporarily during a data transfer.

1.1.3 Arithmetic Section

The arithmetic section of the 3200 processor consists of three operational registers, namely -

(i) A - arithmetic register
(ii) Q - auxiliary arithmetic register
(iii) E - optional arithmetic register.

(i) The A Register (Accumulator)

The A Register is the principal arithmetic register. It is a 24-bit register, whose contents can be displayed on the console of the 3200.

All arithmetic and logical operations use the A register in formulating a result. It is the only register with provision for adding its contents to the contents of a storage word or another register.

(ii) The Q Register (Quotient)

The Q register is an auxiliary register and is generally used in conjunction with the A register. It is a 24-bit register, whose contents can be displayed on the 3200 console. Combined with A it forms a 48-bit register, AQ. Most arithmetic operations possible with the A register are also possible with the AQ register. The Q register often is used to provide temporary storage for the contents of the A register while the A register is used for some other operation.

(iii) The E Register

This register acts as a supplement to the AQ register. It is a 48-bit register, whose contents can be displayed on the 3200 console, in the display sections usually occupied by A and Q. (The upper 24 bits of E - called E_U - are displayed in A, and the lower 24 bits of E - called E_L - are displayed in Q.) The register is used in 48-bit precision multiplication and division, and in floating point multiplication and division.

In BCD operations, the E register is designated the E_D register, and its size is extended to 53 bits, to enable it to handle thirteen 4-bit characters, plus a sign bit.

1.1.4 Program Control

The program control section contains six operational registers, all of which may be displayed on the 3200 console. They are -

(i) F - program control register
(ii) P - Program address counter
(iii) C - Communication register
(iv) B - Three index registers, B_1, B_2, and B_3

(i) The F Register

This 24-bit register is used to hold the instruction during the time it is being executed.

(ii) The P Register

This 15-bit register holds the address of the instruction currently being executed, and generates, in sequence, the storage addresses which contain the individual instructions. After execution of an instruction, P is altered to indicate the address of the next instruction to be read. The address is sent via the S (address) BUS to the specified storage module where the instruction is read.

(iii) The C Register

The 24-bit C register is used to enter quantities into Storage, A, Q, E, B or P registers via the console key board. The quantity is entered in C, and then transferred to the specified register when the "transfer" button on the keyboard is pushed.

(iv) The B Registers

The 15-bit B registers (Index registers) are used principally as counters and instruction modifiers.

1.1.5 Block Control

For a general description of the use of Block Control see Section 10.1.

(i) The Register File

The register file is a 64 word (24-bits per word) rapid access memory with a cycle time 0.5 microseconds. Although the programmer can access all registers in the file with the inter-register transfer instructions, certain registers are reserved for specific purposes. These are defined in the following table:

1.1.5 (cont.)

REGISTER NUMBER	RESERVED FOR
00-07	Modified I/O instruction word containing the current character address (Channel 0-7 control)
10-17	Modified I/O instruction word containing the last character address plus (or minus) one (Channel 0-7).
20	Current character address for search control
21	Source address for move control
22	Real time clock, current time
23	Current character address for typewriter control
24-27	Temporary storage
30	Last character address + 1 for search control
31	Destination address for move control
32	Real time clock, time at which to generate interrupt
33	Last character address + 1 for typewriter control
34-77	Temporary storage

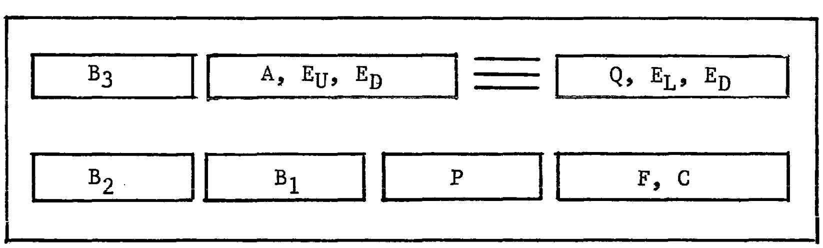
Because of the fast access time, use of Registers 24-27 and 34-77 as temporary storage will speed up program execution. Other registers may also be used for temporary storage if their use will not disrupt operations in progress.

(ii) The Real Time Clock

The real time clock is a 24-bit counter that is incremented each millisecond. The current time is stored in Register 22. It is removed from storage each millisecond, updated, and compared with the contents of Register 32. When the two are equal, an interrupt condition occurs.

The clock has a period of 16,777,216 milliseconds (approximately 4 hours 40 minutes). It starts as soon as power is supplied to the computer. Its contents may be examined at any time by transferring them to the A register using an inter-register transfer statement. It may be reset to any 24 bit quantity (including zero) by loading A, and transferring the contents of A into Register 22.

1.1.6 Diagram of 3200 Console Register Display



1.2 3200 CORE STORAGE

1.2.1 Storage Word

27	26	25	24	23 — 18	17 — 12	11 — 06	05 — 00
P_0	P_1	P_2	P_3	Character 0	Character 1	Character 2	Character 3
Parity bits				Character designators			

The 3200 is a word machine with each word consisting of 28 bits. Each word may be regarded as four 6-bit characters as shown above, with parity bits for each character located in bits 24-27.

1.2.2 Word Addressing

Each word in the storage of the 3200 is addressable. The address of a particular word is its relative position in the storage. The first word is word 00000, the second is word 00001, the third 00002, etc. The address is specified as five octal digits, which may be broken down to indicate the actual location of the word in core.

The 3200 core is composed of modules of 8,192 words each. There may be up to four such modules attached to the computer, and the modules are numbered from 0 through 3. Thus an 8K 3200 would have only one module, numbered 0_8 (00_2), a 16K 3200 would have two modules, 00_2 and 01_2, and so on.

Each 8K module is made up of two 4,096 word fields, numbered field 0 and field 1.

Module 00

Field 0	Field 1

Within each field, words may be regarded as numbered from 0000 to 7777_8 (4096_{10} words). The position of a word in a field is known as its Co-ordinate address in that field.

Thus a 15-bit address 01200_8 may be divided up to indicate its position in core as follows:

bits 00 - 11 indicate the co-ordinate address (1200_8)

bit 12 indicates the field (0)

bits 13 - 14 indicate the module (0)

Examples:

Address 31040_8 = Module 1, field 1, address 1040_8

Address 77777_8 = Module 3, field 1, address 7777_8

INTRODUCTION TO SCOPE/COMPASS

Chapter 2

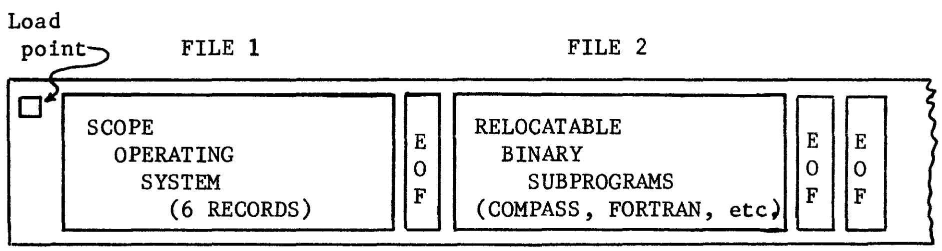
2.1 INTRODUCTION TO THE SCOPE MONITOR

The SCOPE monitor is a program that provides a system of operator and programmer aids to increase through-put and to simplify the operator's job.

Its purpose is to increase job processing efficiency by increasing information through-put, and to minimize operator errors, operator intervention and idle computer time.

2.1.1 SCOPE Library Tape

The library tape serves as the source for the SCOPE operating system as well as those library routines operating under control of SCOPE. The tape consists of two files:



LIBRARY TAPE FORMAT

The first file consists of absolute binary information which, from this point on, will be considered the SCOPE operating system. The second file consists of relocatable binary subprograms such as COMPASS, FORTRAN, COBOL, etc.

2.1.2 SCOPE System Terms

RUN

The complete execution of a subprogram under the control of SCOPE.

JOB

The sets of tasks assigned to SCOPE by the programmer. A job consists of one or more runs.

STACKED JOBS

A stack consists of one or more jobs. The termination of a job is signaled by the printout of the SEQUENCE card for the next job.

NON-STACKED JOBS

A stack which consists of only one job. The presents of the "NS" parameter on the job card indicates that this job is a non-stacked job.

The termination of a non-stacked job is signaled by the printout of "NORMAL END" or "ABNORMAL END" at which time processing will halt.

2.1.2 (cont.)

SUBPROGRAM

The smallest unit recognized by the SCOPE LOADER.

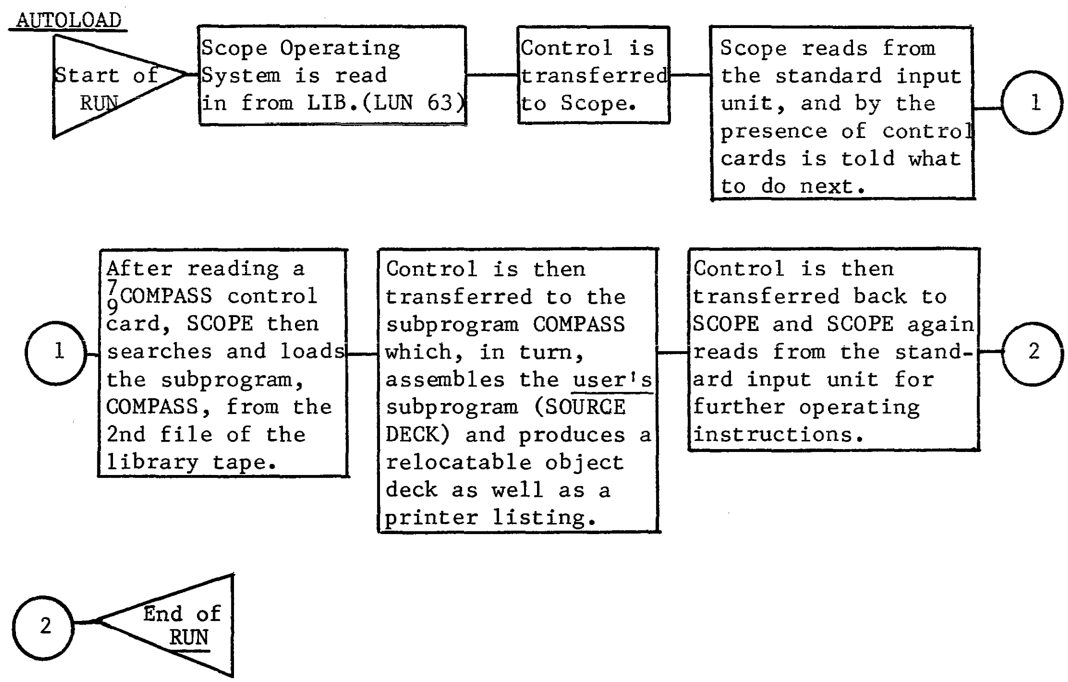
LUN

A two-digit decimal number representing a logical reference to a physical I/O unit.

2.1.3 SCOPE Control Card

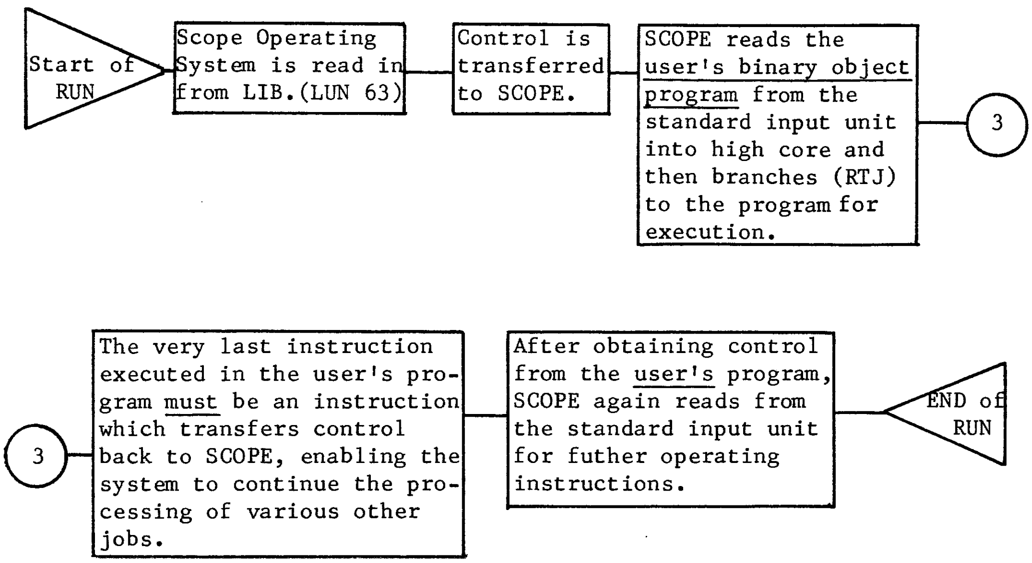
Refer to Chapter 17

2.1.4 SCOPE/COMPASS Run



SCOPE/COMPASS RUN

2.1.5 SCOPE/Program Execution Run



SCOPE/PROGRAM EXECUTION RUN

2.2 INTRODUCTION TO THE COMPASS ASSEMBLY SYSTEM

(a) COMPASS is the COMPrehensive ASsembly System for use with Control Data Computers.

(b) COMPASS operates under the SCOPE monitor system.

(c) COMPASS enables the programmer to write machine language through the use of mnemonic instructions and symbolic addresses. The COMPASS assembler translates these instructions and addresses into machine language.

(d) In COMPASS source language, the programmer is also able to specify constants, exercise control over subprogram communication and control the assembly process with a powerful set of PSEUDO (assembly) instructions.

(e) A COMPASS program consists of a number of linked subprograms, each of which will be assembled independently and linked by the LOADER, prior to execution of the program.

(f) A COMPASS subprogram consists of lines of coding preceded by an IDENT pseudo instruction, and followed by an END pseudo instruction. The size of the subprogram and the magnitude of the problems solved by it are at the discretion of the programmer.

2.2.1 Assembly Process

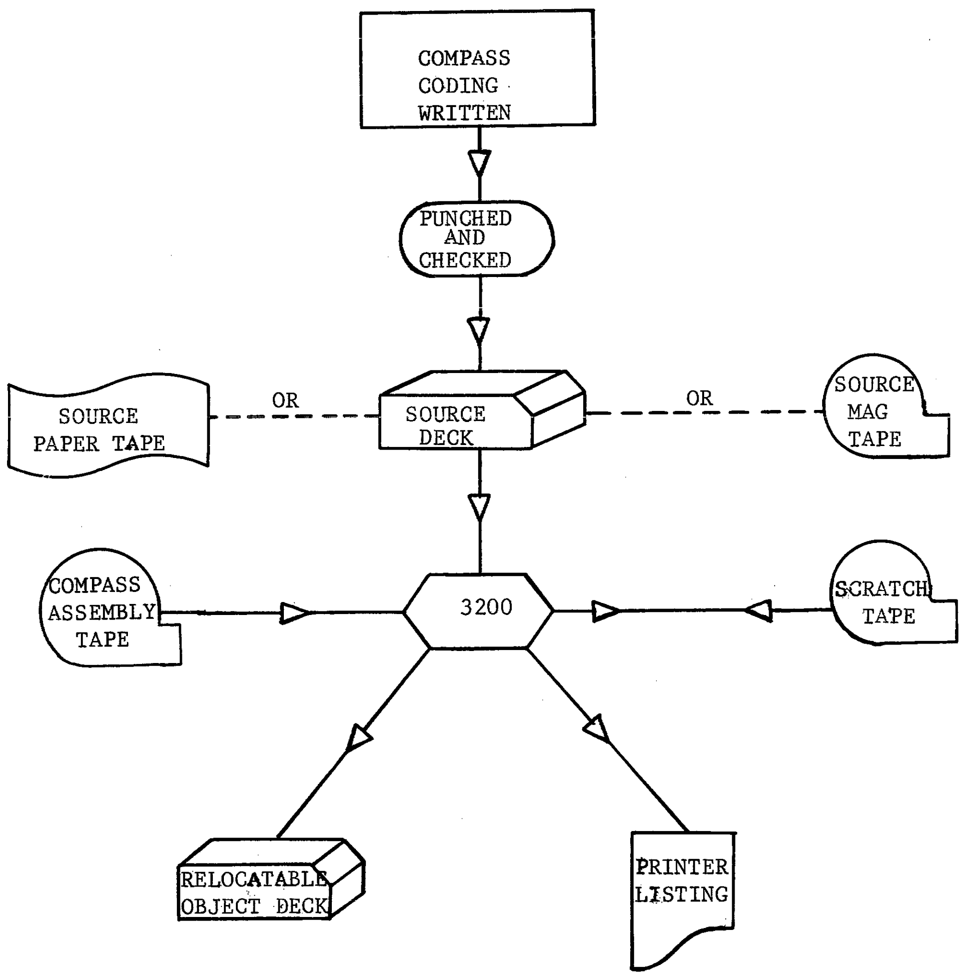
(a) Assembly language is much closer to machine code than languages like FORTRAN and COBOL. A line of FORTRAN coding may generate many machine instructions (perhaps in the ratio of 1:10). Most COMPASS instructions generate only one machine instruction.

Example : STA   CØUNT
If CØUNT is located at address 174_8,
this instruction would be assembled as

40000174

(b) The assembly process may be represented diagrammatically as follows:

DIAGRAM OF THE ASSEMBLY PROCESS



Note: (a) The COMPASS assembly program converts programs written in COMPASS into machine language for execution under the SCOPE monitor system.

(b) Source programs may be punched on cards or paper tape, or written on magnetic tape.

(c) Output from the assembler includes an assembly listing and a relocatable binary object deck. The output deck may be punched out on cards, or written on a magnetic tape for immediate execution.

(d) What does the assembler do?

(i) Allocates storage locations to instructions and to blocks defined in pseudo or area-definition instructions. Note use of "ORGR".

(ii) Replaces symbolic addresses with allocated storage locations from (i).

(iii) Replaces symbolic instruction addresses with actual instruction addresses from (i).

(iv) Indicates index register use and/or indirect addressing in the relevant bits of the necessary instructions.

(v) Converts mnemonic operation-codes to machine language equivalents.

(vi) Stores literals in a special literal table, after checking for any prior use of that literal.

(vii) Replaces literals in the instructions with the addresses of the table locations of the literals.

(viii) Check for assembly language (source language) errors and generates necessary diagnostic messages.

Most assemblers perform these functions in a number of passes. The source program is first written on to tape, at the same time carrying out some of the above functions. Then the tape is passed against the assembler at least once more to carry out the remainder of the functions.

2.2.2 General Word Addressing Instruction Format

The 3200 (24-bit) word addressing instruction takes the following general form -

Bit position	23 – 18	17	16 – 15	14 – 00
	(6 bits)	(1 bit)	(2 bits)	(15 bits)
	f	a	b	m or y

Where f = function code of 6 bits.
Range is 00_8 through 77_8.
This code determines the type of action to be carried out.

e.g. 20_8 = Load the A register.

31_8 = Subtract from the A register.

a = Addressing mode of 1 bit.
If this bit is a zero, direct addressing is carried out.
If this bit is a 1 bit, indirect addressing is carried out.

b = Index designator of 2 bits.
If b = 00, no index is used
If b = 01, index 1 is used
b = 10, index 2 is used
b = 11, index 3 is used.

m = Execution address of 15 bits.
This is the <u>address</u> in memory at which data required for execution will be found. The 24-bit quantity found at that address will be used in a manner determined by the rest of the instruction.

y = Operand of 15 bits.
This specifies a 15 bit <u>quantity</u> which will be used as data in some way. It is the <u>actual data</u>, not the address of the data.

<u>Exercise</u>: Divide up the following octal instructions into their components:

20400100
27100000
56201010
01322222
77654321
46077776
17500000
66766766

Note that the address "m" specified in a word address instruction can be divided further to indicate its actual location in storage.

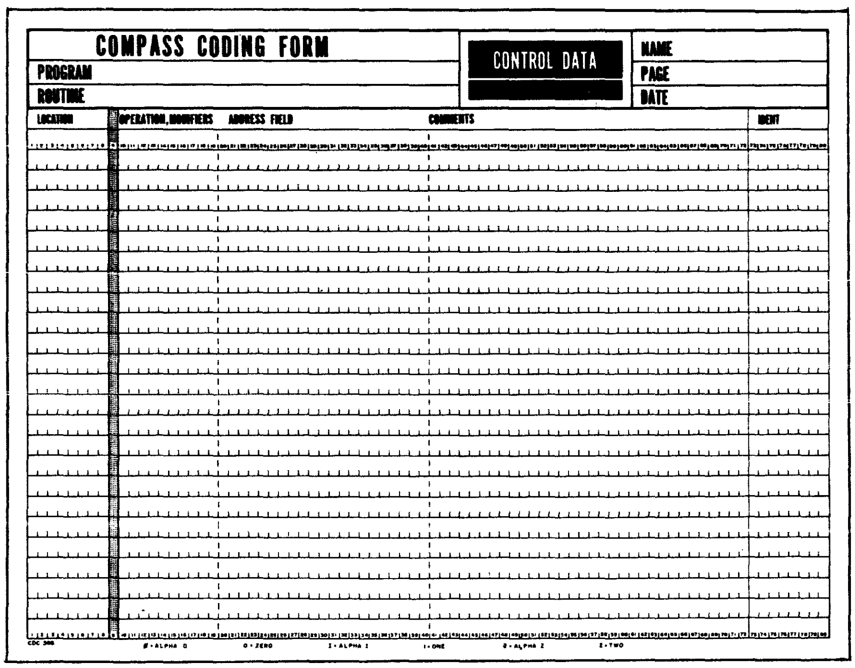
2.2.3. COMPASS Source Program - Coding

The following fields are used on the COMPASS coding sheets and on COMPASS punched cards.

NAME OF FIELD	COLUMNS ON CARD OR CODING SHEET
Location	1 - 8
Operation	10 - 20
Address	21 - 40
Comments	41 - 72
Identification	73 - 80

The use of these fields is discussed following the samples of the COMPASS CODING FORM and the COMPASS CARD.

Instructions in subprograms to be assembled by COMPASS are written on coding forms. The information on the coding form will be punched into cards or prepared on other suitable media for input to COMPASS. Following is a sample COMPASS CODING FORM.

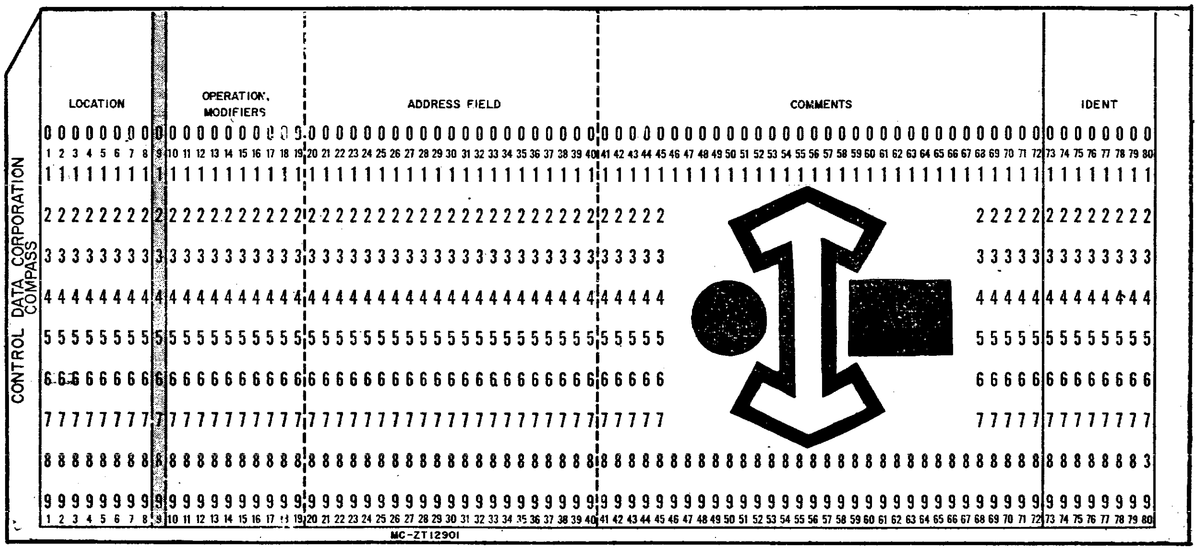

COMPASS CODING FORM
CONTROL DATA
NAME
PAGE
DATE
PROGRAM
ROUTINE
LOCATION
OPERATION, MODIFIERS
ADDRESS FIELD
COMMENTS
IDENT

COMPASS CODING FORM
(half-size)

Each line of the coding form represents one card when punched into cards.

2.2.3 (cont.)

Following is a sample of the COMPASS CARD.



COMPASS CARD (full size)

2.2.3.1 LOCATION Field

Symbolic Address of the instruction written on that line.

```
e.g.      LØØP     ADA      TABLE
                    -
                    -
                    -
                   UJP      LØØP
```

OR Symbolic address of a storage area set up by a pseudo instruction.

```
e.g.      ALEK     ØCT      4
                    -
                    -
                    -
                   LDA      ALEK
```

Restrictions - (a) 1-8 characters (need not be right or left justified).

(b) First character must be alphabetic, others can be alphanumeric.

(c) Special characters are not allowed, except period.

(d) Imbedded blanks are illegal.

Examples:

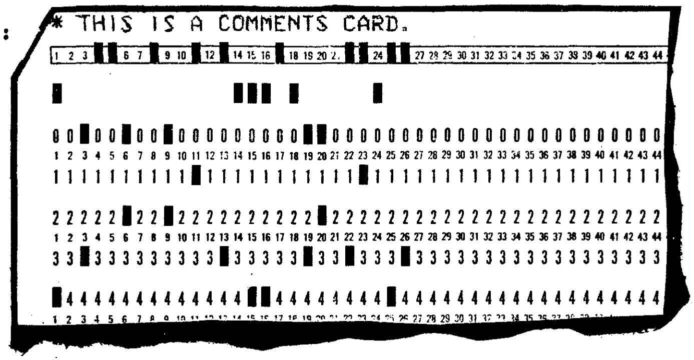
LEGAL		ILLEGAL	
ABCDE	A1A1A1	1A1A1A	Z Z
A1234	XYZ.23	TØM+5	ABCDEFGHIJ
X	PART3	27	FØG*

2.2.3.1 (cont.)

Special Comment Card

An asterisk in Column 1 of the location field means that the rest of the card will be treated as if it is a comment.

Example:



2.2.3.2 OPERATION Field

This field can contain

(a) Mnemonic operation codes.

(b) Pseudo instruction Mnemonics.

(c) Macro instruction names.

(d) Octal instructions 00_8-77_8.

The code must begin in col. 10, otherwise it will assemble as 00_8 (halt code). Modifiers are written in this field.

e.g. CHAR BSS,C 4 means set up an area consisting of 4 characters and labelled "CHAR".

Examples:

```
05
BSS
ENA,S
LDA
LDA,I
INPC,INT,B,H
MACNAME
```

2.2.3.3 ADDRESS Field

This field can contain :

(a) Symbols

(b) Constants

(c) Special Characters

(d) Literals

(e) Expressions

The address field can begin anywhere after the operation field, provided it is separated from the operation field by at least one blank.

However, it must begin before column 41, and finish before column 73.

(a) Symbols:

A symbol appearing in the address field must be defined by appearance in the location field of an instruction in the subprogram, or be declared as external. If it is not so defined, an error flag "U" - undefined symbol - will be given on the listing. The symbol may be relocatable or non-relocatable. The value assigned to a non-relocatable symbol will not be modified on loading.

```
Examples:            LDA     CIC.2  (relocatable)
            CIC.2    ENA     0

                     LDA     INTADDR (non-relocatable)
            INTADDR  EQU     4
```

(b) Constants:

Integer constants can represent a number of functions depending on the type of instruction -

```
e.g.    octal address    (LDA)    (LDA 100B)
        constant value   (ENA)    (ENA 100B)
        shift factor     (SHA)    (SHA 6    )
```

Octal integers must be suffixed by the letter B.

NOTE: Numbers in address field are assumed to be decimal unless followed by a B.

(c) Special Characters:

Two special entries may be made in the address field -

(i) A single asterisk is interpreted as the current value of the address counter when the * is encountered.

```
Example:            ENA        0
                    LDA        *-1
```

means: Load the A register with the instruction preceding the LDA instruction. (i.e. with assembled ENA 0)

(ii) The double asterisk causes the address portion of the instruction to be assembled with a 1-bit in each bit position, and is used where modification of the address will take place during execution.

```
Example:          START      UJP      **
           Assembled as        01077777
```

(d) Literals:

If the address field refers to an operand (a value), the entry may be a literal, expressed as =mv.

```
where    m =   the mode
         v =   the value
```

Double precision literals are expressed as =2mv.

The mode of the literal may be:

(i) Decimal

DVA	=D23
DVAQ	=2D2753

(ii) Octal

LDA	=Ø777
LDAQ	=2Ø7777777777777777

(Up to 16 octal digits may be specified for double precision)

(iii) Hollerith

LDA	=HABCD	(max: 4 characters)
LDAQ	=2HABCDEFGH	(max: 8 characters)

During assembly, a literal is converted to binary, and assigned a relocatable address which is substituted for the literal in the object code. Literals are all stored at the end of the subprogram. If two literals of the same value and size are specified, they are not duplicated. When CØMPASS encounters a literal, the value is compared against all other previously assembled literals. If an identical value exists, the address of the previously assigned literal is substituted in the object code.

(e) Address Expression:

Address expressions may be formed.

Examples:		LDA	TØM-2
		ENA	SYM+46B
	SYM	EQU	275B

Subprogram, data and common relocatable symbols may be mixed.

NOTE: External symbols, the double asterisk and literals may not appear in an address expression.

2.2.3.4 COMMENTS Field

Comments may be included with any instruction. A blank column must separate them from the last character in the address field and they may extend to column 72.

Comments have no effect on assembly, but will be included on the assembly listing.

It is highly recommended that liberal use should be made of comments and comments cards.

An example is shown on the following page.

2.2.3.4 (cont.)

```
             IDENT     ØNE
*
* COMPASS    CØURSE    EXERCISE 3
*            J. SMITH
*
             ENTRY     START          *SCOPE ENTRY*
START        UJP       **
             ENQ       14B
             ENA       0              INITIALIZATION
             STA       SUM             OF COUNTERS
             STA       CØUNT
*
*
LØØP         LDA       SUM
             ADA       CØUNT
             STA       SUM            MAIN
             LDA       CØUNT           LØØP
             AQJ,EQ    START
             INA       1
             STA       CØUNT
             UJP       LØØP
*
*
*
CØUNT        BSS       1
SUM          BSS       1
             END       START
```

2.2.4 Coding Simple COMPASS Programs

2.2.4.1 Beginning the Program

The first card in the deck must be an IDENT card. This card has the word IDENT punched beginning at Column 10, and the program name (of 1-8 alphanumeric characters, the first of which must be alphabetic) punched beginning at Column 20.

Examples:

		IDENT	TEST42
or		IDENT	G427
or		IDENT	ØPCØDER

2.2.4.2 Ending the Program

The last card in the deck must be an END card. The word END is punched beginning at Column 10, and the entry point (the beginning instruction in the program) is punched beginning at column 20. (However, see later section on END statement in relation to programs containing more than one sub-program).

Examples:

	1	10	20
		END	START
or		END	BEGIN
or		END	LØØPIN

2.2.4.3 SCOPE Entry

So that the program can be run under SCOPE, it is necessary to ensure that control returns to SCOPE when the program is finished. The entry point into the program should take the following form to enable this to be done:

	1	10	20
	START	UJP	**
or	BEGIN	UJP	**
or	LØØPIN	UJP	**

This will be the first executable statement in the program. SCOPE will enter the return address into the location START instead of the two asterisks. The last executable instruction in the program should be a jump back to the beginning so that control can be returned to SCOPE.

Examples:

	1	10	20
		UJP	START
or	TØM	UJP	BEGIN
or		UJP	LØØPIN

2.2.4.4 Deck Structure for COMPASS Course Exercises

(i) Assembly only

$^{7}_{9}$SEQUENCE,666

$^{7}_{9}$JOB,1112115,6404,5

$^{7}_{9}$COMPASS,L

(COMPASS source deck
(

FINIS (punching begins in column 10)

$^{77}_{88}$ (end of file card)

(ii) Assembly and execution:

$^{7}_{9}$SEQUENCE,666

$^{7}_{9}$JOB,1112115,6404,3

$^{7}_{9}$EQUIP,56=MT

$^{7}_{9}$COMPASS,L,X

(COMPASS source deck
(

FINIS

$^{7}_{9}$LOAD,56

$^{7}_{9}$RUN,4

Data

$^{77}_{88}$ (end of file card)

(iii) Alternative "assembly only".

Use all cards as for execution, except RUN and DATA. Any LOADER errors will then be indicated, but the program will not be executed.

NOTE: 1. The $^{7}_{9}$ is a multiple punching in column 1 of the card.

2. The end of file card has a multiple 7,8 punching in columns 1 and 2. It signifies the end of the job. (EOF cards used on other systems that use

```
    12 12
     1  1
     4  4   in column 1 thru 4 are also acceptable.)
 7  7  7  7
 8  8
```

STUDENT NOTES

Chapter 3

COMPASS INSTRUCTIONS

3.1 LOAD INSTRUCTIONS

3.1.1 Load A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDA, I	m, b

23 18	17	16 15	14 00
20	a	b	m

a = addressing mode designator

b = index designator

m = storage address.

Description : Loads A Register with the 24-bit contents of storage address M, where M = m+(B^b).
NOTE: ( ) indicates contents of.

Examples : (i) If the contents of location 100_8 in memory is 52307777, what will be the contents of A after execution of the following statement?

LDA 100B

Answer : (A) = 52307777

(ii) If location 100_8 is called by the symbolic address LØC, what will be the contents of A after execution of the following statement?

LDA LØC

Answer : (A) = 52307777

(iii) A block of memory in octal is as follows:

LØC	00 00 00 01
	00 00 00 10
	00 00 01 00
	00 00 10 00
	00 01 00 00
	00 10 00 00

What will be the contents of A after executic of the following statement?

LDA LØC+4

Answer : (A) = 00 01 00 00

Exercises on Load A:

(i) LØC LDA **

.

.

.

LDA LØC

What will be the contents of A at the end of the above section of a program?

(The function code for LDA = 200).

(ii) If location 101_8 contains

101 010	000 011	111 110	001 100	(in binary)

3.1.1 (cont.)

What is the octal amount loaded in A as a result of the following instruction?

LDA   101B   52037614

(iii) If MASK is location 105_8, and a block of memory is as follows,

104	1234 1234
105	7023 1307
106	1111 2222
107	6073 4261
110	3333 3333
111	4444 3066

What will be in A after execution of the following instruction?

LDA   MASK+3

(iv) The instruction to be executed is:

LDA   =D43

Which answer gives the correct contents of A after the instruction has been executed?

a. 43_8

b. 35_{10}

c. The contents of location 43

d. 53_8

3.1.2 Load Q

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDQ,I	m,b

23–18	17	16–15	14–00
21	a	b	m

a = addressing mode indicator

b = index designator

m = storage address.

Description : Load Q with a 24-bit quantity from storage address M where M = m + (B^b)

Examples : (i) LDQ   MASK

Load Q with the 24-bit quantity at the symbolic address MASK.

(ii) If MASK contains 00001111

LDQ   MASK

(Q) = 0000 1111

(iii) If MASK = location 104_8 and a block of memory is as shown, what will be the contents of Q after execution of the following instruction?

LDQ MASK-4

76	14 00 00 20
77	25 25 52 52
100	11 22 33 44
101	55 66 77 00
102	17 53 17 53
103	20 64 20 64
104	31 75 31 75
105	42 06 42 06
106	53 17 53 17
107	64 20 64 20

(Q) = 11 22 33 44

Exercises on Load Q

(1) What will be the contents of Q after execution of each of the following instructions? (The block of memory to be used is shown below).

00267	00 00 01 01
	20 10 40 40
	11 11 17 17
	20 20 20 20
	16 25 34 07
LØC	60 60 60 60
	21 22 23 24
	10 00 00 10

(a) LDQ 272B
(b) LDQ 184
(c) LDQ LØC-3
(d) LDQ LØC+2

(2) If PLACE = location 2617_8, and a block of memory is as shown,

	01 47 26 35
	12 50 37 46
	23 61 40 57
02616	34 72 51 60
	45 03 62 71
	56 14 73 02
	67 25 04 13
	70 36 15 24
	01 47 66 65

3.1.2 (cont.2)

What will be the contents of Q after execution of each of the following instructions?

(a) LDQ 2613B

(b) LDQ PLACE-1

(c) LDQ PLACE+3

(d) LDQ 1427

3.1.3 Load Index

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDI,I	m,b

23 – 18	17	16 15	14 – 00
54	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description : Load Index Register B^b with the lower 15 bits of the contents of storage address m. No address modification using index registers is possible.

"b" indicates which index register is to be loaded.

Examples : (i) If (CIØ) = 12345670

What will be the contents of index register 2 as a result of the following instruction?

LDI CIØ, 2

Answer: B_2 = 45670

(ii) A block of memory is as shown:

LØC	0 0 0 0 0 0 0 1
	7 7 7 7 7 7 7 7
	2 3 4 2 3 4 2 3
	1 0 4 1 0 4 0 4
	4 4 4 4 1 0 0 0
	2 0 0 2 2 1 2 4
	4 1 2 3 4 4 1 4

The index registers are as follows:

B1	0 0 0 0 2
B2	0 0 0 1 4
B3	7 7 7 7 3

What will be the contents of the registers after the following?

LDI LØC+3,3
LDI LØC+6,1
LDI LØC,2

3.1.3 (cont.)

Answer: B_1 = 34414

B_2 = 00001

B_3 = 10404

Exercises on Load Index instruction

(1) What will be the contents of the index registers after execution of each of the following instructions, if

(CAB) = 00100001

(STØRE) = 77777771

(TEMP) = 40100010

(HIGH) = 20002020

(LØC3) = 33003303

(a) LDI CAB,1

(b) LDI HIGH,3

(c) LDI STØRE,2

(d) LDI TEMP,1

(e) LDI LØC3,3

(f) LDI HIGH,2

(2) A block of memory is as shown:

405	00 00 00 21
	04 04 04 04
	32 57 14 13
	51 21 41 61
	00 00 00 00
	21 04 00 10
	12 74 11 11
	00 07 77 75

If TAG = Location 410_8, what will be the contents of the Index registers after execution of the following instructions?

(a) LDI TAG-2,3

(b) LDI TAG+4,1

(c) LDI 411B,2

(d) LDI TAG,1

(e) LDI TAG+2,3

3.2 STORE INSTRUCTIONS

3.2.1 Store A

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	STA,I	m,b

23–18	17	16–15	14–00
40	a	b	m

a = addressing mode designator

b = index designator

m = storage address.

Description : Stores the contents of the A Register in storage location M. $(M = m+(B^b))$. Contents of A are unchanged.

Examples : (i) STA HØLD

The value in A is stored in the location specified by the symbol HØLD.

(ii) (A) = 1212 3434

TEMP = Location 101_8

HØLD = Location 103_8

100	00 00 00 00	
101	11 11 11 11	TEMP
102	22 22 22 22	
103	33 33 33 33	HOLD
104	44 44 44 44	
105	55 55 55 55	
106	66 66 66 66	
107	77 77 77 77	
110	00 00 00 00	

What will be contained in the above block after the following:

```
LDA    100B
STA    TEMP+2
LDA    HØLD-2
STA    106B
LDA    HØLD+5
STA    TEMP
```

Answer:

100	00 00 00 00
101	00 00 00 00
102	22 22 22 22
103	00 00 00 00
104	44 44 44 44
105	55 55 55 55
106	11 11 11 11
107	77 77 77 77
110	00 00 00 00

Exercises on STA Instruction

(i) If TEMPY is location 302_8, and the block of memory shown results from the following instruction

STA TEMPY+4

What were the contents of A before execution of the instruction?

301	7723 7723
302	1111 1111
303	2222 2222
304	3044 6133
305	2442 4224
306	1212 3434
307	7777 5555

(ii) If HØLD = Location 103_8 and TAG = Location 101_8, what will be the contents of the block of memory below after execution of the following instructions?

```
LDA     HØLD-1
STA     TAG+3
```

100	0000 0000
101	1111 1111
102	2222 2222
103	3333 3333
104	4444 4444
105	5555 5555
106	6666 6666

(iii) If the above instructions were followed by

```
LDA     101B
STA     69
LDA     TAG+5
STA     TAG-1
LDA     HØLD
STA     HØLD+3
```

What would be the final contents of the block of memory?

3.2.2 Store Q

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	STQ,I	m,b

23 – 18	17	16 – 15	14 – 00
41	a	b	m

a = addressing mode designator
b = index designator
m = storage address

3.2.2 (cont.)

Description : Stores the 24-bit quantity in Q at address M, where $M = m + (B^b)$

Example :

```
          LDQ       *+1
          STQ       RESULT      (= 41 00 05 00)
           .
           .
           .
           .
          ORGR      500B
RESULT    BSS       1
```

What would be the contents of RESULT after execution of the above?

Answer: RESULT = 41000500

Exercise :

A block of memory is as shown:

LØC	20 00 01 00
	00 00 04 01
	00 04 44 00
	21 23 25 27
MASK	07 04 07 04
	12 34 56 70
	00 00 00 01

What will be its contents after execution of the following?

```
LDQ     LØC+3
STQ     LØC+1
LDQ     LØC+2
STQ     MASK+1
LDQ     MASK-4
STQ     LØC+6
```

3.2.3 Store Index

LOCATION	OPERATION, MODIFIERS ADDRESS FIELD
	STI,1 m,b

23 18	17	16 15	14 00
47	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Store the (B^b) in the lower 15 bits of storage address m. N.B. The upper 9 bits of m remain unchanged. "b" indicates the index register. If b = 0, the lower 15 bits of "m" are set to zero.

Examples: (i) STI TMP2,2 where (TMP2) = 40050012
(B^2) = 63636

After execution (TMP2) = 40063636

(ii) If (FIELDA) = 31244444
(CHANGE) = 11111111

What will be the contents of TEMPY after execution of the following?

```
LDA     FIELDA
STA     TEMPY
LDI     CHANGE,3
STI     TEMPY,3
```

Answer: (TEMPY) = 31211111

(iii) If (B^1) = 00502

```
STA     **
LDA     *-1
STA     HØLD
STI     HØLD,1
```

What will be the contents of HØLD?

Answer: (HØLD) = 4000 0502

Exercises on Store Index instruction

(1) If (LØC) = 21043072
(B^2) = 00004

What will be contents of LØC after execution of the following?

```
STI     LØC,2
```

(2) If (LØC) = 21043072
(TEMP) = 00140001

What will be the contents of LØC and TEMP after execution of the following?

```
LDA     LØC
LDI     TEMP,2
STA     TEMP
STI     TEMP,2
```

(3) If (TEMP) = 23002000, (BIG) = 77777772, and (HØLD) = 00000001,

What will be contents of TEMP and BIG after execution of the following?

```
LDA     TEMP
STA     HØLD
LDI     BIG,3
STI     HØLD
LDI     TEMP,3
STI     BIG,3
LDA     HØLD
STA     TEMP
```

3.3 ARITHMETIC, FIXED POINT, 24-BIT PRECISION

3.3.1 Add to A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ADA,I	m,b

23–18	17	16–15	14–00
30	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Adds the 24 bit quantity located at address M to the contents of Register A. The result is stored in A. M = m + (B^b).

Examples: (i) If (100_8) = 10001010

(A) = 00077777

What will be the contents of A after execution of the following instruction?

ADA 100B

Answer: (A) = 10101007

(ii) If ØPR = location 100_8 in the block of memory shown, what will be the contents of A and index register 2 after execution of the following?

100	0 0 0 0 0 0 1 1
101	0 0 1 4 1 3 1 0
102	2 1 0 0 0 0 0 5
103	1 4 0 1 4 0 0 0
104	0 0 7 7 1 7 7 7
105	2 0 2 0 1 0 2 0

B_2 = 00014

```
LDA    ØPR+2
STA    ØPR+4
LDA    ØPR+3
ADA    ØPR+4
STA    ØPR+2
STI    ØPR+2,2
LDA    ØPR+5
ADA    ØPR+2
LDI    ØPR+1,2
```

Answer:

(A) = 55201034

(B_2) = 41310

3.3.1 (cont.)

Exercise:

A block of memory is as shown:

100	00 00 00 01
	00 00 00 02
	00 00 00 03
	00 00 00 04
	00 00 00 05
	00 00 00 06
	00 00 00 07
	00 00 00 10

(a) Write a program segment which will add together the contents of locations 100, 102, 104 and 106 and store the result in 107.

(b) Write a program segment which will add up locations 101 and 102 and store the result in 103, add 103 and 104 and store the result in 105, and add 105 and 106 and store the result in 107.

3.3.2 Subtract from A

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	SBA,I	m,b

23 18	17	16 15	14 00
31	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Subtracts the 24-bit quantity located at address M from (A). The difference appears in A. $M = m + (B^b)$.

Examples: (i) If (A) = 10404040

(100_8) = 10303030

SBA 100B

Answer: (A) = 00101010

(ii) If (A) = 04444444

(TEMP) = 02132132

SBA TEMP

Answer: (A) = 02312312

(iii)

TEMP	10000001
	24001020
	77777777
	14021020
	00001000
	00002222
	02020202

What will be in this section of memory after the following?

```
LDA     TEMP
ADA     TEMP+6
STA     TEMP+2
SBA     TEMP+4
STA     TEMP+5
```

Answer:

10000001	TEMP
24001020	
12020203	
14021020	
00001000	
12017203	
02020202	

Exercises on Subtract from A

(a)

```
LDA   =D401
SBA   =D30
```

What will then be the contents of A?

(b) If (CØDE) = 00000001

What will be the contents of HØLD after the following?

```
LDA     CØDE
ADA     CØDE
STA     HØLD
ADA     HØLD
STA     HØLD
ADA     HØLD
ADA     HØLD
STA     HØLD
```

(c) Write a program segment to multiply the contents of X by two and subtract from the answer,the contents of locations Y and Z. Store your answer in ANSWER.

3.3.3 Multiply A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	MUA,I	m,b

23–18	17	16–15	14–00
50	a	b	m

a = address mode designator

b = index designator

m = storage address

Description: Multiply the contents of A by the contents of Address M. The 48-bit product appears in QA with the lowest order bits in A.

$M = m + (B^b)$

Examples: (i) What will be the contents of QA after execution of the following instructions? A contains 100_8, and TABLE contains 5.

```
STA     SUM24
LDA     TABLE
MUA     SUM24
```

Solution: SUM24 = | 00 00 01 00 |

A = | 00 00 00 05 |

	Q	A
Answer =	00 00 00 00	00 00 05 00

(ii) If TABLE contains 5 and A contains 20000000_8, what will be the contents of QA after execution of the following instructions?

```
STA     SUM24
LDA     TABLE
MUA     SUM24
```

Solution: SUM24 = | 20 00 00 00 |

A = | 00 00 00 05 |

	Q	A
Answer =	00 00 00 01	20 00 00 00

Exercises on Multiply A Instruction

(a) If (A) = 10 , (TABLE) = 3 , (SUM24) = 5 , and (HØLD) = 0 what will be the contents of A after execution of the following instructions?

```
MUA     TABLE
STA     HØLD
LDA     SUM24
MUA     TABLE
ADA     HØLD
```

3.3.3 (cont.)

(b) A block of memory is as shown

100	00 00 00 01
	00 00 00 02
	00 00 00 03
	00 00 00 04
	00 00 00 05
	00 00 00 06
	00 00 00 07
	00 00 00 10

Write a program segment to add the contents of 100 and 101, multiply the result by the contents of 102, add the contents of 103, 104 and 105, multiply the result by (106), and then add (107). Store the result in 100.

(c) What will be the contents of A after execution of the following sequence of instructions, if the initial contents of A = 0, (ØNE) = 6, (TWØ) = 2, (THREE) = 10_{10}.

```
ADA     ØNE
MUA     TWØ
SBA     THREE
MUA     ØNE
MUA     ØNE
SBA     TWØ
ADA     THREE
```

3.3.4 Divide A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	DVA,I	m,b

23	18 17	16 15	14 00
51	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Divide the 48 bit quantity in AQ by the quantity in storage at address M (M = m + (B^b)). The quotient appears in A, and the remainder with its sign extended appears in Q.

If a divide fault* occurs, the instruction halts and the program advances to P + 1. (The contents of A and Q are usually meaningless in this case.) A divide fault occurs whenever the number of leading sign bits (0 or 1, ie, + or -) in M is greater than or equal to the number of leading sign bits in AQ. A fault can also occur if the number of sign bits in M is one less than that in AQ; however, the actual number in M and in AQ now has to be considered. Since the number in AQ is usually achieved by shifting AQ 24 bits to the right, extending the sign thru A into Q, an overflow rarely occurs.

*Quotient greater than $2^{23}-1$

3.3.4 (cont.)

Example:

If (AQ) = | 00000000 | 37777777 |

and (D) = | 00000001 |

What will be in A and Q after execution of:

DVA D

Answer: (A) = $\boxed{37777777}$ = Quotient

(Q) = $\boxed{00000000}$ = Remainder

Divide Fault bit = 0, ie, 'No Divide Fault"

Note: Had the initial contents of AQ been just one number larger, a Divide Fault would have occurred.

Exercises:

(a) If (A) = 0000 0000
(Q) = 0000 4040
(TAG) = 0000 2000

What will be in A and Q after execution of the following instruction?

DVA TAG

(b) If (A) = 00000000
(Q) = 00000122
(LOC) = 00000005

What will be in A and Q after execution of the following instruction?

DVA LØC

(c) If (A) = 7777777
(Q) = 7777771
and Index Register 2 contains 00003

What would be in A and Q after the instruction:

DVA TAG,2

TAG	0000 0007
	0014 0140
	0771 7717
	0000 0004
	7777 7773

(d) If Index Register 2 contains 4, TAG is as above, and (A) and (Q) are as shown:

A	Q
7777 7777	7777 7771

What would be in A and Q after execution of the following instruction?

DVA TAG,2

(e) Draw diagrams of the machine instruction word which would be assembled from the following CØMPASS instructions:

(i) DVA 474B,1

(ii) DVA 100B

3.3.5 Replace Add

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	RAD, I	m, b

23–18	17	16–15	14–00
34	a	b	m

a = address mode designator

b = index designator

m = storage address.

Description: Replace the quantity at address M with the sum of (M) and the contents of A register. $M = m + (B^b)$.

The A register remains unchanged.

Examples:

(i) If A = 67432136_8 and
(INC) = 100_8

```
STA     LØC
LDA     INC
RAD     LØC
```

LØC now equals 67432236B.

(ii) If (A) = 200_8 and (INC) = 500_8

```
RAD     INC
```

Answer: (INC) = 700_8

Exercise:

If (A) = 100_8 and (INC) = 200_8

```
RAD     INC
STA     TEMP
LDA     INC
STA     ØNE
LDA     TEMP
RAD     INC
LDA     INC
STA     TWØ
LDA     TEMP
RAD     INC
LDA     INC
STA     THREE
```

What will be the contents of ØNE, TWØ and THREE?

3.4 REGISTER OPERATIONS WITHOUT STORAGE REFERENCE

3.4.1 Increase A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INA,S	y

23 18	17	16 15	14 00
15	1	b	y

b = 0 if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INA,S	y

23 18	17 15	14 00
15	4	y

b = 2 if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INA	y

23 18	17 15	14 00
15	6	y

Description: Adds the amount "Y" to the contents of the A register. If there is no sign extension specified, only the 15 bits of "Y" are added to A.
If sign extension is specified, the sign bit of y is extended before addition to A. (Note - if A is increased by a negative number, sign extension should be used.)

Examples: (i) If (A) = 00 00 00 01

INA 12B

(A) = 00 00 00 13

(ii) If (A) = 00 00 00 01

INA,S 40000B

(y = 777 4 0000)

Answer : (A) = 77740001

Exercises: (ERRØRC) = 00004040B

(a) What will be the contents of ERRØRC after the following?

```
LDA    ERRØRC
INA    55565B
STA    ERRØRC
```

(b) If the instructions had been

```
LDA    ERRØRC
INA,S  55565B
STA    ERRØRC
```

What would have been the final contents of A?

3.4.1 (Cont.)

(c) If (ERRØRC) = 60_{10}, write the coding necessary to increase it to 100_{10}.

(d) If (A) = 10_8, what will be the final contents of A after execution of the following?

INA,S 77776B

3.4.2 Increase Q

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INQ,S	y

23 18	17	16 15	14 00
15	1	b	y

b = 1 if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INQ,S	y

23 18	17 15	14 00
15	5	y

b = 3 if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INQ	y

23 18	17 15	14 00
15	7	y

Description: Adds the amount "Y" to the contents of the Q register. If there is no sign extension specified, only the 15 bits of "Y" are added to Q.
If sign extension is specified, the sign bit of y is extended before addition to Q. (note: if Q is increased by a negative number, sign extension should be used.)

Examples:

(i) If (Q) = 00 00 00 20
INQ 60B

Answer : (Q) = 00 00 01 00

(ii) If (Q) = 00 00 00 20
INQ,S 44444B
(y = 777 44444)

Answer : (Q) = 777 44464

Exercises:

(i) If (Q) = 577_8, what will be the result in Q after the instruction INQ 547B is executed?

3.4.2 (cont.)

(ii) If (Q) = 50B, (STACK) = 500B what will be the result in Q after the following sequence of instructions?

INQ	100B
STQ	TEMP
LDA	TEMP
RAD	STACK
LDQ	STACK
INQ,S	27711B

3.4.3 Increase Index

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	INI	y,b

23 – 18	17	16 15	14 – 00
15	0	b	y

b = index register designator

Description: Adds the 15-bit quantity "y" to the contents of the index register specified.

Examples: (i) INI 6,2 where $(B^2) = 12B$

What will be the contents of B^2?

$(B^2) = 20B$

(ii) LDI 100B,3

INI 10B,3

What will be the contents of B^3?

$(B^3) = (100B) + 10B.$

(iii) If a block of memory is as shown below, what will be in the index registers as a result of the following:

107	20	00	00	04
	40	10	00	21
	60	00	00	01
	77	77	77	77
	00	00	00	20
	04	01	07	01
	22	22	33	33

LDI	110B,1
LDI	111B,2
INI	20B,2
LDI	113B,3
INI	70B,3

Answer: $B_1 = 21B$

$B_2 = 21B$

$B_3 = 110B$

Exercises on Increase Index instruction

(i) A block of memory is as shown:

100	00 00 00 01
	00 00 00 10
	00 00 01 00
	00 00 10 00
	00 01 00 00
	00 10 00 00
	01 00 00 01

What will be the contents of the three index registers after execution of the following?

```
LDA    101B
RAD    100B
LDI    100B,1
INI    100B,1
LDI    104B,2
INI    17777,2
LDI    106B,3
INI    100B,3
STI    106B,3
LDA    106B
RAD    106B
LDI    106B,3
```

(ii) If index 1 contains 1, write a program using this index to store the numbers 1,3, 5, 7 and 8 in 5 consecutive locations beginning at location 100.

3.4.4 Enter Register

23 18	17	16 15	14 00
14	d	b	y

Enter A

(a) d = 1
b = 2

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENA	y

23 18	17 15	14 00
14	6	y

(b) d = 1
b = 0

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENA,S	y

23 18	17 15	14 00
14	4	y

Enter Q

(c) d = 1
b = 3

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENQ	y

23 18	17 15	14 00
14	7	y

(d) d = 1
b = 1

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENQ,S	y

23 18	17 15	14 00
14	5	y

Enter Index

(e) d = 0
b = index designator

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENI	y,b

23 18	17	16 15	14 00
14	0	b	y

If b=0, this is a no-operation instruction.

3.4.4 (cont.)

Description: The 15-bit quantity "y" is entered in the specified register. The register is cleared before "y" is entered. If sign extension is specified, the sign bit of "y" is extended before "y" is entered into the register.

Examples:

(i) ENA 14B

(A) = 00 00 00 14

(ii) ENQ,S 40001B

(Q) = 777 40001

(iii) ENI 77B,1

(B^1) = 00077

Exercises on the Enter Register Instructions

(1) If (Q) = 11025321, and location 70_8 contains 10101_8 what will be the contents of Q after execution of the following?

```
ENQ   70B
```

(2)

```
AA   ENA   0
     LDA   *-1
     INA   40
     STA   AA
```

What will be the contents of storage location "AA" after execution?

(3) If (FIELD) = $\boxed{1010\ 1010}$

and FIELD = locaton 456B

What will be the contents of the A Register after execution of the instruction

```
ENA     FIELD
```

(4)

```
ENA,S    0
STA      100B
ENI      10B,1
INI      100B,1
STI      100B,1
LDA      100B
INA,S    40000B
STA      100B
LDI      100B,2
```

What will be the contents of A, B^1 and B^2 after execution of the above?

3.5 JUMP INSTRUCTIONS

3.5.1 Unconditional Jump

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	UJP,I	m,b

23 18	17	16 15	14 00
01	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Unconditionally jump to address M, where $M = m + (B^b)$.

Examples: (i) EØF LDA 100B

.
.
.
.

UJP EØF

Control will jump back to statement EOF

(ii) AAA UJP *+2 (AAA = address 10)

Program jumps to address 12.

Where the address to which control is to jump is not known at the time of assembly, but will be entered in during execution, the instruction is usually coded as follows, to enable easy recognition of the statement in assembled programs:

```
        UJP     **      (assembled as 01077777)
```

This causes 1 bits to be set in the address portion of the word, and this will be replaced during execution by the actual address to which control is to jump.

SCØPE entry to a program takes this form. (See section 2.2.4.3)

However, in such cases, the contents of the address portion of the word may be any legal address. Whatever the address is, it will be replaced by the correct address during execution. Thus:

```
        UJP     **
        UJP     *
        UJP     *+7
START   UJP     START
```

will all serve the same purpose, for they will all be modified as required in the program, during execution.

3.5.2 Compare A with Zero, Jump

23 18	17	16 15	14 00
03	0	j	m

j = jump designator (0-3)
m = jump address

(a) j = 0, jump if A = +0 or -0

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AZJ,EQ	m

23 18	17 15	14 00
03	0	m

(b) j = 1, jump if A ≠ +0 or -0

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AZJ,NE	m

23 18	17 15	14 00
03	1	m

(c) j = 2, jump if A ≥ +0 (-0 < +0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AZJ,GE	m

23 18	17 15	14 00
03	2	m

(d) j = 3, jump if A < +0 (-0 < +0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AZJ,LT	m

23 18	17 15	14 00
03	3	m

<u>Description</u>: (A) are compared with zero to establish test conditions as above. If the condition specified by the modifier is true, the program jumps to address "m". If the test condition is not true, RNI from address P + 1. (RNI = read next instruction).

Example: If (A) = 1

(i) What will be the RNI address after execution of

```
AZJ,EQ      LØØP
```

Answer: RNI at address P + 1

(ii) If the instruction had been

```
AZJ,GE      LØØP
```

Answer: RNI at address LØØP

Exercises:

Given the information below, give the RNI addresses for each problem.

(i) If (A) = 77777777

```
AZJ,EQ      100B
  RNI =     ____ ?
```

(ii) If (A) = 00020000

```
AZJ,EQ      STØRE
  RNI =     ____ ?
```

(iii) If (A) = 00000000

```
AZJ,NE      CARRY+1
  RNI =     ____ ?
```

(iv) If (A) = 77777776

```
AZJ,LT      NEXT
  RNI =     ____ ?
```

(v) If (A) = 03675671

```
AZJ,GE      ØNE
  RNI =     ____ ?
```

(vi) If (A) = 00000000

```
AZJ,GE      LØØP
  RNI =     ____ ?
```

(vii)

```
ENA,S       40001B
AZJ,GE      YES
  RNI =     ____ ?
```

(viii)

```
ENA         77777B
AZJ,LT      MAYBE
  RNI =     ____ ?
```

(ix)

```
ENA,S       20741B
AZJ,GE      200B
  RNI =     ____ ?
```

(x)

```
ENA,S       32767
AZJ,LT      FINISH
  RNI =     ____ ?
```

3.5.2 (cont.2)

(xi) Which Halt will be reached after execution of the following program segment?

```
            LDA      =Ø423
            SBA      =Ø424
            AZJ,EQ   HLT
            UJP      HLT+1
HLT         HLT      1
            HLT      2
```

3.5.3 Compare A with Q, Jump

23 18	17	16 15	14 00
03	1	j	m

j = 0-3 jump designator (0-3)
m = jump address

(a) j = 0, jump if A = Q (+0 = -0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AQJ,EQ	m

23 18	17 15	14 00
03	4	m

(b) j = 1, jump if A ≠ Q (+0 = -0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AQJ,NE	m

23 18	17 15	14 00
03	5	m

(c) j = 2, jump if A ≥ Q (+0 > -0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AQJ,GE	m

23 18	17 15	14 00
03	6	m

(d) j = 3, jump if A < Q (+0 > -0)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AQJ,LT	m

23 18	17 15	14 00
03	7	m

3.5.3 (cont.)

Description: The quantity in A is compared to the quantity in Q to establish a comparison or test - condition. If the test-condition is true, RNI from address "m". If not true RNI = P+1.

Examples: (i) AQJ,EQ LØØP (A) = 00000000
(Q) = 77777777

RNI LØØP

(ii) AQJ,GE LØØP (A) = 00000000
(Q) = 77777777

RNI LØØP (+0 > -0)

Examples: Given the information below, supply the RNI's for each problem:

(a) AQJ,LT LØØP (A) = 07234567
(Q) = 04444444

RNI = _ _ _ _ ?

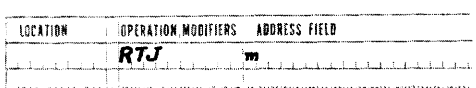
(b) AQJ,GE LØØP (A) = 50523417
(Q) = 23456733

RNI = _ _ _ _ ?

(c) AQJ,NE LØØP (A) = 00 00 00 01
(Q) = 10 00 00 01

RNI = _ _ _ _ ?

3.5.4 Return Jump



23–18	17–15	14–00
00	7	m

Description: The address portion of the contents of address m is replaced by the return address P + 1. The program jumps to m + 1, i.e. RNI = m + 1. This instruction is used for subroutine linkage.

Examples: (i) RTJ XSØRT

Here the address portion of XSØRT will be replaced by the address of the RTJ instruction + 1, and the program control will advance to XSØRT+1.

```
(ii)               RTJ        SUBRØUT          [100]
                   -
                   -
                   -
                   -
        SUBRØUT    UJP        **               [200]
                   -
                   -
                   -
                   UJP        SUBRØUT          [210]
```

If the numbers in brackets indicate the addresses of the respective instructions, the assembled program before execution would appear as:

```
00100      00700200
              -
              -
              -
00200      01077777
              -
              -
              -
00210      01000200
```

After execution the contents of memory would appear as:

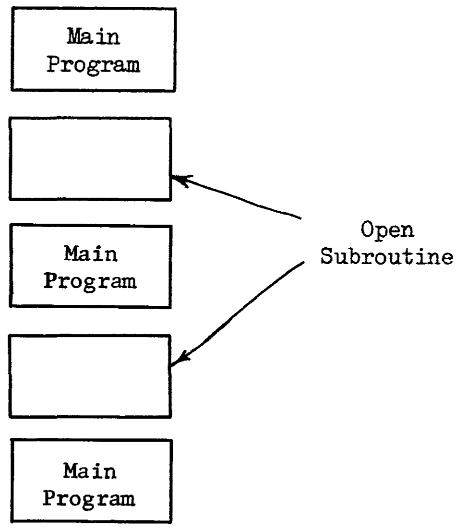
```
00100      00700200
              -
              -
              -
00200      01000101
              -
              -
              -
00210      01000200
```

Note: ** is assembled as 77777_8 and is used where the value is to be changed at run time, such as the address portion of the instruction at address 00200. Or, to say it another way, ** = TBC (To Be Clobbered.)

Use of the RTJ statement

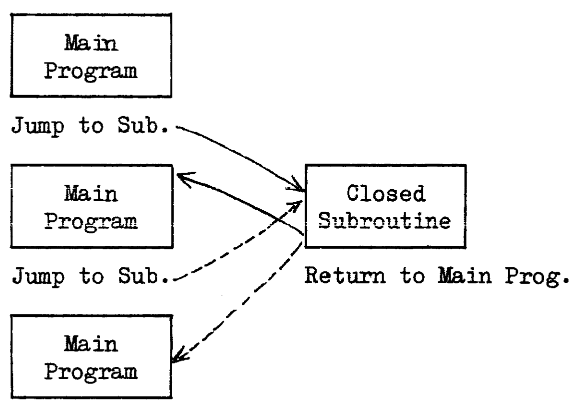
There are two types of subroutines used in CØMPASS - open and closed. An open subroutine is a series of instructions which is required more than once during a program, and is inserted where it is required.

e.g.



This method has obvious disadvantages and it is more usual to employ the closed subroutine method.

e.g.



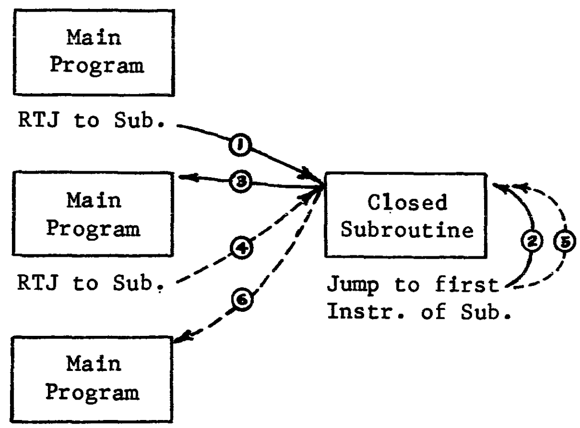
What is the problem here?

It is that the program jumps to the subroutine from two or more points in the main program, and once the program is in the subroutine, how does it know to which main program instruction it should return?

It doesn't, since it doesn't know where the jump to the subroutine was located in the Main Program.

This problem is eliminated by using the RTJ (Return Jump) instruction in the Main Program when a jump to the subroutine is desired. The instruction stores the address of the instruction following the RTJ in the lower 15 bits of the first instruction of the subroutine. The first instruction is then skipped and the first instruction executed is actually the second instruction of the subroutine.

e.g.



Following is a section of a Compass Program that illustrates this latter method:

```
         ENI       0,1
         LDA       100B
         SBA       101B
         RTJ       SUB
         LDA       105B
         MUA       155B
         RTJ       SUB
         LDA       255B
         INA       21
          .
          .
         etc.
          .
          .
SUB      UJP       **
         AZJ.LT    SUB
         INI       1,1
         UJP       SUB
```

When the RTJ instruction is encountered, execution jumps to SUB, and the address portion of SUB is replaced by the address of the RTJ instruction + 1. After execution of the instructions in the subroutine, a jump is made back to SUB, which instruction is now an unconditional jump to the instruction after the RTJ instruction. Execution of the Main Program then continues.

3.5.5 Unconditional Halt

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	HLT	m

23 18	17 15	14 00
00	0	m

Description: Unconditionally stop at this instruction. Upon restarting, RNI from address "m"

Example:

```
CTR.1    LDA    CTR.2
         INA    100B
         STA    TØM,1
         ISE    10,1
         UJP    CTR.1-3
         HLT    SEVEN
SEVEN    LDQ    MASK
           .
         END
```

3.5.6 Selective Jump

23 18	17 15	14 00
00	j	m

j = 1 - 6 = SELECTIVE JUMP switch number

j = 1, jump if "SELECT JUMP 1" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ1	m

j = 2, jump if "SELECT JUMP 2" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ2	m

j = 3, jump if "SELECT JUMP 3" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ3	m

j = 4, jump if "SELECT JUMP 4" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ4	m

j = 5, jump if "SELECT JUMP 5" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ5	m

j = 6, jump if "SELECT JUMP 6" switch is on

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SJ6	m

j = 0, see HLT instruction
j = 7, see RTJ instruction

3.5.6 (cont.)

Description: Jump to address m if the jump key specified is set "on". Otherwise RNI P+1.

Example:

```
            SJ4     BYPASS
CARDS       LDA     CARD,1
            ADA     TEMP,1
            UJP     ENDING
BYPASS      LDA     TAPE,2
            ADA     STØRE,2
ENDING      HLT     LØC4
             .
             .
            END
```

If jump switch 4 is set "on" jump to BYPASS otherwise RNI at address CARDS.

3.5.7 Index Jump (Incremental/Decremental)

23 – 18	17	16 – 15	14 – 00
02	d	b	m

b = index register designator

d = 0, Index Jump Increment

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	IJI	m, b

23 – 18	17 – 15	14 – 00
02	b	m

d = 1, Index Jump Decrement

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	IJD	m, b

23 – 18	17 – 15	14 – 00
02	b + 4	m

Description: Jump to "m" if $(B^b) \neq 0$ and increment (or decrement) index by 1. There are 3 possible conditions:

(i) If b = 0, the instruction is a no-op. and RNI from P + 1.

(ii) If $(B^b) = 0$ RNI from P + 1.

(iii) If $(B^b) \neq 0$, the jump test condition is satisfied. One is added or subtracted to (B^b); jump to address m and RNI.

N.B. The counting is done in a one's complement adder. Negative zero is not generated because the count progresses .....77775, 77776, 00000, stopping at +0. If a −0 is initially in B^b, the count progresses 77777, 00001, etc.

Examples:

```
          ENI    9,2
LØØP      LDA    BUFFER,2
          STA    DATA,2
          IJD    LØØP,2
          HLT
```

How many words will transfer?

Answer: 10_{10}

Exercises:

```
          ENI    -5,1
LØØP      LDA    TØM
           .
           .
           .
          IJI    LØØP,1
          HLT
```

How many times will the loop be executed?

3.6 SKIP INSTRUCTIONS

3.6.1 Skip if Equal

23–18	17	16–15	14–00
04	d	b	y

(i) d = 1
b = 0

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ASE,S	y

23–18	17–15	14–00
04	4	y

(ii) d = 1
b = 2

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ASE	y

23–18	17–15	14–00
04	6	y

(iii) d = 1
b = 1

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	QSE,S	y

23–18	17–15	14–00
04	5	y

(iv) d = 1
b = 3

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	QSE	y

23–18	17–15	14–00
04	7	y

(v) d = 0
b = index designator

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ISE	y,b

23–18	17–15	14–00
04	b	y

b = index register designator (1-3)

If b = 0, y is compared to zero.

Description: If the instruction is ASE, QSE or ISE; ($A_{lower\ 15}$), ($Q_{lower\ 15}$) or (B^b) respectively is compared bit for bit to "y". If equal, RNI from P+2, otherwise RNI from P+1.

Note: To be equal to "y", the quantities must be exactly the same, thus if (A) or (Q) = xxx00000 or (B^b) = 00000, "y" must be 00000 to be equal. Or, if (A) or (Q) = xxx77777 or (B^b) = 77777, "y" must be 77777 to be equal.

If sign extension is specified, i.e. the instruction is ASE,S or QSE,S the sign of "y" (bit 14) is extended and the 24 bit quantity is compared with the quantity in the specified register.

Note: In this case, if (A) or (Q) = 77777777 or 00000000 and "y" is 77777 or 00000, the quantities are considered to be equal. For all other values in A or Q, the sign extended "y" value must be exactly the same to be considered equal.

Examples:

(i) ISE 300B,2

If (B_2) = 300_8, RNI P + 2.

(ii) ISE 50,1 (B^1) = 62_8

What is the RNI?

RNI = P + 2

(iii)
```
BEGIN   LDQ   FIELDA
        QSE   64210B
        ...
        ...
        ...
FIELDA  ØCT   50964210
```

What is the RNI after QSE?

RNI = P + 2 (=BEGIN + 3)

(iv) Example of use of ASE instruction in a loop.

```
        ENA     0
LØØP    STA     CIC.1
        STA     TEMP
        LDA     *-2
        INA     1
        STA     *-4
        LDA     TEMP
        INA     5
        ASE     25
        UJP     LØØP
        HLT
TEMP    BSS     1
```

This will store numbers 0, 5, 10, 15 and 20 in consecutive locations, begining at location CIC.1.

(iv) Use of Index skip-if-equal in a loop.

```
          ENI       0,1
LØØP      LDA       VALUE
          MUA       =D5
          DVA       =D8
          STA       RESULT
          LDA       LØØP
          INA       1
          STA       LØØP
          LDA       *-4
          INA       2
          STA       *-6
          INI       1,1
          ISE       100,1
          UJP       LØØP
          HLT
VALUE     ØCT       1
```

Exercises on SKIP-if-equal instructions

(a) How many times will the following loop be executed?

```
          ENQ       0
LØØP      LDA       ANS
          MUA       TW
          STA       ANS
          INQ       5
          QSE       100
          UJP       LØØP
          HLT
```

(b) Write a program segment to move ten numbers in consecutive locations, beginning at STORE, to consecutive locations beginning at RESULT.

(c) If CHECK contains 20100010, how many times will the following loop be executed?

```
          LDQ       CHECK
LØØP      LDA       TØM
          INQ       1
          .
          .
          .
          .
          QSE       12
          UJP       LØØP
          HLT
```

3.6.1 (cont.3)

(d) What will be the final contents of HOLD after execution of the following?

```
ENI    0,1
ENA    0
STA    HØLD
INA    10
INI    1,1
ISE    10,1
UJP    *-3
STA    HØLD
```

3.6.2 Skip if Greater Than or Equal

23 18	17	16 15	14 00
05	d	b	y

(i) d = 1
b = 0

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ASG,S	y

23 18	17 15	14 00
05	4	y

(ii) d = 1
b = 2

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ASG	y

23 18	17 15	14 00
05	6	y

(iii) d = 1
b = 1

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	QSG,S	y

23 18	17 15	14 00
05	5	y

(iv) d = 1
b = 3

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	QSG	y

23 18	17 15	14 00
05	7	y

(v) d = 0
b = index designator

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ISG	y,b

23 18	17 15	14 00
05	b	y

3.6.2 (cont.)

Description: If the instruction is ASG, QSG or ISG; ($A_{lower\ 15}$), ($Q_{lower\ 15}$) or (B^b) respectively is compared to "y". If greater than or equal, RNI from P+2, otherwise RNI from P+1.

Note: If the (A) or (Q) = xxx77777 or (B^b) = 77777, the instruction will skip if "y" is either 77777 or 00000. If the (A) or (Q) = 00000000 or (B^b) = 00000, the instruction will skip if "y" is 00000 but will not skip if it is 77777.

If sign extension is specified, i.e. the instruction is ASG,S or QSG,S the sign of "y" (bit 14) is extended and the 24 bit quantity is compared with the quantity in the specified register. If the sign bits are different the one with a sign bit of zero is larger.

Note: If the (A) or (Q) = 00000000, the instruction will skip if "y" is either 77777 or 00000. If the (A) or (Q) = 77777777, the instruction will skip if "y" is 77777 but will not skip if it is 00000.

Examples: (i) If (A) = 00002020

```
ASG   2020B
```

(A) is equal to y, skip next instruction, RNI at P + 2

(ii) If (A) = 10000001

```
ASG,S 40002B
```

y = 77740002 with sign extended

(A) is greater than y, skip next instruction, RNI at P + 2

Exercises in SKIP-IF-GREATER-THAN-OR-EQUAL Instruction

(a) To which STOP location will control jump?

```
ENA,S   40000B
INA     20B
ASG,S   40040B
UJP     STØP1
ASG     40020B
UJP     STØP2
UJP     STØP3
```

(b) To which location will control jump?

```
ENQ     200B
QSG,S   128
UJP     ENDING
UJP     PAUSE1
```

(c) How many times will the loop be executed?

```
ENI     0,1
LDA     PERSØN,1
MUA     RATE1
SHAQ    24
DVA     RATE2
STA     TAX,1
INI     1,1
ISG     500,1
UJP     *-7
HLT
```

3.6.3 Index Skip Incremental/Decremental

23–18	17	16–15	14–00
10	d	b	y

d = 0, Index Skip Incremental

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ISI	y, b

23–18	17–15	14–00
10	b	y

b = index register designator

d = 1, Index Skip Decremental

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ISD	y, b

23–18	17–15	14–00
10	b + 4	y

b = index register designator

Description: If $(B^b) = y$ skip to P + 2 and clear the index register. If $(B^b) \neq y$ RNI from P + 1 and add 1 to (or subtract 1 from) the index register.

Examples: (i)

```
ENI     0,1
LDA     BUFFER,1
STA     DATA,1
ISI     9,1
UJP     *-3
HLT
```

What is this series of instructions doing?

Answer: Moving 10 words from BUFFER to DATA

(ii) How can the same problem be done using the ISD instead of the ISI?

```
ENI     9,1
LDA     BUFFER,1
STA     DATA,1
ISD     0,1
UJP     *-3
HLT
```

Exercise: Write a program segment to move 50 numbers from BUFFER to locations beginning at STORE. FIND the total of these numbers and store the answer in RESULT.

3.7 STORE WORD ADDRESS

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SWA,I	m,b

23–18	17	16–15	14–00
44	a	b	m

Description: Stores the lower 15 bits of (A) in the storage location M. The high - order 9 bits of (M) are unchanged.

Examples:

(i)

```
         SWA    INST          (A) = 17603216
          .
          .
          .
INST     LDA    **
```

What will be the contents of INST?

(INST) = 20077777 (Before)

(INST) = 20003216 (After)

(ii)

```
INST     LDA    *+1
         SWA    *-1
```

Where INST = 76B, what will be the contents of words 76B and 77B?

(76B) = 20000076

(77B) = 44000076

Exercise: What, if any, is the difference between the modification achieved by the two program segments below?

Program A

```
         LDA    FØUR06
         SWA    INST
          .
          .
          .
INST     ENA    **
          .
          .
          .
FØUR06   ØCT    406
```

Program B

```
         LDA    INST
         ENA    406
         STA    INST
          .
          .
          .
          .
INST     ENA    **
```

3.8 SHIFT INSTRUCTIONS

3.8.1 Shift Instruction format

23 — 18	17	16 15	14 — 00
f	d	b	k

d = an operation designator, which is virtually an extension of the function code. It differentiates between 2 instructions using the same f code.

e.g. SHA d = 0

SHQ d = 1

b = index register designator
The contents of the index register is treated as a 15 bit signed number and is used as a shift direction and/or number-of-bits modifier.

k = Shift count, base
It may be positive or negative (in complement form) depending on the direction of the shift.

Left shift = positive

Right shift = negative

K = shift count, actual
$K = (B^b) + k$ if $b \neq 0$ otherwise $K = k$ if $b = 0$.
If the sum is 77777_8 or larger, subtract 77777_8 to get the true sum, otherwise the sum is the true sum.
If the true sum is between 00000 and 37777_8, the righthand two octal digits are the actual shift count for a left shift. If the true sum is between 40000 and 77777_8, the complement of the righthand two octal digits are the actual shift count for a right shift.

Shift timing if K = + (use only lower 2 digits of K)*

Mx \ xN	x0	x1	x2	x3	x4	x5	x6	x7
0x	1.3 usec							
1x	1.3 usec							
2x	1.45 usec							
3x	1.7 usec							
4x	1.95 usec							
5x	2.2 usec							
6x	2.45 usec							
7x	2.7 usec							

Mx + xN = octal shift count

*if K = -, complement and use the lower 2 digits to determine the timing

3.8.2 Shift A and Shift Q

23 — 18	17	16 — 15	14 — 00
12	d	b	k

d = 0, Shift A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SHA	k, b

23 — 18	17 — 15	14 — 00
12	b	k

b = index register designator

d = 1, Shift Q

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SHQ	k, b

23 — 18	17 — 15	14 — 00
12	b + 4	k

b = index register designator

Description: The 24-bit contents of the register are shifted according to the magnitude and sign of K (i.e., k + b)

If K is +, instruction is left shift end around
If K is -, instruction is right shift end off

e.g. Shift left 6 positions: K = 00006
Shift right 6 positions: K = 77771

N.B. (i) During right shift, the sign bit is extended and the low order bits are discarded.

(ii) During left shift, the high order bits are brought end around.

(iii) (B^b) and k, with their signs extended, are added to give K. The computer then senses bits 00-05 and bit 23 to determine the size and direction of shift, respectively.

3.8.2 (cont.)

Examples of Shift A and Shift Q

(i)	SHA 6		(A) = 10203040
	After Shift		(A) = 20304010
(ii)	SHA -6		(A) = 12345671
	After Shift		(A) = ?
	(A) = 00123456		
(iii)	SHA -6		(A) = 50367123
	After Shift		(A) = ?
	(A) = 77503671		

Exercises on Shift A and Shift Q

(a) If (A) = 20000010

What will be the contents of A after

```
SHA    4
SHA    -4
```

(b) If (A) = 21354706

What will be the contents of A after

```
ENI    2001,1
SHA    8,1
```

(c) If (Q) = 10000001

What will be the contents of Q after

```
SHQ    6
```

(d) If (Q) = 12345670

What will be the contents of Q after each shift in the following?

```
ENI    307,2
SHQ    4,2
SHQ    -13
```

(e) If (LABEL) = 10421045

What will be the contents of LABEL after

```
LDA    LABEL
SHA    -15
STA    LABEL
LDQ    LABEL
SHQ    1404B
STQ    LABEL
```

STUDENT NOTES

INSTRUCTION MODIFICATION

Chapter 4

4.1 SIGN EXTENSION

Certain instructions offer the option of extending the sign of a 15 or 17-bit operand by putting a modifier "S" in the operation field.

e.g. ENA,S 06370B (A) = 00006370

ENQ,S 76432B (Q) = 77776432

Examples:

(i) ASE,S 77777B where (A) = 77777777

What is RNI address?

RNI from P + 2.

(ii) ENA,S -6 what will be (A)?

(A) = 77777771

(iii) ENQ,S 405B what will be (Q)?

(Q) = 00000405

(iv) ENA,S 7B what will be (A)?

(A) = 00000007

(v) ENQ,S 43125B what will be (Q)?

(Q) = 77743125

(vi) Where (Q) = 00054631B

QSE,S 54631B will result in the RNI being (a) P + 1 or (b) P + 2?

Answer : P + 1

(vii) ASG,S 43671B where A = 43671234

what is RNI?

Answer : "y" extended = 77743671

(A) is not greater than or equal to "y",

because "y" is less negative.

(A) = -34106543
y = -00034106

RNI at P + 1

4.2 ADDRESS MODES

There are three address modes as follows:

(a) No address

e.g. Operand ENA 10B
Shift count SHAQ 5

(b) Direct Addressing

a = 0

m - operand address

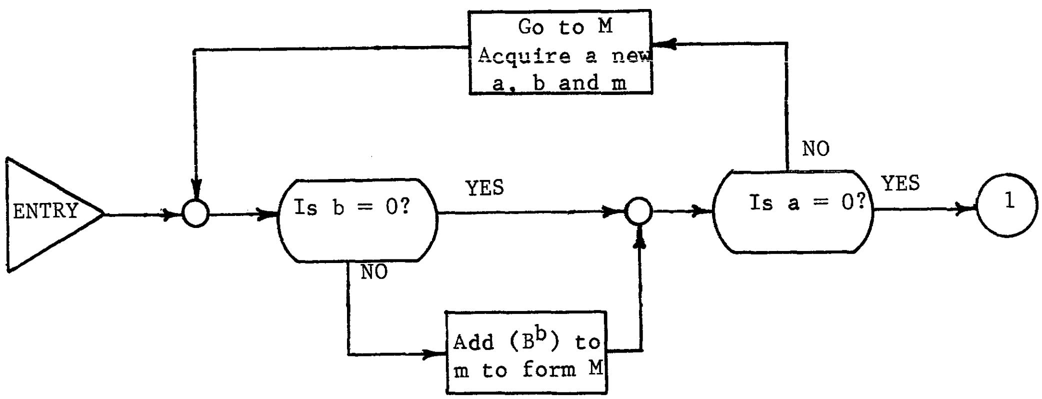
e.g. LDA 45B will load the contents of word 45B into the A register.

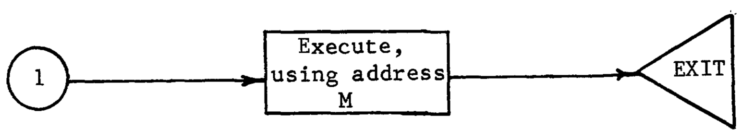
(c) Indirect Addressing

a = 1

e.g. LDA,I m the "I" specifies indirect addressing and generates a "1" bit in bit 17.

The best way to explain is with the following flow chart and examples.





Examples:

In the following examples use the contents of these 5 words

100	26000101	
101	37421623	$(B^1) = 2$
102	00000103	
103	76543214	$(B^2) = 4$
104	40500100	

<u>4.2 (cont.)</u>

(i) LDA 100B

What will be the (A) after execution?
(A) = 26000101.

(ii) LDA,I 100B

What will be the (A) after execution?
(A) = 37421673

(iii) LDA,I 100B,1

What will be the (A) after execution?
(A) = 76543214

(iv) LDA,I 100B,2

What will be the (A) after execution?

4.3 INDEX MODIFICATION OF WORD ADDRESSING INSTRUCTIONS

The 3200 has 3 Index Registers each of 15-bit capacity. These Index Registers can be used to modify the address fields of many instructions.

e.g. LDA STORE will load the contents of STORE into the A Register. But LDA STORE,1 will load the contents of (STORE + (B^1)) into the A Register, (i.e. if (B^1) = 1, it will load STORE + 1).
How is an indexed instruction assembled?
LDA STORE,2 where STORE = 00142B will assemble as: 20200142
Why?

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDA	m,b

23 18	17	16 15	14 00
20	a	b	m

a = addressing mode designator
b = index register designator

b = 00_2 means no index register

b = 01_2 means index register 1

b = 10_2 means index register 2

b = 11_2 means index register 3

Example LDA TAG,1 where (B^1) = 3
and TAG = 100B

100	11111111
101	22222222
102	33333333
103	44444444
104	55555555

(A) = 44444444

Restrictions on Indexing

The following instructions cannot specify indexing.

LDI	ISE	INA
STI	ASE	INQ
INI	QSE	ENA
ENI		ENQ
		AQJ
		AZJ

Exercises on Index Modification *

*Additional material on Index Modification is located in Chapter 8.3

1. A block of memory is as shown:

TABLE	00000000
	11111111
	22222222
	33333333
TABLEX	44444444
	55555555
	66666666
	77777777

4.3 (cont.)

What will be the contents of memory as a result of the following:

```
ENI  0,1
LDA  TABLE,1
STA  TABLEX,1
INI  1,1
LDA  TABLE,1
STA  TABLEX,1
INI  2,1
LDA  TABLE,1
STA  TABLEX,1
```

2. A block of memory contains the values shown

100	00000001
	00002222
	00000303
	04040404
	50055005
TAG	06606606
	77777777
	00000000
	11111111

What will be contained in the block after execution of the following instructions:

```
ENI  0,1
LDA  100B,1
INI  2,1
STA  100B,1
ENI  3,2
LDA  100B,1
STA  100B,2
ENI  5,3
LDA  TAG-6,3
STA  TAG,1
STA  TAG,2
```

48-BIT OPERATIONS

5.1 LOAD AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDAQ,I	m,b

23 18	17 16	15 14	00
25	a	b	m

a = addressing mode designator

b = index designator

m = storage address.

Description: Loads Registers A and Q with the two words from address M and M + 1 respectively, where M = m + (B^b).

Example: (SUM48) = 11 11 11 11
(SUM48+1) = 22 22 22 22

```
LDAQ        SUM48
```

	A	Q
AQ =	11 11 11 11	22 22 22 22

Exercises: (i) A block of memory is as follows:

103	1111 1111
104	2000 2000
105	6666 6666
106	2323 2323
107	0111 1110
110	7070 7070
111	3333 4444

This has been set up by a subprogram, part of which was:

```
        ORGR    100B
        BSS     5
FIELD   BSS     3
```

What would be the contents of AQ after execution of:

```
        LDAQ    FIELD+3
```

5.1 (cont.)

Exercises: (Continued)

(ii) A block of memory is as follows:

77	11 11 11 11
100	22 22 22 22
101	33 33 33 33
102	44 44 44 44
103	55 55 55 55
104	66 66 66 66
105	77 77 77 77

A portion of a program reads:

```
        LDAQ     TABLE
        LDQ      TABLE+3
        STA      TABLE+2
        STQ      TABLE+1

        ORGR     100B
TABLE   BSS      10
```

What would be the contents of the block after execution of the above program?

5.2 STORE AQ

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	STAQ,I	m,b

23 18	17	16 15	14 00
45	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Store the contents of Registers A and Q in storage locations M and M + 1 respectively.

Example: (i) If (A) = 1111 1111

(Q) = 3333 3333

	A	Q
i.e. AQ =	11 11 11 11	33 33 33 33

What will be the contents of locations 100_8 and 101_8 after execution of the following instruction?

STAQ 100B

Answer : (00100) = 11111111
(00101) = 33333333

(ii) If FIELD = location 204_8
(A) = 22334455
(Q) = 66006600

STAQ FIELD

Answer : (FIELD) becomes 22334455
(FIELD + 1) becomes 66006600

Exercise :

100	2 0 0 0 0 0 0 1
101	3 0 0 0 1 0 0 1
102	0 0 0 0 0 0 0 0
103	1 1 1 1 2 2 0 0
104	0 0 0 0 0 0 0 0
105	1 4 0 1 4 0 1 0
106	0 0 0 0 0 0 0 0

What will be the contents of the above after execution of the following instructions:

```
LDAQ    102B
STAQ    105B
LDAQ    100B
STAQ    104B
```

5.3 SHIFT AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SHAQ	k, b

23 – 18	17 – 15	14 – 00
13	b	k

b = index register designator

Description: The contents of A and Q are shifted as one 48-bit register (AQ).

Everything else is the same as for SHA and SHQ.

Examples:

(i) SHAQ -12 where (A) = 12345677

(Q) = 22223333

What will be the contents of A and Q?

(A) = 00001234

(Q) = 56772222

(ii) If (A) = 00010444 and (Q) = 11335577

SHAQ 35

Answer : (A) = 66774000
(Q) = 42220455

48-BIT, FIXED POINT, ARITHMETIC

Chapter 6

6.1 ADD TO AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ADAQ,I	m,b

23 18	17 16	15 14	00
32	a	b	m

a = addressing mode design

b = index designator

m = storage address

$M = m + (B^b)$

Description : Add the 48-bit contents of two consecutive locations M and M + 1 to the contents of AQ. The sum appears in AQ.

Examples:

(i) If

A	Q
0 0 0 0 0 0 0 0	00 14 76 21

and

ØP48	ØP48+1
0 0 0 0 0 0 0 1	32 41 71 71

What will be the contents of AQ after execution of the following instruction?

ADAQ ØP48

Solution:

Final AQ =

A	Q
0 0 0 0 0 0 0 1	32 56 70 12

(ii) If (A) = 0000 0123

(Q) = 7000 0000

(Index register 1) = 1

77	1004 0404
100	0000 0200
101	7000 0000
102	7777 7713

What will be the contents of A and Q after execution of the instruction:

ADAQ 77B,1

Solution:

AQ =

A	Q
0000 0324	6000 0000

Exercises:

(i) What will be the contents of AQ after execution of the following section of a program?

```
ENI      0,1
ENA      24314B
STA      100B,1
INA      14741B
INI      1,1
STA      100B,1
ENA,S    34567B
ENQ,S    15677B
ADAQ     100B
```

(ii) If (TAG) = 0202 0303

(TAG+1) = 0404 0505

(A) = 2662 6626

(Q) = 1457 1406

What will be the contents of A and Q after execution of the following instruction?

```
ADAQ     TAG
```

6.2 SUBTRACT FROM AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SBAQ,I	m,b

23–18	17	16–15	14–00
33	a	b	m

a = addressing mode indicator

b = index designator

m = storage address

$M = m + (B^b)$

Description: Subtract the contents of 2 consecutive locations M and M + 1 from the contents of AQ. The difference appears in AQ.

Examples:

(i)

A	Q
0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0

TAG	TAG+1
0 0 0 0 0 0 0 0	7 7 7 7 7 7 7 7

SBAQ TAG

Final AQ =

A	Q
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 1

(ii) If (A) = 0

(Q) = 0000 0003

(TAG) = 0

(TAG+1) = 0000 0004

What will be in A and Q after execution of the following instruction?

SBAQ TAG

Answer:

A	Q
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 3

minus

TAG	TAG+1
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 4

=

A	Q
7 7 7 7 7 7 7 7	7 7 7 7 7 7 7 6

(using end around borrow in the subtraction)

6.2 (cont.)

Exercise:

(i) (A) = 0005 7777

(Q) = 7777 0000

(TAG) = 0000 0234

(TAG+1) = 5670 0000

What will be in A and Q after execution of the following instruction?

SBAQ TAG

(ii) A block of memory is as shown:

100	21	21	21	21
101	00	00	01	35
102	21	64	16	45
103	14	14	21	21
104	00	00	00	27
105	77	77	77	77
106	56	56	57	57

What will be the contents of AQ after execution of the following instruction?

```
ENQ,S    0
ENA,S    2222B
SBAQ     101B
SBAQ     104B
```

6.3 MULTIPLY AQ

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	MUAQ,I	m,b

23 18	17 16	15 14	00
56	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: The instruction uses the 48-bit E register to extend the precision of AQ (by forming AQE). Muliply the contents of AQ by the 48-bit operand in two consecutive locations M and M + 1, where M = m + (B^b). The 96-bit product appears in AQE, with the least significant bits in E.

Example:

A	Q
0 0 0 0 0 0 0 0	7 6 0 0 0 0 0 0

TAG	TAG+1
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 2

MUAQ TAG

The final results in AQE =

A	Q	E
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 1 7 4 0 0 0 0 0 0

Exercise:

A block of memory is as shown

400	00 00 01 11
401	00 00 00 00
402	00 00 00 07
403	25 37 32 10
404	24 24 42 44
405	00 00 17 07

What will be the contents of AQE after execution of the following instructions?

```
LDA     404B
SBA     405B
STA     404B
LDQ     404B
LDA     400B
MUAQ    401B
```

6.4 DIVIDE AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	DVAQ,I	m,b

23 18	17 16	15 14	00
57	a	b	m

a = addressing mode designator

b = index designator

m = storage address

$M = m + (B^b)$

Description: Divide (AQE) by the 48 bit contents of two consecutive addresses, M and M + 1. The answer appears in AQ, and the remainder, with sign extended, in E.

Example :

A	Q	E	
0 0 0 0 0 0 0 0	0 0 0 0 6 7 4 3	2 6 5 4 3 1 7 4	2 0 0 0 0 0 0 0

DVAQ TAG

TAG	TAG+1
0 0 0 0 0 0 0 1	0 0 0 0 0 0 0 0

Answer is in AQ =

A	Q
0 0 0 0 6 7 4 3	2 6 5 4 3 1 7 4

Remainder is in E =

(Sign extended)

E	
0 0 0 0 0 0 0 0	2 0 0 0 0 0 0 0

Note : If a divide fault occurs, this operation halts, and the program advances to the next instruction.
The final contents of AQ and E are meaningless if this occurs.

STUDENT NOTES

LOGICAL OPERATIONS

Chapter 7

7.1 LOGIC TABLES

7.1.1 Logical "AND" (Logical product)

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Note: C is only a "1" if both A and B are "1's".

Example : AND of 1001 and 1010 (binary numbers)

```
1001
1010
----
1000
```

7.1.2 Inclusive "OR" (Selective Set)

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Note: C is a "1" if either or both A and B are "1's".

Example : Inclusive OR of 1001 and 1010

```
1001
1010
----
1011
```

7.1.3 Exclusive "OR" (Selective Complement)

A	B	C
0	0	0
0	1	1
1	0	1
1	1	0

Note: C is a "1" only if A and B are different.

Example : Exclusive OR of 1001 and 1010

```
1001
1010
----
0011
```

7.1.4 Examples of Logical Operations Using Octal Numbers

(i) What is the logical "AND" of 43B and 62B?

Answer : 42B

(ii) What is the exclusive "OR" of 7021B and 33B?

Answer : 7012B

(iii) What is the inclusive "OR" of 361B and 403B?

Answer : 763B

(iv) What is the exclusive "OR" of 361B and 777B?

Answer : 416B

7.2 LOAD A LOGICAL

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	LDL,I	m,b

23 18	17	16 15	14 00
27	a	b	m

a = addressing mode indicator

b = index designator

m = storage address

$M = m + (B^b)$

Description: A is loaded with the logical product (AND) of Q and the contents of location M. In this instruction, Q serves as a mask.

Q	M	A
0	0	0
0	1	0
1	0	0
1	1	1

Note: The bit in A is a "1" only if both of the corresponding bits in Q and M are "1's".

Examples:

(i) LDL 100B

100	32470235
101	12345670
102	24601357

Q = 70770770

(A) = 30470230

(ii) If index register 3 contains 00002

LDL 100B,3

M = 00100 + 00002

= 00102

	octal	binary
(00102B) =	24601357_8	$010\ 100\ 110\ 000\ 001\ 011\ 101\ 111_2$
(Q) =	70770770_8	$111\ 000\ 111\ 111\ 000\ 111\ 111\ 000_2$
(A) =	20600350_8	$010\ 000\ 110\ 000\ 000\ 011\ 101\ 000_2$

Answer: (A) = 20600350

7.3 LOAD COMPLEMENTS

7.3.1 Load A Complement

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LCA,I	m,b

23 18	17	16 15	14 00
24	a	b	m

a = addressing mode indicator

b = index designator

m = storage address

Description: The instruction load A with the complement of the 24-bit word located at M, where $M = m + (B^b)$

Examples:

(i) LCA 100B

100	36476521
101	67543210
102	42454251
103	72130215

(A) = 41301256

(ii) If index register 2 contains 00003

LCA 100B,2 $M = 00100 + (B^2) = 00103$

(A) = 05647562

7.3.2 Load AQ Complement

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LCAQ,I	m,b

23 18	17	16 15	14 00
26	a	b	m

a = addressing mode indicator

b = index designator

m = storage address

Description: The instruction loads A with the complement of M, and Q with the complement of M + 1, where $M = m + (B^b)$

Examples:

(i) LCAQ 100B (using example above)

(A) = 41301256

(Q) = 10234567

(ii) If index register 3 contains 00002

LCAQ 100B,3 $M = 00100 + (B^3) = 00102$

(A) = 35323526

(Q) = 05647562

7.4 LOGICAL "AND" OPERATIONS

7.4.1 Logical Product A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LPA,I	m

23 18	17	16 15	14 00
37	a	b	m

a = addressing mode designator

b = index register designator

m = storage address

Description: Replace (A) with the logical product of (A) and (M) (logical AND)

Examples:

(i) LPA 100B where (100) = 55555555

(A) = 52525252

What will (A) be after execution?

(A) = 50505050

(ii) LDA MASK where (MASK) = 77777777

LPA CIØX and (CIØX) = 43752016

Answer (A) = 43752016

(iii) ENA,S 20301B where (MASK) = 77777777

LPA MASK

Answer (A) = 00020301

(iv) LDA STATUS where (STATUS) = 10203040

LPA STATMASK (STATMASK) = 76543210

Answer (A) = 10003000

7.4.2 AND of A and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANA,S	y

23–18	17	16–15	14–00
17	1	b	y

b = 0, if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANA,S	y

23–18	17–15	14–00
17	4	y

b = 2, if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANA	y

23–18	17–15	14–00
17	6	y

Description: Enter the 24 bit logical product of (A) and y (with sign extension if specified) into A. If sign extension is not specified, zeros are extended rather then the sign of y.

A	Y	A
0	0	0
0	1	0
1	0	0
1	1	1

Note: The bit in A is a "1" only if both of the corresponding bits in A and y are "1's".

Examples:

(i) ANA 23456B

Where (A) =	12345670	001 010 010 100 101 110 111 000
	00023456	000 000 000 010 011 100 101 110
	00001450_8	$000\ 000\ 000\ 000\ 001\ 100\ 101\ 000_2$

(ii) ANA,S 23456B

Where (A) =	07654321	000 111 110 101 100 011 010 001
	00023456	000 000 000 010 011 100 101 110
	00000000_8	$000\ 000\ 000\ 000\ 000\ 000\ 000\ 000_2$

(iii) ANA,S 43456B

Where (A) =	07654321	000 111 110 101 100 011 010 001
	77743456	111 111 111 100 011 100 101 110
	07640000_8	$000\ 111\ 110\ 100\ 000\ 000\ 000\ 000_2$

(iv) ANA,S 70707B

Where (A) =	11111111	001 001 001 001 001 001 001 001
	77770707	111 111 111 111 000 111 000 111
	11110101_8	$001\ 001\ 001\ 001\ 000\ 001\ 000\ 001_2$

7.4.3 AND of Q and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANQ,S	y

23 18	17	16 15	14 00
17	1	b	y

b = 1, if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANQ,S	y

23 18	17 15	14 00
17	5	y

b = 3, if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANQ	y

23 18	17 15	14 00
17	7	y

Description: Enter the 24 bit logical product of (Q) and y (with sign extension if specified) into Q. If sign extension is not specified, zeros are extended rather then the sign of y.

Examples: As for ANA,S y

7.4.4 AND of Index Register B^b and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ANI	y, b

23 18	17	16 15	14 00
17	0	b	y

b = index register designator (1-3)

Description: Enter the logical product of (B^b) and y into index register b.

Examples: (i) ENI 77B, 3

ANI 12B, 3

Index 3 contents = 00077

"AND" with 00012

00012

Answer : 00012 in index register 3

7.4.4 (cont.)

Examples: (Continued)

```
(ii)  ENI      12345B,2
      ANI      25252B,2

     (Index 3) = 12345
      "AND" with 25252
                 00240

      Answer :  00240 in index 2
```

7.5 EXCLUSIVE "OR" OPERATIONS

7.5.1 Selectively Complement A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SCA,I	m,b

23–18	17	16–15	14–00
36	a	b	m

a = addressing mode designator

b = index register designator

m = storage address

Description: Selectively complements corresponding bits in A for all 1-bits at address M. (Exclusive OR)

Examples:

(i) SCA 100B where (100) = 70707070

(A) = 52525252

What will (A) be after execution?

Answer : (A) = 22222222

(ii) ENA,S 77777B where (MASKS) = 10203040
SCA MASKS

Answer : (A) = 67574737

(iii) ENA,S 40001B where (SIGN) = 40000001
SCA SIGN

Answer : (A) = 37740000

(iv) LDA TAG where (TAG) = 77777777
SCA SETBIT (SETBIT) = 52525252

Answer : (A) = 25252525

(v) LDA GTRC where (GTRC) = 40000001
SCA GTRC

Answer : (A) = 0000 0000

7.5.2 Exclusive OR of A and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØA,S	y

23 18	17	16 15	14 00
16	1	b	y

b = 0, if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØA,S	y

23 18	17 15	14 00
16	4	y

b = 2, if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØA	y

23 18	17 15	14 00
16	6	y

Description: Enter the 24 bit exclusive OR of (A) and y (with sign extension if specified) into A. If sign extension is not specified, zeros are extended rather then the sign of y.

A	y	A
0	0	0
0	1	1
1	0	1
1	1	0

Note: The bit in A is a "1" only if the corresponding bits in A and y are different.

Examples: (i) XØA 44444B if A = $\boxed{33333333}$

$3_8 = 011_2$

$4_8 = 100_2$

OR = $7_8 = 111_2$

33333333
00044444
$\boxed{33377777}$ = answer

(ii) XØA,S 44444B if A = $\boxed{33333333}$

44444 is a negative number since $4_8 = 100_2$; therefore, find exclusive OR of (A) and 77744444.

$3_8 = 011_2$

$7_8 = 111_2$

OR = $4_8 = 100_2$

3333 3333
7774 4444
$\boxed{4447\ 7777}$ = answer

7.5.2 (cont.)

(iii) XØA,S 40001B

Where A = 20117070

40001 is negative and equals 77740001 with sign extended, therefore

```
20117070
77740001
--------
57657071
```

Answer: (A) = 57657071

7.5.3 Exclusive OR of Q and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØQ,S	y

23 18	17	16 15	14 00
16	1	b	y

b = 1, if sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØQ,S	y

23 18	17 15	14 00
16	5	y

b = 3, if no sign extension

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØQ	y

23 18	17 15	14 00
16	7	y

Description: Enter the 24 bit exclusive OR of (Q) and y (with sign extension if specified) into Q. If sign extension is not specified, zeros are extended rather then the sign of y.

Examples: As for XØA,S

7.5.4 Exclusive OR of Index Register B^b and y

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	XØI	y,b

23 18	17	16 15	14 00
16	0	b	y

b = index designator (1-3)

Description: Enter the exclusive OR of (B^b) and Y into B^b
No sign extension is possible on either (B^b) or y.

Examples: (i) XØI 77B,1

where index 1 contains 32B

$$
\begin{array}{rcl}
00032 & = & 000\ 000\ 000\ 011\ 010 \\
00077 & = & \underline{000\ 000\ 000\ 111\ 111} \\
 & & 000\ 000\ 000\ 100\ 101_2 = 00045_8
\end{array}
$$

Answer : Index register 1 will contain 45B

(ii) XØI 77777B,2

Where index register 2 contains 74321B

$$
\begin{array}{rcl}
74321 & = & 111\ 100\ 011\ 010\ 001 \\
77777 & = & \underline{111\ 111\ 111\ 111\ 111} \\
 & & 000\ 011\ 100\ 101\ 110_2 = 03456_8
\end{array}
$$

Answer : Index register 2 contains 3456B

7.6 SELECTIVELY SET A

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	SSA,I	m,b

23 18	17	16 15	14 00
35	a	b	m

a = addressing mode designator

b = index register designator

m = storage address

Description: Selectively set 1-bits in A for all 1-bits in M

N.B. This instruction leaves "1" bits which were already present in the register; i.e. it does not clear A before execution.
This instruction is performing an "inclusive OR" operation.

Examples:

(i) SSA 100B where (100) = 70707070
(A) = 52525252

What will (A) be after execution.

(A) = 72727272

(ii) ENA,S 0 where (ABIT) = 76543210
SSA ABIT

Answer: (A) = 76543210

(iii) ENA,S 21010B where (MØD) = 11111111
SSA MØD

Answer: (A) = 11131111

(iv) ENA,S 44444B where (MØD) = 11111111
SSA MØD

Answer: (A) = 77755555

CHARACTER MODE OF OPERATION

Chapter 8

8.1 INTRODUCTION

Data may be stored in two ways in the 3200. It may be stored in full words - that is, the information stored in 24 bits. Or, it may be stored in character form.

Each word in the 3200 may be broken up into four 6-bit characters, which are called characters 0, 1, 2 and 3 in the particular word, as shown:

23 18	17 12	11 06	05 00
0	1	2	3

Information may be stored in characters, instead of in words, for convenience and economy. For instance, if we wish to store fifty digits, it could be more convenient to store them as 50 characters, to take up only 12½ words of storage, rather than put each digit into a separate computer word.

The computer is able to address any character in any word in storage. To find the character address of any particular character, the word address of the word containing the character is multiplied by 4; and the character position is added on.

The process is simpler if the arithmetic is done in binary. To multiply by 4 in binary you suffix two zeros to the righthand end of the number. The character positions are (in binary) 00, 01, 10 and 11. Therefore to find the character address:

(i) Change the word address to binary

(ii) Add the character position in binary as 2 extra low order bits

(iii) Convert back to octal

Example: Character 2 in word 104

(i) Binary = 001 000 100

(ii) Add on character position = 001 000 100 10 (Character position)

After regrouping bits = 00 100 010 010

(iii) Convert to octal = 422B = Character Address

Exercise: Find the character addresses of the following characters.

Word Address	Character Position	Character Address
100	3	
405	1	
1021	0	
477	2	
4001	1	
2664	0	
17777	3	

Similarly, if we know a character address, we can determine the word address in which the character is contained, and its position in the word.

8.1 (cont.1)

The steps are:

(i) Convert to binary

(ii) Remove the last two binary digits. (These are the character position)

(iii) Convert the remainder to octal.

Example: Character address 422

(i) Binary = 100 010 010

(ii) Divide by 4 = 100 010 0_2 Remainder = 10_2 = 2_8 = Character Position

(iii) Regrouped = 1 000 100_2 Octal = 104 = word Address

Answer - Character 2 in word 104

Exercise: (i) Find the word address and character position of the following character addresses:

(a) 201	(e) 2110
(b) 3	(f) 4231
(c) 417	(g) 16524
(d) 555	(h) 66666

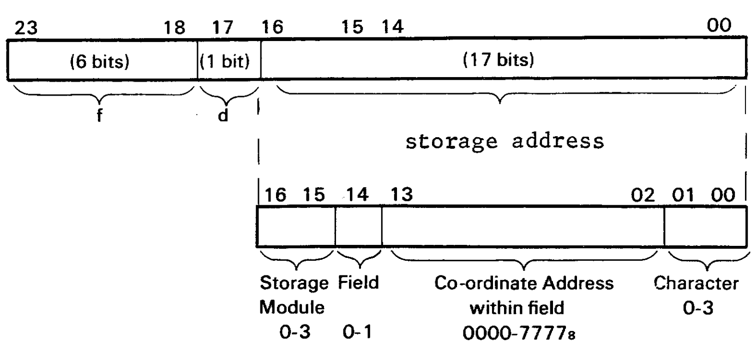
(ii) What is the smallest character address?

(iii) What is the largest character address in an 8K computer?

(iv) What is the largest character address in an 32K computer?

Character Address Instruction Format

The instruction format enables the address of a particular character in a word to be specified.



Character-Addressed Instruction Format

(i) Function Code (f)

6 bit code of action to be carried out.

(ii) Operation Designator (d) - 1 bit

If d = 1, modify address "m" by contents of a set index for the particular instruction.

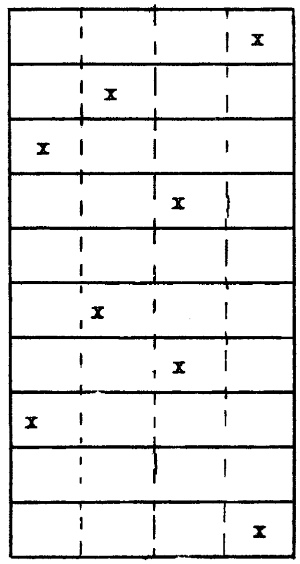
If d = 0, no modifications.

(iii) Storage Address (17 bits)

The address of the character required is specified. This may be broken up into the module, field and co-ordinate address, as for word addressing, plus two bits to indicate the character position in the word.

Exercise:

Assume that the following block of memory is in Field 1 of an 8K computer. What will be the character addresses of the characters marked x? The co-ordinate address of the first word in the block is 3124_8.



8.2 CHARACTER ADDRESS INSTRUCTIONS

8.2.1 Load A Character

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LACH	m,1

23 — 18	17	16 — 00
22	b	m

m = 17 bit character address

b = index designator - but can be only one bit, so has special use. See section on indexing(section 8.3).

Description: Clears (A) and loads into bits 00-05 of A, the contents of the character specified by M. $(m + (B^1))$

Examples:

(i) LACH 403B

(A) = 40012431
(100) = 01020304
(400) = 05060701
(403) = 02030405

What will be the contents of the A Register?

(A) = 00000004 since 403B (char.) = 100B (word), pos. 3.

(ii) LACH 5B

What will be the contents of the A Register after execution?

0	01234567
1	12345670
2	23456701
3	34567012
4	45670123
5	5670 1234

(A) = 00000034

(iii) LACH HRTABLE+3
•
•
•
HRTABLE BSS 4

HRTABLE

01	23	45	67
12	34	56	70
11	22	33	44
55	66	77	00

What will be the (A) after execution?

(A) = 00000067

(iv) In (iii) what would be the (A) if the instruction was
LACH HRTABLE+13B
(A) = 00000044

8.2.2 Load Q Character

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LQCH	m,2

23 — 18	17	16 — 00
23	b	m

Description: Same as LACH except substitute Q Register for A Register, and it uses a different index register (which also is different from SQCH)

8.2.3 Store A Character

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SACH	m,2

23 18	17	16 00
42	b	m

m = 17 bit character address

b = index designator - but can be only one bit, so has special use. See section 8.3 on indexing.

Description: Store the contents of bits 0-5 of the A Register in the specified character address.
N.B. The contents of A and the remaining 3 characters in the storage word, are unchanged.

Examples:

(i) SACH 43B if (A) 20012345

Which character position of which word is affected, and what will be the contents of the character position?

Answer : (1) Word 10
(2) Position 3
(3) 45B

(ii) SACH LØC+3 (A) = 11560133

....

LØC BSS 5

What changes will be made to the 5 words shown?

(LØC) = 00112233

i.e. no change!

LØC	
LØC	00 11 22 33
	44 55 66 77
	01 02 03 04
	05 06 07 00
	12 34 56 07

8.2.4 Store Q Character

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SQCH	m,1

23 18	17	16 00
43	b	m

Description: Same as SACH except substitute Q register for A register, and it uses a different index register (which also is different then that used by LQCH)

8.2.5 Store Character Address

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	SCHA	m,b

23 18	17	16 15	14 00
46	a	b	m

a = addressing mode designator
b = index register designator
m = storage address

Description: Stores the lower 17 bits of (A) in the lower 17 bits of word M. The upper bits of M and the whole of A are unchanged. The instruction is used for character address modification. Compare with SWA instruction.

Examples:

(i) SCHA 50B (A) = 10747021

(50) = 23064513

What will be the contents of 50 after execution?

(50) = 23347021

(ii)

Location	Instruction		Assembled as
100	SCHA	*+1	46000101
101	LACH	**	22377777

If (A) = 11117643 when 100 is executed, what will be the contents of 101 after execution?

Answer: (101) = 22117643

8.2.6 Enter Character Address into A

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	ECHA,S	y

23–18	17	16–00
11	d	y

d = 0, if no sign extension

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	ECHA	y

23–18	17	16–00
11	0*	y

d = 1, if sign extension

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	ECHA,S	y

23–18	17	16–00
11	4*	y

Description: Enters the 17 bit quantity "y" into the A register. When d = 1, the sign of the quantity (2^{16} bit) is extended in A. When d = 0, the upper 7 bits of the A register are set to zero. "y" is usually a character address. If "y" is a symbolic word address, the actual machine address is multiplied by 4 before it is assembled in the instruction.

Examples:

(i) If ØUTBUF is character position 3 in the word at word address 100, what would be the contents of A after:

ECHA ØUTBUF

Answer: (A) = 00000403

(ii) What would be the contents of A after execution of:

ECHA 117640B

Answer: (A) = 00117640

(iii) If TABLE starts at word address 40000, what would be the contents of A after:

ECHA TABLE

Answer: (A) = 00200000

ECHA,S TABLE

Answer: (A) = 77600000

8.3 INDEX MODIFICATION OF CHARACTER ADDRESSING INSTRUCTIONS

Character address instructions have limited indexing ability.

f	b	m (17 bits)

b is only one bit, therefore it can only indicate whether a specific index is used or not used.

i.e. If the "b" bit is set, the address is modified by either (B^1) or (B^2) depending on the particular instruction.

```
LACH     m,1

LQCH     m,2

SACH     m,2

SQCH     m,1
```

Also, if the 'm' address is at one or the other end of a table, the table is limited in length to 16383_{10} characters.

i.e. If TABLE equals word address 30000B (character address = 100000B) and the instruction is:

```
        LACH     TABLE,1

(i)     and   (B1)  = 40000B                                77740000
                                                            00100000
        the character address referenced           =         040001

(ii)    or    (B1)  = 77776B                                77777776
                                                            00100000
        the character address referenced           =         077777

(iii)   or    (B1)  = 00000B                                00000000
                                                            00100000
        the character address referenced           =         100000

(iv)    or    (B1)  = 00001B                                00000001
                                                            00100000
        the character address referenced           =         100001

(v)     or    (B1)  = 37777B                                00037777
                                                            00100000
        the character address referenced           =         137777
```

Note: If the index register contains 40000 thru 77776 the reference is backward in memory, whereas if the index register contains 00001 thru 37777 the reference is forward in memory. This means that when writing programs in COMPASS, FORTRAN, ALGOL or COBOL one should be careful not to exceed 16383_{10} when defining character arrays.

Examples: In the following examples assume the contents of the index registers to be:

$(B^1) = 5$

$(B^2) = 2$

$(B^3) = -3$

(i)
```
LDA    LABEL+1,3
STA    LABEL,2
LDQ    LABEL,2
```

	11111111
	22222222
	33333333
LABEL	44444444
	55555555
	66666666
	77777777

What will be the contents of Q after execution of the program segment above?

(Q) = 22222222

(ii)
```
LACH   LABEL,1
```

What will be the contents of A?

Answer (A) = 00 00 00 55

Exercises:

1. A block of memory (maximum length = 100 words) contains numbers stored one to a word. The end of the list is indicated by a word containing BCD blanks. Write a routine which will add the numbers in the list. (Use indexing.)

2. Transfer 57 words located 4 memory locations apart, into 57 consecutive memory locations.

3. Transfer 17 words located 5 memory locations apart, into 17 words located 10 memory locations apart.

4. Calculate the sum of the octal numbers 0-14.

Chapter 9

INTER-REGISTER TRANSFERS

9.1 TRANSFER BETWEEN THE A REGISTER AND INDEX REGISTERS

9.1.1 Index Register to A Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	TIA	b

23–18	17	16–15	14–12	11–00
53	0	b	0	

b = index designator (1-3)
bits 0-11 are not used

Description: Transfer the 15-bit contents of index register B^b to A. (A Register is cleared before the transfer is done.)

Example:

If B^2 contains 54321 and A contains $\boxed{7003\ 2146}$

TIA 2

(a) clear A = 0000 0000

(b) transfer 15 bits in B^2 to lower 15 bit positions of A

(A) = 0005 4321

9.1.2 A Register to Index Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	TAI	b

23–18	17	16–15	14–12	11–00
53	1	b	0	

b = index designator (1-3)
bits 0-11 are not used

Description: Clear index register B^b, and transfer the lower 15 bits of (A) to it.

Example: If B^3 contains 21B and A contains $\boxed{7643\ 1000}$

TAI 3

(a) Clear Index 3

(b) Load it with lower 15 bits of A

(B^3) = 31000

9.2 TRANSFERS BETWEEN THE A REGISTER AND THE REGISTER FILE

(The Register File is a special high speed memory of 100_8 locations numbered from 00_8 - 77_8.)

9.2.1 Register File to A Register

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	TMA	m

23–18	17	16–15	14–12	11–06	05–00
53	0		2		m

m = Register File Address (00-77)

Bits 6 - 11 and 15 - 16 are not used.

Description: Transfer the contents to Register file m to A
A is cleared prior to the transfer.

Example: If A = 0000 0006, and Register file 20 = 0000 0014, what will be in A after execution of the following instruction?

TMA 20B

Answer : (a) A is cleared

(b) Contents of Reg. File 20 put in A

(A) = 00000014

9.2.2 A Register to Register File

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	TAM	m

23–18	17	16–15	14–12	11–06	05–00
53	1		2		m

m = Register File Address (00-77)
Bits 6 - 11 and 15 - 16 are not used.

Description: Register file m is cleared, and the contents of the A register are transferred to m.

Example: If (A) = 0000 1000

Register file 30 = 0000 0777

TAM 30B

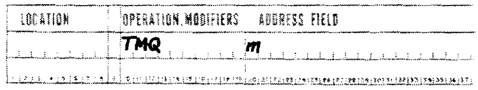
Answer: (a) Register file 30 is cleared

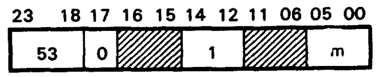
(b) Contents of A placed in Reg. file 30

(Reg File 30) = 00001000

9.3 TRANSFER BETWEEN THE Q REGISTER AND THE REGISTER FILE

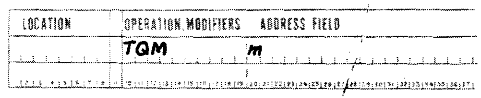
9.3.1 Register File to Q Register

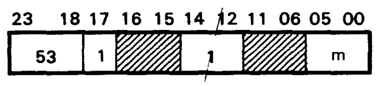




Description: As for TMA except uses Q register

9.3.2 Q Register to Register File





Description: As for TAM except uses Q register

9.4 TRANSFER BETWEEN INDEX REGISTERS AND THE REGISTER FILE

9.4.1 Register File to Index Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	TMI	m,b

23–18	17	16–15	14–12	11–06	05–00
53	0	b	3		m

b = index register designator
m = register file address (00-77_8)
bits 06-11 are not used

Description: Transfer the lower 15 bits of Register m to Index B^b. Index is cleared before transfer.

Example: Index register 3 contains 00010, and Register file 25 contains 0000 2000.

What will be in B^3 after execution of the following statement?

TMI 25B,3

(a) Index 3 is cleared

(b) Lower 15 bits of Register file 25 are put in it.

$B^3 = 02000$

9.4.2 Index Register to Register File

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	TIM	m,b

23–18	17	16–15	14–12	11–06	05–00
53	1	b	3		m

b = index register designator
m = register file address (00-77_8)
bits 06-11 are not used

Description: Clear Register file M, and transfer to it the contents of index register B^b.

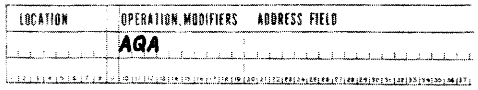
Example: (i) Index 3 contains 22B

TIM 26B,3

$(M_{26}) = \boxed{0000\ 0022}$

9.5 INTER-REGISTER ADDITION

9.5.1 Add Contents of Q to Contents of A



23–18	17–15	14–12	11–00
53	0	4	

Description: Transfer the contents of A plus the contents of Q to A. No information is given in the address field in this instruction.

Example: If (A) = 0000 1000
(Q) = 0000 4104

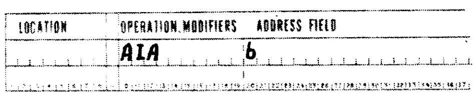
What will be A after execution of the following instruction?

AQA ---

Answer: (A) and (Q) are added together and put in A

(A) = 00005104

9.5.2 Add Contents of Index Register to Contents of A



23–18	17	16–15	14–12	11–00
53	0	b	4	

b = index register designator (1-3)

Description: Transfer the contents of A plus the contents of B^b to A. The contents of B^b is sign extended to perform the addition.

Example: If (A) = 0000 0100

(B^2) = 01404

What will be in A after execution of the following instruction?

AIA 2

Answer: (A) and (B_2) are added and the result stored in A

(A) = 00001504

9.5.3 Add Contents of A to Contents of Index Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	IAI	b

23–18	17	16–15	14–12	11–00
53	1	b	4	

b = index designator (1-3)

Description: The contents of A are added to the contents of Index Register (B^b) and the result stored in B^b. The sign of the original B^b is extended prior to addition, and only the lower 15 bits of the answer are placed in B^b.

Example: (B^2) = 00006

(A) = 0000 0007

What will be the contents of index register 2 after execution of the following statement?

IAI 2

Answer: (B^2) = 00015

Exercises: (i) If (B^3) = 40001

(A) = 0000 0007

What will be the contents of B^3 after execution of the following instruction?

IAI 3

(ii) If (B^1) = 40001

(A) = 1000 0007

What will be the contents of B^1 after execution of the following instruction?

IAI 1

STUDENT NOTES

SEARCH AND MOVE OPERATIONS

Chapter 10

10.1 BLOCK CONTROL

Block control is an auxiliary control section within the 3200 processor. In conjunction with the register file (see section 1.2.5) and program control (see section 1.2.4), it directs the following operations:

(a) External equipment Input/Output
(b) Search and Move operations
(c) Real time clock
(d) Console typewriter Input/Output
(e) High speed temporary storage in the register file.

Block control is called in to initiate Search/Move operations. When the operation is initiated, it then hands control back to program control, allowing program execution to continue while the Search/Move operations are being carried out.

Note that only one operation at a time can take place under Block control. An attempt to initiate, say, a Move operation while a Search operation is in progress, will cause the Move operation request to be rejected, and Program control will skip to the reject address following the instruction.

10.2 SEARCH OPERATIONS

10.2.1 Search for Character Equality

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SRCE,INT	c,m1,m2

P

23 18	17	16 00
71	INT	m_2

P + 1

23 18	17	16 00
c	0	m_1

INT = Interrupt designator
"1" = Interrupt at completion of search
"0" = Do not interrupt at completion of search
C = 00_8-77_8, BCD character to be looked for in memory
m_1 = First character address to be checked
m_2 = Last character address plus 1 to be checked

Description: This instruction attempts to INITIATE a search through a block of characters in storage, looking for a character equal to character "C" (specified in the instruction.)

SEARCH INITIATE POSSIBLE, i.e., the search/move section of block control is not busy. The instruction transfers the lower 18 bits of the first word of the instruction to register file address 30 and transfers all of the second word of the instruction to register file address 20. The hardware then sets flags in the upper 6 bits of register file address 30, the search is started and the computer RNI's from P+3. (During the search, register file addresses 20 and 30 are not to be disturbed, also the upper six bits of register file address 30 cannot be counted on to be any particular combination of bits).

SEARCH INITIATE NOT POSSIBLE, i.e., the search/move section of block control is busy. The instruction in this case executes as if it were a NOP (no operation instruction). It has no effect on the search/move section of block control, the register file or the interrupts if a search cannot be initiated. P+1 will be bypassed and RNI will be from P+2. This latter location is usually filled by the programmer with

```
UJP     *-2
```

to cause the computer to loop until the previous search/move operation is complete and the search can be started.

BUFFERED SEARCH. The search progresses while other instructions following the search initiate instruction are executed. The search is made, beginning at character address m_1 and continues character by character through memory until a character equal to "C" is found or until the address to be processed is equal to m_2. The programmer can find out that the search is complete at the instant it terminates or when he is ready to check. The first is achieved with the interrupt designator, the second by using a sense instruction (both of which are to be covered later).

Assuming that the programmer knows the search has completed, he can now determine if he found a character equal to character "C". If the lower 17 bits of register file address 20 and 30 are equal, no match was found. However, if they are unequal, the lower 17 bits of register file address 20 will contain the exact character address where the match with character "C" occurred. No ambiguity is possible, since register file address 30 (lower 17 bits) contains the last character address to be searched plus one; if the lower 17 bits of register file address 20 is equal to this address, the hardware has checked all addresses to be checked and is beyond the block of characters.

Example: Given the block of data shown

CDIMAGE	00 23 46 44	
	47 21 62 62	
	73 43 73 67	
	73 51 60 60	
	60 60 60 60	(word address of this last word is CDIMAGE+19)
		(character address of the last character is CDIMAGE+79)

and the instruction

```
SRCE      73B,CDIMAGE,CDIMAGE+80
```

what address will be in the lower 17 bits of register file address 20 at the termination of the search?

Answer: The address equal to CDIMAGE+8.
If CDIMAGE is equal to word address 1000_8 (character address 4000_8), then (register file 20, Lower 17) = 004010_8

Special Note: When checking for a no-find condition at termination of the search, the checking is easier if the block to be searched is less then 32768_{10} characters. If this is the case, one of the following two methods can be used:

(m_2 address fixed and lower two bits = 00_2)

```
TMA     20B
SHA     -2
ASE     endaddr
UJP     find
```

(m_2 address variable or lower two bits $\neq 00_2$)

```
TMA     30B
SWA     *+2
TMA     20B
ASE     **
UJP     find
```

10.2.2 Search for Character Inequality

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SRCN,INT	c, m_1, m_2

P

23 18	17	16 00
71	INT	m_2

P + 1

23 18	17	16 00
c	4+	m_1

INT = Interrupt designator
"1" = Interrupt at completion of search
"0" = Do not interrupt at completion of search
C = 00_8-77_8, BCD character to be checked against
m_1 = First character address to be checked
m_2 = Last character address plus 1 to be checked

Description: This instruction attempts to INITIATE a search through a block of characters in storage, looking for the first character not equal to the charater "C" (specified in the instruction.)

SEARCH INITIATE POSSIBLE, i.e., the search/move section of block control is not busy. The instruction transfers the lower 18 bits of the first word of the instruction to register file address 30 and transfers all of the second word to the instruction to register file address 20. The hardware then sets flags in the upper 6 bits of register file address 30, the search is started and the computer RNI's at P+3. (during the search, register file addresses 20 and 30 are not to be disturbed, also the upper six bits of register file address 30 cannot be counted on to be any particular combination of bits.)

SEARCH INITIATE NOT POSSIBLE, i.e., the search/move section of block control is busy. The instruction in this case executes as if it were a NOP (no operation instruction). It has no effect on the search/move section of block control, the register file or the interrupts if a search cannot be initiated. P+1 will be skipped and RNI will be from P+2. This latter location is usually filled by the programmer with

```
UJP    *-2
```

to cause the computer to loop until the previous search/move operation is complete and the search can be started.

BUFFERED SEARCH. The search progresses while other instructions following the search initiate instruction are executed. The search is made, beginning at character address m_1 and continues character by character through memory until the first character not equal to "C" is found or until the address to be processed is equal to m_2. The programmer can find out that the search is complete at the instant it terminates or when he is ready to check. The first is achieved with the interrupt designator, the second by using a sense instruction (both of which are to be covered later.)

Assuming that the programmer knows the search has completed, he can now determine if there were any characters other then the character "C" and where the first of those occurred. If the lower 17 bits of register file address 20 and 30 are equal, no characters others then "C" exist in the block. However, if they are unequal, the lower 17 bits of register file address 20 will contain the exact character address where the first character other then "C" occurred. No ambiguity is possible, since register file address 30 (lower 17 bits) contains the last character address to be searched plus one; if the lower 17 bits of register file address 20 is equal to this address, the hardware has checked all addresses to be checked and is beyond the block of characters.

Example: Given the block of data shown

CDIMAGE	60 60 60 60	
	60 60 60 60	
	60 62 51 23	
	45 60 60 60	
	60 60 60 60	(word address of this last word is CDIMAGE+19) (character address of this last character is CDIMAGE+79)

and the instruction

```
SRCN        60B,CDIMAGE,CDIMAGE+80
```

what address will be in the lower 17 bits of register file address 20 at the termination of the search?

Answer: The address equal to CDIMAGE+9. If CDIMAGE is equal to word address 10000_8 (character address 40000_8), then the contents of register file address $20_{\text{lower 17 bits}} = 040011_8$

Special Note: See the Special Note for the SRCE instruction (Section 10.2.1) for techniques in determining type of termination.

10.3 MOVE INSTRUCTION

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	MØVE,INT	y, m_1, m_2

P

23 18	17	16 00
72	INT	m_2

P + 1

23 17	16 00
y	m_1

INT = Interrupt designator
"1" = Interrupt at the completion of the Move
"0" = Do not interrupt at the completion of the Move
y = Number of characters to be Moved
If y = $001\text{-}177_8$, $001\text{-}127_{10}$ characters are Moved
If y = 000 , 128_{10} characters are Moved
m_1 = First character address of data source
m_2 = First character address of data destination

Description: This instruction attempts to INITIATE the copying of a block of "y" characters in one area in storage into a second area of storage. "y" is specified in the instruction.

MOVE INITIATE POSSIBLE, i.e., the search/move section of block control is not busy. The instruction transfers the lower 18 bits of the first word of the instruction to register file address 31 and transfers all of the second word of the instruction to register file address 21. The hardware then sets flags in the upper 6 bits of register file address 31, the move is started and the computer RNI's at P+3. (During the move, register file addresses 21 and 31 are not to be disturbed, also the upper six bits of register file address 31 cannot be counted on to be any particular combination of bits.)

MOVE INITIATE NOT POSSIBLE, i.e., the search/move section of block control is busy. The instruction in this case executes as if it were a NOP (no operation instruction). It has no effect on the search/move section of block control, the register file or the interrupts if a move cannot be initiated. P+1 will be skipped and RNI will be from P+2. This latter location is usually filled by the programmer with

```
UJP     *-2
```

to cause the computer to loop until the previous search/move operation is complete and the move can be started.

BUFFERED MOVE. The move is made beginning at character address m_1 (source) and m_2 (destination) and continues through memory until "y" characters have been moved. If both m_1 and m_2 are character addresses that represent character position 0 and the number of characters to be moved is a multiple of four, the data is copied a word at a time. If all three conditions are not met, the copying proceeds a character at a time. The word move only takes one-fourth the time of a character move for the same number of characters, so should be used when possible. As soon as the "y" characters have been moved, the move operation terminates and the search/move section of block control reverts to the not busy status.

Example: Given the block of data shown,

```
MOVE    6,410B,424B
UJP     *-2
```

101	21	14	16	32
102	60	60	60	60
103	21	31	41	21
104	60	60	60	60
105	17	01	17	01
106	25	25	25	25

What is in storage at end of MOVE Operation?

Answer:

101	21	14	16	32
102	60	60	60	60
103	21	31	41	21
104	60	60	60	60
105	60	60	60	60
106	21	31	25	25

Special Note: If "y" is set by the programmer, he should remember that it is 7 bits. A SACH (or SQCH) into the upper 6 bits of "y" represents a character move of twice the number represented by ($A_{lower\ 6}$) or ($Q_{lower\ 6}$) (or is twice+1 depending on the least significant bit of the original "y").

Techniques for changing "y":

Word Move, "y" originally set to 0, number of words to be moved in A register (right justified).

```
SHA     1
SACH    Moveinst+4
```

Word Move, "y" current contents unknown, Number of words to be moved in A register (right justified).

```
SHA     2
LDQ     Moveinst+1
SHQ     7
SHAQ    17
STA     Moveinst+1
```

Character Move, Number of characters to be moved in A register(right justified).

```
LDQ     Moveinst+1
SHQ     7
SHAQ    17
STA     Moveinst+1
```

Also if the source and destination blocks overlap, be sure that the source address is the higher address in memory or some of the source data will be destroyed.

10.4 PAUSE INSTRUCTION (as used with SEARCH/MOVE Instructions)

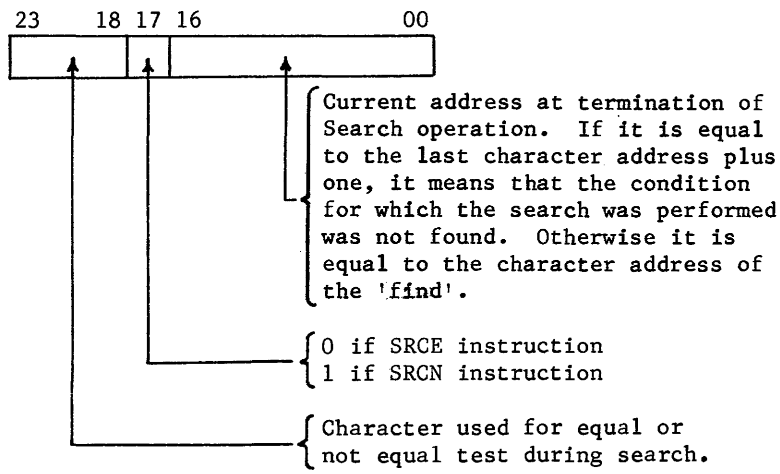
LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	PAUS	4000B

23–18	17–15	14–12	11–00
77	6		4000

Description: Once the main program has begun a Search/Move operation, it hands over control of that part of the program to the Search/Move section of Block Control. The main program is then resumed at P + 3. If it is necessary to find the result of the Search/Move operation before the main program goes on with further calculations, etc, the PAUS instruction is used.

This instruction senses the status of the Search/Move section of Block Control. If it is busy, the machine main control pauses for 40 msec., or until the Search/Move section becomes not busy. If it stays busy for 40 msec., the computer RNI's at P + 1. If it was originally not busy or becomes not busy during the 40 msec. interval, the computer RNI's at P + 2.

At the completion of a Search/Move operation, Register File Location 20 contains the final current word address for a Search operation and Register File Location 21 contains it for a Move. The contents of that word is generally not useful to the programmer in the case of a Move, but is quite important in the case of a Search. Here is how the word at Register File Location 20 is divided:



Examples: i) The instructions to be performed are:

```
SRCN    21B,400B,414B
UJP     *-2
PAUS    4000B
UJP     *-1
TMA     20B
HLT
```

The block of characters to be searched is:

100	21 21 21 21
101	21 21 21 21
102	21 21 20 21

What will be the contents of the A register when the computer halts on the HLT instruction?

Answer: (A) = 21400412 =

23–18	17	16–00
21	1	000414

ii) Given the block of data shown, where the word address of RHT = 17714_8, what will be the contents of A after execution of:

```
SRCE    21B,RHT,RHT+33
UJP     *-2
PAUS    4000B
UJP     *-1
TMA     20B
```

RHT

00 00 00 25
00 00 00 31
00 00 00 46
00 00 00 27
03 21 60 60
00 00 00 41
00 00 00 31
77 77 77 77

Answer: (A) = 21077501

iii) If the word address of STØRE is 17717_8, and the character address of CEASE is 77514_8, given the block of data shown, what will be the contents of A after execution of:

```
SRCN    60B,STØRE,CEASE
UJP     *-2
PAUS    4000B
UJP     *-1
TMA     20B
```

STØRE

60 60 60 60
60 60 60 60
60 60 21 60
60 60 60 60

Answer: (A) = 60477506

STØRE = word addr 17717_8 = $001\ 111\ 111\ 001\ 111_2$
= char position 0_4 = 00_2
= char address $001\ 111\ 111\ 001\ 111\ 00_2$
regrouped = $00\ 111\ 111\ 100\ 111\ 100_2$ = 77474_8

iv) If the word address of INBUFF is 17000_8 and the word address of ØUTBUFF is 17400_8 and the number of characters to be moved is 8, what will be the contents of the A register after the move is complete?

```
MØVE    8,INBUFF,ØUTBUFF
UJP     *-2
PAUS    4000B
UJP     *-1
TMA     21B
```

Answer: (A) = 00074010

At the start of the Move, the contents of Register file location 21 was:

04074000

Exercises: i) INBUFF currently contains a card image. Somewhere in the card image is a comma. Write the code that will search for the comma and then copy all the information up to the comma into an output area called ØUTBUFF. ØUTBUFF is large enough to contain all of INBUFF.

ii) ZUP currently contains a twelve digit BCD number with leading zeros. Using the Search Instruction, find the most significant digit and replace all leading zeros with 60B codes.

iii) Using the Search instruction, check the character in the A register against a table of characters, seven characters long. The table is as follows:

FTNØP	13 20 34 40
	54 61 74 00

If the character is equal to any of these characters, transfer control to location WASØP, otherwise continue to the next section of code.

STUDENT NOTES

STORAGE TESTS

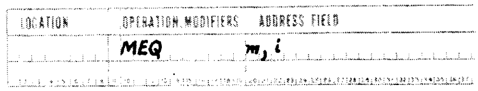
11.1 MASKED EQUALITY SEARCH

11.2 MASKED THRESHOLD SEARCH

11.3 STORAGE SHIFT

11.4 COMPARE (WITHIN LIMITS TEST)

Chapter 11



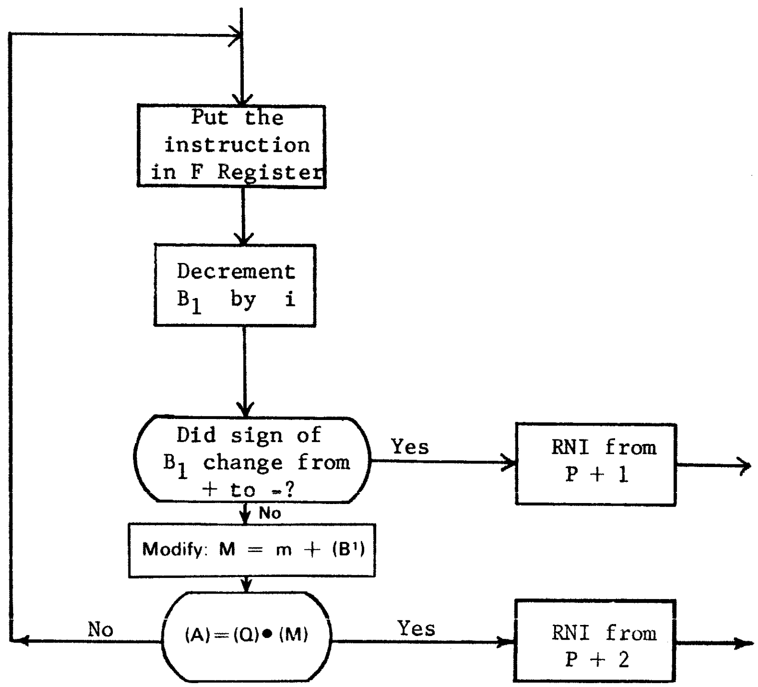
23–18	17–15	14–00
06	i	m

i = 0 thru 7 = interval designator

m = storage address (of first word)

Description: (A) is compared with the logical product of (Q) and (M) where M = m+(B^1)

NOTE: This instruction uses B^1 exclusively.



N.B. i = 1 means interval 1
i = 7 " " 7
i = 0 " " 8

Examples: (i) Given the following conditions:

(B^1) = 5
(Q) = 77777777_8
(A) = 60606060_8

100	00674320
101	21314367
102	60606060
103	67676767
104	47532167

and the following program section:

```
ENI      5,1
ENQ,S    -0
MEQ      100B,1
UJP      NØFIND
INI      100B,1
STI      FIND,1
```

do the following:

11.1 (cont.)

Answer:

(a) Decrement B^1 by 1 and calculate M.

$$M = m + (B^1)$$
$$= 100 + 4$$
$$= 104$$

(b) Compare (A) with logical product of (Q) and (104)

$$\begin{aligned} (Q) &= 77777777 \\ (104) &= \underline{47532167} \\ & 47532167 \end{aligned}$$

which is not equal to A.

(c) Decrement B^1 by 1 and repeat

$$\begin{aligned} (Q) &= 77777777 \\ (103) &= \underline{67676767} \\ & 67676767 \end{aligned}$$

which is not equal to A.

(d) Decrement B^1 by 1 and repeat

$$\begin{aligned} (Q) &= 77777777 \\ (102) &= \underline{60606060} \\ & 60606060 \end{aligned}$$

which is equal to A.

RNI P + 2.

(e) Contents of FIND = 102.

11.2 MASKED THRESHOLD SEARCH

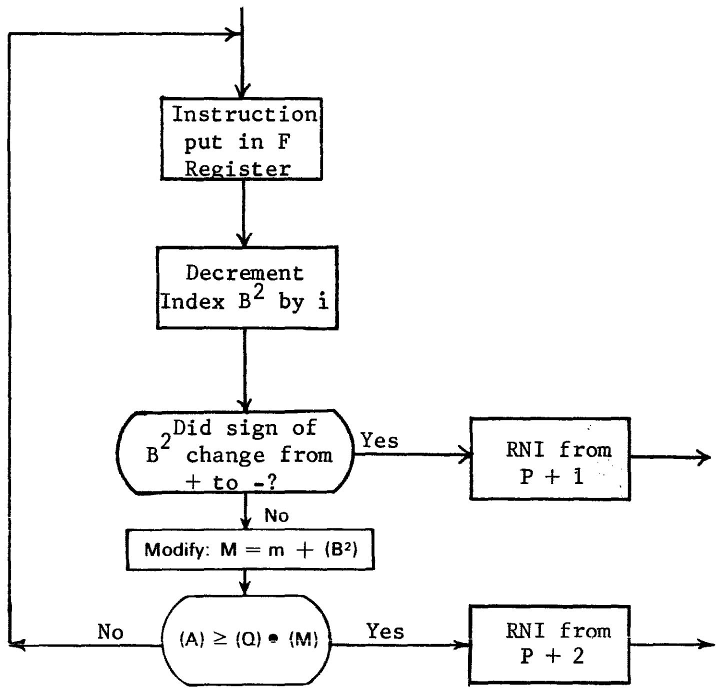
LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	MTH	m, i

23 18	17 15	14 00
07	i	m

i = 0 thru 7 = interval designator

m = storage address (of first word)

Description: This instruction is similar to the MEQ; the only differences being that RNI from P+2 occurs when (A) ≥ (Q) x (M), and that index B^2 is used exclusively.



Example: Given the following conditions and program section:

$(B^2) = 6$

$(Q) = 77777777_8$

$(A) = 00000040_8$

100	00000067
101	00000104
102	00000040
103	00000111
104	00000700
105	00000077
106	00000052

```
MTH     100B,2
UJP     NØFIND
INI     100B,2
STI     FIND,2
```

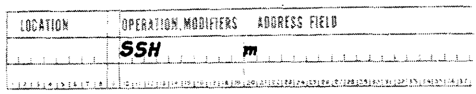
a) What will be the contents of FIND after this program section is executed?

b) What locations will have been checked?

Answers: a) $(FIND) = 00000102_8$

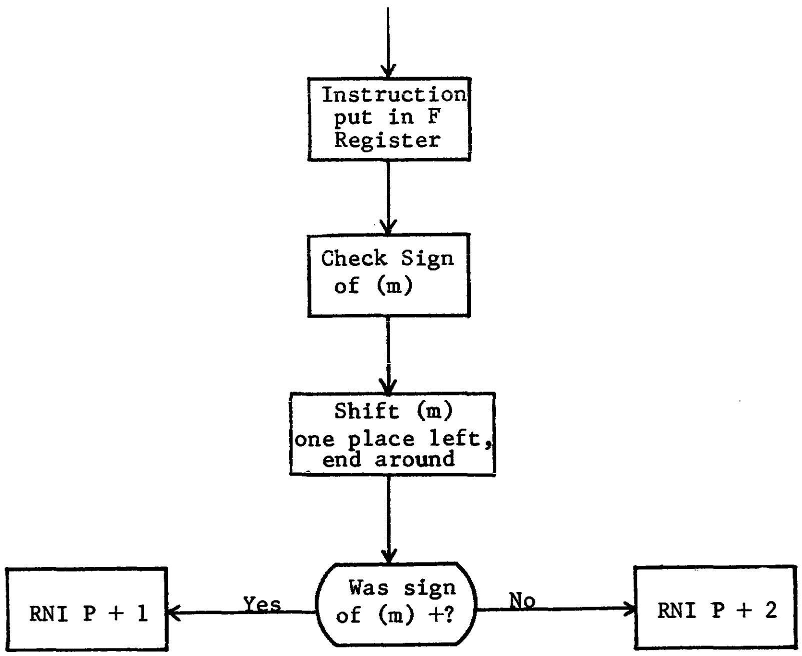
b) Locations checked = 104B and 102B

11.3 STORAGE SHIFT



23 – 18	17 – 15	14 – 00
10	0	m

Description: Sense bit 23 of (m).
Shift (m) one place left, end around, and replace it in storage. If bit 23 of (m) was a 1-bit, RNI from P+2, if 0 RNI from P+1.



Examples:

```
(i)          SSH       100B
             UJP       STØP
             UJP       *-2          (100) = 52525252
      STØP   HLT
```

First time through (100) = 101 010 101 010 101 010 101 010
which is negative, so RNI at P + 2.

Second time through (100) = 010 101 010 101 010 101 010 101
which is positive, so RNI at P + 1 and jump to Halt.

11.4 COMPARE (WITHIN LIMITS TEST)

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	CPR, I	m, b

23 – 18	17	16 – 15	14 – 00
52	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: The Compare, within limits test, instruction, is a two phase instruction. The first phase compares the contents of the M address against the contents of the A register. If the contents of memory is larger, the computer RNI's at P + 1. If the contents of memory is less than or equal to the contents of the A register, the instruction proceeds to the second phase of the test. This phase compares the contents of the Q register against the contents of the M address. If the contents of Q is larger, the computer RNI's at P + 2. If the contents is less than or equal to control passes to P + 3.

Summarized: If (M) > (A), RNI at P + 1
otherwise, next test

If (Q) > (M), RNI at P + 2
otherwise, RNI at P + 3

Expanded these relations become:

$$\left.\begin{array}{l} (Q) > (M) > (A) \\ (Q) = (M) > (A) \\ (M) > (Q) > (A) \\ (M) > (A) = (Q) \\ (M) > (A) > (Q) \end{array}\right\} \text{RNI at } P + 1$$

$$\left.\begin{array}{l} (A) > (Q) > (M) \\ (A) = (Q) > (M) \\ (Q) > (A) > (M) \\ (Q) > (M) = (A) \end{array}\right\} \text{RNI at } P + 2$$

$$\left.\begin{array}{l} (A) = (M) = (Q) \\ (A) = (M) > (Q) \\ (A) > (M) = (Q) \\ (A) > (M) > (Q) \end{array}\right\} \text{RNI at } P + 3$$

All possible relationships between A, Q and M are shown.

Normally, the value in the A register is greater than or equal to the value in the Q register. If this is the case, the following indicates the action of the instruction.

(M) > (A) ———————— RNI at P + 1
(A) ⩾ (M) ⩾ (Q) ——— RNI at P + 3
(Q) > (M) - RNI at P + 2

While the instruction is almost always used in situations where the contents of A is greater than or equal to the contents of Q, occasionally it is not. Following is a discussion of the instruction in these alternate uses.

Stated in shorthand form, where the contents of the A register is less than the contents of the Q register, the instruction behaves as follows:

(M) $>$ (A) RNI at P + 1
otherwise, RNI at P + 2

Note: RNI at P + 3 is not possible because if (M) $\leqslant$ (A) then (M) $<$ (Q) as (A) $<$ (Q).

Reversing positions of A and M, the branching conditions become:

(A) $<$ (M) RNI at P + 1
(A) $\geqslant$ (M) RNI at P + 2

This then is nothing more then an ASG with a full 24 bit operand. However, one value that A can take on is troublesome and that is 37777777. When this is the contents of A, (A) $<$ (Q) is not possible as 37777777 is the largest possible positive number.

While this form of the instruction looks useful, it rarely is used as it can usually be replaced by a load Q and an AQ test. The coding that way ends up shorter and executes faster.

Another possible use of the instruction exists where the contents of the A register is set to 37777777_8 or the contents of the Q register is set to 40000000_8.

In the case where (Q) is set to 40000000_8, the instruction acts as follows:

(M) $>$ (A) RNI at P + 1
otherwise, RNI at P + 3

This looks very much like the previous form except for the RNI's. It is essentially an A skip greater than or equal to where the skip is two words rather than one. Since P + 2 is unused, M can be set equal to it with (M) equal to the test value.

e.g.
```
LDQ     =Ø40000000
CPR     *+2
UJP     less-than-routine
ØCT     test-value
greater-than-or-equal-condition-next-instr.
```

In the case where (A) is set to 37777777_8, the instruction acts as follows:

(Q) $>$ (M) RNI at P + 2
otherwise, RNI at P + 3

This is essentially a Q test. Also since P + 1 is unused, M can be set equal to it with (M) equal to the test value.

e.g.
```
LDA     =Ø37777777
CPR     *+1
ØCT     test-value
UJP     greater-than- routine
less-than-or-equal-condition-next-instr.
```

Note in both of the two previous forms that A or Q must be set prior to the execution of the instruction and both A and Q are in use. Here as with the condition earlier, a load A or a load Q coupled with an AQ test usually produces shorter code which executes faster.

Still another possible use of the instruction exists where the contents of the A register is set equal to the contents of M or the contents of the Q register is set equal to the contents of M.

Where (Q) = (M), the instruction executes as indicated:

(M) > (A)   RNI at P + 1
otherwise, RNI at P + 3

This is similar to the case where the contents of Q is set to 40000000_8. As in that case, P + 2 is unused. Therefore, M can be set equal to P + 2 with (M) set equal to (Q) during execution.

e.g.
```
STQ     *+3
CPR     *+2
UJP     less-than-routine
BSS     1
greater-than-or-equal-to-next-instr.
```

Where (A) = (M), the instruction executes as follows:

(Q) > (M)   RNI at P + 2
otherwise, RNI at P + 3

This is similar to the case where the contents of A is set to 37777777_8. As in that case, P + 1 is unused. Therefore, M can be set equal to P + 1 with (M) set equal to (A) during execution.

e.g.
```
STA     *+2
CPR     *+1
BSS     1
UJP     greater-than-routine
less-than-or-equal-to-next-instr.
```

Note: In the case where (Q) is set equal to (M), the same thing could have been achieved by:

```
AQJ,GE   *+2
```

Likewise, in the case where (A) is set equal to (M), the following instruction serves the same purpose:

```
AQJ,GE   *+2
```

Since *+1 will almost certainly be a UJP, these can be replaced by a:

```
AQJ,LT   address-in-UJP-instruction
```

Obviously, the forms of the instruction where (Q) = (M) or (A) = (M) are not useful.

About the only useful form of the instruction other then the one where it is known that (A) ⩾ (Q), is where the (Q) is totally unknown and of no concern. When this is the case, the instruction is applied as follows:

$$(M) > (A) \qquad \text{RNI at } P + 1$$
$$\text{otherwise, RNI at } P + 2 \text{ or } P + 3$$

When used in this manner, it is nothing more then an ASG where the test value is a 24 bit operand and (P+2) must be a NOP.

No matter how the CPR instruction is applied, the following is always true:

$$00000000 \neq 77777777$$
$$\text{and, } 00000000 > 77777777$$

Example: Assuming the following initial conditions, what does this program do?

(A) = 100B
(Q) = 50B

(100) = 00000064
(101) = 00000104
(102) = 70000000
(103) = 00000700

```
BEGIN  CPR   100B
       UJP   *+2
       UJP   *-2
       CPR   101B
       CPR   102B
       UJP   *+2
       CPR   103B
       HLT   0
       UJP   *-5
```

Answer: RNI sequence = BEGIN
BEGIN+3
BEGIN+4
BEGIN+6
BEGIN+7 (Halt)

Exercise: Table IQ contains 100 IQ values. Count all the IQ's in the following ranges 0-79, 80-119, 120-up. Use the CPR instruction, then do it without the CPR instruction.

STUDENT NOTES

FLOATING POINT OPERATIONS

Chapter 12

12.1 INTRODUCTION

12.1.1 Storage of floating point numbers

Any number can be expressed in the form kB^n

when k = coefficient

B = base

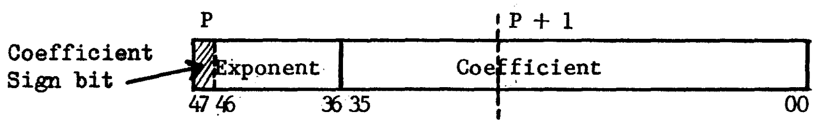
n = exponent

Floating point is always packed into 2 words in the 3200, making a 48-bit representation of the number.

The lower 36 bits = the coefficient

next 11 bits = exponent and sign of exponent

Upper bit = sign of the coefficient



12.1.2 Normalizing the coefficient

The coefficient is a 36-bit fraction, which is adjusted before packing, so that the fraction lies between ½ and 1.

i.e. $1 > \text{FRACTION} \geqslant \frac{1}{2}$

The coefficient is always adjusted so that a binary 1 follows the radix point, and nothing is in front of the radix point. The adjustment is made by shifting the radix point and multiplying the answer by the required power of 2.

e.g. 4_8 = 100.0 in binary
= $.100 \times 2^3$ in binary
= $.4 \times 2^3$ in octal

101_8 = 1 000 001. in binary
= $.100\ 000\ 100 \times 2^7$ in binary
= $.404 \times 2^7$ in octal

$.06_8$ = .000 110 in binary
= $.110 \times 2^{-3}$ in binary
= $.6 \times 2^{-3}$ in octal

$.00001_8$ = .000 000 000 000 001 in binary

$$\left.\begin{array}{l} = .100 \times 2^{-16} \text{ in binary} \\ = .4 \times 2^{-16} \text{ in octal} \end{array}\right\} \quad -16 \text{ exponent} = -16_8 = -14_{10}$$

12.1.3 The Exponent

lies in the range 0000 - 3777_8. However 1777_8 is not possible as it implies an exponent of -0 which will never result when performing a floating point operation. If one of the operands has 1777 for an exponent, it will be used as though it were 2000.

12.1.3 (cont.)

It is always biased before packing to enable comparison with other Floating point numbers.

This biasing ensures that the exponent is always positive.

RULE: If positive, 2000_8 is added to it.

If negative, 1777_8 is added to it.

Thus if the biased value lies in the range 0000_8 - 1776_8, it is a negative exponent. 1777_8 does not normally occur as it = -0.

But if the biased value lies in the range 2000_8 - 3777_8, it is a positive exponent.

---

e.g. $k \times 2^4$ Exponent is positive, therefore 2000 added.

= 2004

and $k \times 2^{407}$ = 2407

---

e.g. $k \times 2^{-4}$ Exponent is negative, therefore 1777_8 added

$= 1777_8 + (-4)$

$= 1773_8$

and $k \times 2^{-407} = 1370_8$

12.1.4 Conversion Procedures

(1) Convert the number to binary

(2) Normalize the number

(3) Bias the exponentt

(4) Assemble the number

(5) If negative, complement the result

Example: 4.0

(1) Binary = 100.

(2) Normalize $= .100 \times 2^3$

$= .4_8 \times 2^3$

(3) Exponent = 3 + 2000

= 2003

(4) Assemble = | 2003 | 4000 ¦ 0000 0000 |

Leftmost octal number = 2 = 010 in binary

Sign bit = 0 = POSITIVE NUMBER

e.g. Pack 563_8

(1) Binary = 101 110 011

(2) Normalize = $.101\ 110\ 011 \times 2^{11} = .563 \times 2^{11}$

(3) Exponent = 11 + 2000 = 2011

(4) Assemble =

2011	5630	0000	0000

e.g. Pack -563_8

Steps (1) to (4) as above

Then, because it is negative, complement the result.

=

5766	2147	7777	7777

Note: Bit 47 (top bit) = 1, because 5 = 101 in binary.

e.g. Pack -1463_8

(1) Binary = 001 100 110 011.

(2) Normalize = $.110\ 011\ 001\ 100 \times 2^{12}$ ← octal. exponent

= $.6314 \times 2^{12}$

(3) Exponent = 12 + 2000 = 2012

(4) Assemble =

2012	6314	0000	0000

Complement because number is negative

=

5765	1463	7777	7777

e.g. Pack $-.35_8$

(1) Binary = .011101

(2) Normalize = $.111010 \times 2^{-1}$

= $.72 \times 2^{-1}$

(3) Exponent = 1777 + (-1) = 1776

(4) Assemble =

1776	7200	0000	0000

Number is negative, so complement the number

=

6001	0577	7777	7777

12.1.5 Unpacking Floating Point Numbers

Rules:

(1) If upper bit is a one, number is negative. Complement, and note that sign of the final answer must be negative.

(2) If exponent is less than 1777_8, exponent is negative. Subtract 1777 from exponent.

(3) If exponent is greater than 2000_8, exponent is positive. Subtract 2000 from it.

e.g. UNPACK

2000	4000	0000	0000

(1) Number is positive (the upper bit = 0)

(2) Exponent is positive ($\geq$ 2000)

= 2000 - 2000 = 0

(3) Number = $.4 \times 2^0$

= .4

e.g. UNPACK

6002	0777	7777	7777

(1) Upper bit is 1 - number is therefore negative, so first complement it

=

1775	7000	0000	0000

(2) Exponent is < 1777, and is negative

= 1775 - 1777

= -2

Shift coefficient to right 2 places

(3) Coefficient = .7

= .111

Shift = .001 110

= .16

Answer = -0.16_8 or -0.21875_{10}

12.2 EXECUTION OF FLOATING POINT OPERATIONS

12.2.1 Addition

(1) Equalize exponents by shifting coefficient of the algebraically smaller number to the right.

(2) Add coefficients, and normalize

e.g. $10_8 + 100_8$

$10_8 = \boxed{2004 \mid 4000 \mid 00000000}$ $\qquad$ $100_8 = \boxed{2007 \mid 4000 \mid 00000000}$

Shift coefficient of 10_8

$$.1_2 \times 2^4 = .0001_2 \times 2^7$$
$$= .04_8 \times 2^7$$
$$= \boxed{2007 \mid 0400 \mid 00000000}$$

Add coefficients and normalize

$$\begin{array}{r} .4000\ 0000\ 0000 \times 2^7 \\ \underline{.0400\ 0000\ 0000} \times 2^7 \\ = .4400\ 0000\ 0000 \times 2^7 \end{array}$$

this is normalized already

$$\begin{aligned} \text{Number} &= .100100000000\ 000000000000\ 000000000000_2 \times 2^7 \\ &= 1001000. \\ &= 001\ 001\ 000_2 \\ &= \quad 1 \quad 1 \quad 0_8 \end{aligned}$$

12.2.2 Subtraction

(1) Equalize exponents

(2) Subtract coefficients and normalize

e.g. $43_8 - 6_8$

$$43_8 = .100011 \times 2^6 = 2006430000000000$$
$$6_8 = .110 \times 2^3 = 2003600000000000$$

Equalize exponents, ie, 2003 6000 0000 0000 $(.110_2 \times 2^3)$

becomes

2006 0600 0000 0000 $(.000110_2 \times 2^6)$

Subtract coefficients and normalize

$$\begin{array}{r} .4300\ 0000\ 0000 \times 2^6 \\ (-)\underline{.0600\ 0000\ 0000} \times 2^6 \\ .3500\ 0000\ 0000 \times 2^6 \\ .7200\ 0000\ 0000 \times 2^5 \end{array}$$ after being normalized

$$\begin{aligned} \text{Number} &= .111010000000\ 000000000000\ 000000000000_2 \times 2^5 \\ &= 11101. \\ &= 011\ 101_2 \\ &= \quad 3 \quad 5_8 \end{aligned}$$

12.2.3 Rounding of Floating Point Numbers

In floating point operations, the E register is joined to the AQ register, to form a 96-BIT REGISTER AQE (the uppermost bit is the sign).

A			Q	E_U	E_L
Sign	Exponent		Coefficient		
1	11 bits	12 bits	24 bits	24 bits	24 bits

To carry out rounding, the sign of AQ is compared with the sign of E. If sign of AQ is not equal to sign of E, number in AQ is rounded.

Example:

(i) If AQ_{47} = 0, number is positive.

If E_{47} = 1, number in E must begin with either a 4, 5, 6 or 7

i.e. E can begin 100 = 4
101 = 5
110 = 6
or 111 = 7

The number in AQ is therefore rounded up by adding one to AQ.

(ii) If AQ_{47} = 1, number is negative.

If E_{47} = 0, number in E must begin with either a 0, 1, 2 or 3

which is -7, -6, -5, and -4.

The number in AQ is therefore rounded down by subtracting one from AQ.

e.g.

AQ	E
247 ---------- 6	512 ---------- 7

BIT_{47} = 0 BIT_{47} = 1

Positive number is rounded.

e.g.

AQ	E
247 ---------- 6	277 ---------- 7

No rounding is necessary.

e.g.

AQ	E
777 ---------- 7	166 ---------- 7

BIT_{47} = 1 BIT_{47} = 0

Rounded down because negative number.

Summary: If the sign of AQ is different from the uppermost bit of E, one is added to AQ if AQ is positive or one is subtracted from AQ if AQ is negative.

12.2.4 Multiplication

(i) Unbias the exponents by subtracting 2000_8 or 1777_8, as the case may be.

(ii) Add the unbiased exponents.

(iii) Multiply the coefficients.

(iv) Normalize the coefficient resulting and adjust the exponent.

(v) Assemble the number.

e.g. Multiply 100_8 by 10_8

100_8 = 001000000

= $.100000 \times 2^7$ (Binary)

= $.4 \times 2^7$ (Octal)

= | 2007 | 4000 | 00000000 |

10_8 = 001000

= $.100 \times 2^4$ (Binary)

= $.4 \times 2^4$ (Octal)

= | 2004 | 4000 | 00000000 |

(i) Unbias exponents

2007 becomes 7

2004 becomes 4

(ii) Add unbiased exponents

$$\begin{array}{r} 7 \\ +4 \\ \hline 13_8 \end{array}$$

(iii) Multiply coefficients

100_8 becomes $.4_8$ when normalized

10_8 becomes $.4_8$ when normalized

product = $.20_8$

(iv) Normalize resulting coefficient

$.20 \times 2^{13}$

= $.010 \times 2^{13}$ (Binary)

= $.100 \times 2^{12}$

= $.4 \times 2^{12}$ (Octal)

(v) Assemble answer

= | 2012 | 4000 | 00 00 00 00 |

(vi) Checking

$100_8 \times 10_8 = 1000_8$

= $001\ 000\ 000\ 000_2$

= $.100 \times 2^{12}$ (Binary - exponent in octal)

= $.4 \times 2^{12}$ (Octal - exponent in octal)

12.2.5 Division

(i) Unbias the exponents

(ii) Subtract the unbiased exponents

(iii) Divide the coefficients

(iv) Normalize the coefficient resulting and adjust the exponent

(v) Assemble the numbers

e.g. Divide 100_8 by 10_8

$100_8 = 001\ 000\ 000$

$= .1 \times 2^7$ (Binary)

$= .4 \times 2^7$ (Octal) $=$ | 2007 | 4000 | 00000000 |

$10_8 = 001\ 000$

$= .1 \times 2^4$ (Binary)

$= .4 \times 2^4$ (Octal) $=$ | 2004 | 4000 | 00000000 |

(i) Unbias the exponents

2007 becomes 7

2004 becomes 4

(ii) Subtract unbiased exponents

$$\begin{array}{r} 7 \\ \underline{-4} \\ 3 \end{array}$$

(iii) Divide coefficients

100_8 becomes $.4_8$ when normalized

10_8 becomes $.4_8$ when normalized

quotient $= 1.0_8$ ie, $.4 \overline{)\ .4}$ 1.0

(iv) Normalize resulting coefficient

1.0×2^3

$= .1 \times 2^4$ (Binary)

$= .4 \times 2^4$ (Octal)

(v) Assemble answer

$=$ | 2004 | 4000 | 0000 0000 |

(vi) Checking

$100_8 \div 10_8 = 10_8$

$10_8 = 001\ 000$ (Binary)

$= .100 \times 2^4$

$= .4 \times 2^4$ (Octal)

12.3 FLOATING POINT INSTRUCTIONS

12.3.1 Floating Point ADD

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	FAD,I	m,b

23–18	17	16–15	14–00
60	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Add the contents of two consecutive locations (M and M + 1) to the contents of AQ, where $M = m + (B^b)$ The normalized and rounded sum appears in AQ.

Example:

FAD FPSUM

	A		Q
AQ =	2 0 0 7	4 0 0 0	0 0 0 0 0 0 0 0
	FPSUM		FPSUM+1
	2 0 0 4	4 0 0 0	0 0 0 0 0 0 0 0

Final result of AQ

A		Q
2 0 0 7	4 4 0 0	0 0 0 0 0 0 0 0

Exercise: If contents of Registers and a part of memory are:

(A) = 20014500
(Q) = 00000000

FPSUM	6060	6060
FPSUM+1	2007	3621
FPSUM+2	00000000	
FPSUM+3	2004	4000
FPSUM+4	0000	0000

Index register 3 contains 3, and

Index register 1 contains 1,

What would be AQ after execution of

(a) FAD FPSUM,3

(b) FAD FPSUM,1

12.3.2 Floating Point SUBTRACT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	FSB,I	m,b

23–18	17	16–15	14–00
61	a	b	m

a = addressing mode designator

b = index designator

m = storage address

12.3.2 (cont.)

Description: Subtract the contents of two consecutive locations (M and M + 1) from the contents of AQ, where M = m + (B^b)

Example:

If (AQ) =

A		Q	
2 0 0 6	4 3 0 0	0 0 0 0 0 0 0 0	$= 35_{10}$

FSB FPØP

FPØP		FPØP+1	
2 0 0 3	6 0 0 0	0 0 0 0 0 0 0 0	= 6

Final result of AQ :

A		Q	
2 0 0 5	7 2 0 0	0 0 0 0 0 0 0 0	$= 29_{10}$

12.3.3 Floating Point MULTIPLY

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	FMU,I	m,b

23 – 18	17	16 – 15	14 – 00
62	a	b	m

a = addressing mode designator

b = index register

m = storage address

Description: Multiply the contents of AQ by the contents of 2 consecutive locations, M and M + 1, where M = m + (B^b).

The product appears in AQ normalized and rounded.

Example:

FMU

If (AQ) =

A		Q
2 0 0 7	4 0 0 0	0 0 0 0 0 0 0 0

and (EPØP) =

EPØP		EPØP+1
2 0 0 4	4 0 0 0	0 0 0 0 0 0 0 0

and the instruction = FMU EPØP

the final (AQ) =

A		Q
2 0 1 2	4 0 0 0	0 0 0 0 0 0 0 0

12.3.4 Floating Point DIVIDE

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	FDV,I	m,b

23 18	17	16 15	14 00
63	a	b	m

a = addressing mode designator

b = index designator

m = storage address

Description: Divide the contents of AQ by the contents of 2 consecutive location , M and M + 1, where $M = m + (B^b)$. The result appears in AQ, normalized and rounded.

Example: If (AQ) are as shown below, FPØP contains 20044000, and FPØP+1 contains 0, what would be the contents of AQ after execution of the instruction.

FDV FPØP

Solution:

A		Q
2 0 0 7	4 0 0 0	0 0 0 0 0 0 0 0

FPØP		FPØP+1
2 0 0 4	4 0 0 0	0 0 0 0 0 0 0 0

Final result of AQ

A		Q
2 0 0 4	4 0 0 0	0 0 0 0 0 0 0 0

48-BIT REGISTER OPERATIONS

Chapter 13

13.1 48-BIT E REGISTER

13.1.1 Introduction

The E register is a 48-bit, octal register* used as a supplement to AQ in floating point and 48-bit precision operations. It extends the size of AQ to 96 bits by forming AQE.

All 3200 computers do not contain the hardware for the E register, which therefore cannot be displayed on the console of these machines. (Where the full hardware is available, the contents of the E register can be displayed on the console in the displays usually containing A and Q.)

---

* The E register is the lower 48 bits of the 52 bit + sign E_D register. The upper 4 bits of E_D and the sign of E_D are not affected by Floating point, 48-bit multiply or divide, or inter-register operations.

13.1.2 Trapped Instructions for the E Register

Floating point and 48-bit precision operations are handled on the 3204 basic processor by a special software package. The instructions are detected by the hardware, and "trapped". They are then processed by the special software programs OPTBOXS and FDPBOXS. OPTBOXS examines each trapped instruction to see if it is a Floating point/48-bit instruction or a BCD instruction (see Section 14.3). If it is a BCD instruction, the program BCDBOXS is used to process it. If it is a Floating point or a 48-bit precision instruction, the program FDPBOXS is used.

FDPBOXS simulates the hardware for the E register so that the instructions can be executed without the hardware being present.

13.2 TRANSFERS BETWEEN A AND E_U

13.2.1 Transfer E_U to A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EUA	

23 18	17 15	14 00
55	2	

Description: This instruction transfers the contents of E_{upper} (bits 47-24) to the A register. The E register is not disturbed by the transfer.

Example: Suppose ØP48 contains 0, and ØP48+1 contains 2. If A contains 0, and Q contains 76000000, what will be in A as a result of:

MUAQ ØP48
EUA

Answer:

AQ	00000000	76000000		
	ØP48	ØP48+1		
Multiplied by	00000000	00000002		
	A	Q	E_U	E_L
results in	00000000	00000000	00000001	74000000

Transferring E_U to A, (A) = 00000001

13.2.2 Transfer A to E_U

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AEU	

23 18	17 15	14 00
55	6	

Description: This instruction transfers the contents of the A register to E_{upper} (bits 47-24). E register bit positions 51 thru 48 and 23 thru 00 are not disturbed by the transfer. Also the A register remains unchanged as does the sign of E.

Example: What will be in E_U after execution of the following instructions:

ENA 20321B
AEU

Answer: E_U = 00020321

13.3 TRANSFERS BETWEEN Q AND E_L

13.3.1 Transfer E_L to Q

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ELQ	

23 18	17 15	14 00
55	1	

Description: The lower 24 bits of E, ie, E_{lower}, are transferred to the Q register. The E register remains unchanged at the end of the transfer.

Example: In the EUA example, if the instructions had been:

```
MUAQ      ØP48
EUA
ELQ
```

What would be in Q after execution?

Answer: (Q) = 74000000

13.3.2 Transfer Q to E_L

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	QEL	

23 18	17 15	14 00
55	5	

Description: The contents of the Q register is transferred to E_{lower} (bits 23-00). Bit positions 51 thru 24 and the sign of E are not disturbed by the transfer. Likewise the Q register remains unchanged.

Example: In the following example:

```
ENQ       20321B
QEL
```

What will be in E_L after execution of the instructions?

Answer: (E_L) = 00020321

13.4 TRANSFERS BETWEEN AQ AND E

13.4.1 Transfer E to AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EAQ	

23 18	17 15	14 00
55	3	

Description: Transfer the 48 bit contents of E (bits 47-00) to AQ. E_U(bits 47-24) is transferred to A and E_L(bits 23-00) is transferred to Q. The contents and sign of E is not disturbed by the transfer.

Example: In the EUA example, if the instructions had been:

```
MUAQ     ØP48
EAQ
```

What would be in AQ after execution?

Answer: AQ =

A	Q
00000001	74000000

13.4.2 Transfer AQ to E

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	AQE	

23 18	17 15	14 00
55	7	

Description: Transfer the 48 bit contents of AQ to E (bits 47-00). A is transferred to E_U(bits 47-24) and Q is transferred to E_L(bits 23-00). E_O(bits 51-48) and the sign of E are unaffected by the transfer. The contents of A and Q are not disturbed and remain after the transfer.

Example: Divide the 48 bit operand in AQ by ØP48. Write the appropriate coding. (ØP48) = 2.

Answer:

```
AQE               Transfer Number to E for Div.
SHAQ    -47       Set AQ to sign of E
DVAQ    ØP48      (AQ) = Quotient,(E) = remainder
```

At Start AQ =

A	Q
77777777	77777765

After AQE AQE =

A	Q	E_U	E_L
77777777	77777765	77777777	77777765

After SHAQ AQ =

A	Q
77777777	77777777

After DVAQ AQE =

A	Q	E_U	E_L
77777777	77777772	00000000	00000000

13.5 SCALE AQ

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SCAQ	k, b

23–18	17	16–15	14–00
13	1	b	k

b = index designator

k = shift designator

Description: AQ is shifted left, end around, until the upper two bits (46 and 47 are unequal.)

During the operation, the computer makes a shift count. A quantity K = k minus the shift count.

If b = 0, this residue is discarded

If b = 1-3, the residue is placed in index register B^b.

Example:

	A	Q
AQ initial contents	0 3 0 0 0 0 0 0	0 0 0 0 0 0 0 0

SCAQ 24,2

Top bits of A = 000 011 000 etc.

To get top 2 bits unequal, shift left 3 places = 011 000 etc.

	A	Q
AQ becomes	3 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0

$k = 24_{10}$

$= 30_8$

K = k - shift count

$= 30_8 - 3$

$= 25_8$, which is placed in Index Reg. 2.

Exercise: If A contains 100B, and Q contains zero, what would be in A, Q and Index register 1 after execution of the following instruction?

SCAQ 2027B,1

13.6 USE OF THE SCALE AQ INSTRUCTION

It is used to pack floating point numbers.

Example:

100_8 =

2 0 0 7	4 0 0 0	0 0 0 0 0 0 0 0

In previous example (using 100_8)

AQ, after scaling, was

A	Q
2 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0

and Index Register 1 = 2007

(a) Then shifting AQ to right 11 places

=

00004000	00000000

(b) by storing AQ elsewhere,
Reading Index Register 1 into A,
and shifting it left 12 places,
we have the exponent at the top of the AQ.

A =

0 0 0 0 2 0 0 7

=

2 0 0 7 0 0 0 0

after shifting

(c) By then adding back to AQ the stored value previously in AQ, (the normalized exponent) we have the packed floating point number

A		Q
2 0 0 7	0 0 0 0	0 0 0 0 0 0 0 0

STØRE		STØRE+1
0 0 0 0	4 0 0 0	0 0 0 0 0 0 0 0

Final AQ

=

A		Q
2 0 0 7	4 0 0 0	0 0 0 0 0 0 0 0

(d) This will only work with positive numbers.

(e) **For negative numbers, complement the number first. Then pack the number, as above and complement the packed number.**

Alternate method for packing floating point numbers:

If the computer has floating-point hardware and if the number to be packed is a single precision integer (24-bit operand), then the following method is used instead of the one just illustrated:

```
          SHAQ   -24          FØRM 48-BIT SIGNED ØPERAND
          SCA    K2044        MERGE WITH PRØPER EXPØNENT
          FAD    K2044        NØRMALIZE THE F.P. NUMBER
           .
           .
           .
           .
           .
          UJP
*
K2044     ØCT    20440000,0   F.P. CØNSTANT = 2044000000000000
```

Here the FAD instruction is used to do the normalizing instead of the SCAQ. Also the normalizing is done after forming the floating point number rather then before. If the operand to be packed is larger than 24-bits or if the computer doesn't have floating point hardware, the number can be packed faster using the SCAQ instruction.

Chapter 14

BCD DIGIT OPERATIONS

14.1 INTRODUCTION

14.1.1 BCD Digits

The BCD instructions handle 4-bit BCD DIGITS. These digits are the decimal digits 0-9 represented as follows:

0000 = 0

0001 = 1

0010 = 2

0011 = 3

.
.
.
.
.
.

1001 = 9

Each 24-bit word of storage is divided into 4 BCD Digit characters of 6 bits, as shown:

23 18	17 12	11 06	05 00

The lower 4 bits in each character are the BCD Digit. The upper 2 bits in the least significant character is used to represent the sign of the field.

14.1.2 Field

A field is a group of BCD Digits, of a maximum length of 12 digits. The length of the field is stored in the D register, which consists of a 4 bit register within the hardware. It is not displayed on the Console.

14.1.3 Sign Bits

This represents the sign of the field as a whole - not of the individual BCD digit. It is stored in the least significant digit in the field. The signs bits of the other digits in the field must be 00, or a fault is generated.

If the sign bit stored is 10,

the field is negative.

For all other combinations, it is positive

i.e. (00 xxxx)
(01 xxxx) positive field
(11 xxxx)

Example:

00 0001	00 0100	00 0011	00 1000	= 1438
00 0110	00 0010	00 1001	00 0000	= 6290

If the Field is 7 digits long, the sign is stored with the least significant digit (i.e. the rightmost of the field, = 9). It is 00, so the number in memory is positive = 1,438,629.

14.1.4 The E_D Register (in machine) - where hardware is available.

This is a decimal register, consisting of 12 BCD decimal digits and 1 overflow BCD decimal digit.

14.1.5 The E_D Register (on console) - where hardware is available.

Displayed in the AQ register as decimal numbers. Displays the full E_D register plus 3 additional characters, as shown.

Sign of digit being currently accessed + or -

+	1	+	1	12 DEC DIGITS

Digits being currently accessed

Sign of E_D + or -

Overflow digit

Max number in E_D = 999,999,999,999

If one more is added, the digit in the overflow position will become a one.

14.1.6 BCD Fault

Programmer can arrange for an interrupt to occur if a BCD fault is discovered. He can also arrange to keep sensing for a fault without an interrupt.

3 conditions will produce a fault.

(a) If the upper 2 bits of any digit (except those of the least significant digit in the field) are not 00.

(b) If an illegal digit is present
i.e. any four bit combination greater than 9.

e.g. 1011 = 11 is illegal

(c) If the contents of the D register are greater than 12 (14_8)

BCD fault is sensed by the SENSE Internal Status Instruction:

```
INS       4000B
If BCD fault, RNI P + 1
If no fault,  RNI P + 2
```

14.2 BCD INSTRUCTIONS

14.2.1 Shift E_D Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SFE	k,b

23–18	17	16–15	14–00
70	0	b	k

k = shift count
b = index designator

Description: The E_D register is shifted in one character steps (i.e. 4 bits at a time)

$K = k + (B^b)$ with sign extension

(The instruction senses bits 0-3 and 23 only of the sum of k and (B^b).
If bit 23 = 0, Shift is left, end off, zero fill.

If bit 23 = 1, Shift is right, end off, zero fill.)

N.B. : BOTH SHIFTS ARE END OFF.

Example: SFE 1

Shifts E_D 1 character to left (i.e. shifts one digit to the left.)

0	0 0 0	0 0 0	0 0 1	8 2 9	Before Shift

0	0 0 0	0 0 0	0 1 8	2 9 0	After Shift

Exercises:

(i) If the E_D register contains

0	6 7 8	4 3 7	9 2 1	6 9 8

What will it contain after the following instructions

ENI 1,1
SFE 3,1

(ii) If the above result is followed by

SFE -8,1

What will be the final contents of E_D?

14.2.2 E_D equal to ZERO Jump

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EZJ,EQ	m

23 18	17 15	14 00
70	4	m

m = storage address

<u>Description:</u> The contents of the 52-bit E_D register are compared with zero

If $(E_D) = 0$, RNI address m

If $(E_D) \neq 0$, RNI P + 1

<u>Example:</u>

	EZJ,EQ	ENDLØØP
	SFE	1,2
	UJP	*+5
ENDLØØP	LDA	144B
	etc.	

14.2.3 E_D less than ZERO Jump

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EZJ,LT	m

23 18	17 15	14 00
70	5	m

m = storage address

<u>Description:</u> The contents of the 52-bit E_D register are compared with zero

If $(E_D) < 0$ RNI address m

If $(E_D) \geq 0$ RNI P + 1

14.2.4 E_D Overflow Jump

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EØJ	m

23 18	17 15	14 00
70	6	m

m = storage address

<u>Description:</u> If the upper 4 bits of the E_D register contain anything but zero, control jumps to address m.

If Upper 4 bits contain zero, RNI P + 1

14.2.4 (cont.)

Examples:

0	4 2 1	3 5 7	6 1 9	8 7 8

- no overflow, jump RNI P + 1

4	0 0 0	0 0 0	0 0 0	2 4 1

- O/flow, jump RNI Address m.

14.2.5 Setting Field Length in D Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SET	y

23 18	17 15	14 04	03 00
70	7		y

y = field length indicator

Description: The instruction takes the lower 4 bits of y and puts them in the D register. Maximum length of field is 14B for all operations except STE, when maximum length of the field is 15B. The D register remains at the value set until it is set again.

It is not cleared in Master Clear operations.

Example: SET 14B

Sets D register to 14B for field length

14.2.6 Load E_D

ONLY INDEX REGISTER 1 CAN BE USED

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LDE	m,1

23 18	17	16 00
64	b	m

b = index designator
If b = 0, m is the unmodified address
If b = 1, m is modified by (B^1) sign extended
m = storage address (character address)

Description: The instruction loads the E_D register with a field of up to 12 numeric BCD characters. The field length is specified by the D register. Characters are put in the lower end of E_D, with zero fill to the left.

Example: SET 7

LDE 400B

Find least significant digit

100	3	6	8	9
101	4	5	6	8

14.2.6 (cont.)

$= M + (D - 1)$

$= M + (6) = 406$

Loads this character into E_D first, into leftmost bits of E_D. The R shifts one character, adds in next digits, shifts, etc. When loaded D characters, zero fills rest of E_D from left.

Answer : E = | 0 | 000003689456 |

14.2.7 Store E_D

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	STE	m,2

ONLY INDEX REGISTER 2 CAN BE USED

23 18	17	16 00
65	b	m

b = index designator
    If b = 0, m is the unmodified address
    If b = 1, m is modified by (B^2) only
m = storage address (character address)

Description: The instructions stores a field of up to 13 decimal digits (B.C.D. numeric characters), beginning at address M (the address of the most significant digit in the field). The length of the field is determined by the D register.
The least significant digit is stored first, and the register is then Shifted right one digit. The next digit is stored, and the register shifted right again, and so on. NOTE THAT STORING DESTROYS THE CONTENTS OF E_D.

Example: SET 14B

STE 400B

E = | 0 | 746871264789 |

Field = 12 characters

Address of least significant character $= (D - 1) + M$
$= (13) + 400$
$= 413$
$= 100\ 001\ 011$

Character address = $= 001\ 000\ 010\ 11$
= Word 102
character 3

12 digits in E stored as follows:

100	7	4	6	8
101	7	1	2	6
102	4	7	8	9

14.2.7 (cont.)

NOTE:

DUMP OF MEMORY:

If an area of memory containing BCD numeric characters is dumped out, the 6 bits for each character (2 sign bits, and 4 bits for the digit) will be dumped in octal numbers:

e.g. 00 1000 = 8 in BCD digit

But would be 001 000 = 10 in octal during dump.

Example: A block of memory is as follows (Characters are BCD Digits)

100	4	7	8	9
101	6	4	3	1
102	8	7	4	9
103	6	2	1	3

A program working on this is as follows:

```
SET   12B
LDE   402B   (a)
SET   6
STE   405B   (b)
SET   14B
LDE   403B   (c)
```

What would be contained in E_D at the end of the operations?

14.2.8 Add to E_D

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ADE	m,3

MODIFIED BY INDEX REGISTER 3 ONLY

23 18	17	16 00
66	b	m

b = index designator
If b = 0, m is the unmodified address, i.e. M = m
If b = 1, m is modified by (B^3) only, M = m + (B^3)
m = storage address (character address)

Description: This instruction adds 'D' numeric BCD digits to the E_D register. The 'D' digits are lined up with the lower 'D' digits of the E_D register before they are added. The E_D register has a maximum capacity of 13 digits, i.e., 12 digits plus overflow digit. The maximum number of digits in the number to be added is 12, i.e., D may not be greater than 12. M is the most significant digit of the number to be added. M + D - 1 is the least significant digit.

14.2.8 (cont.)

Example: If (E_D) =

0	0 0 0	0 0 0	8 7 6	5 4 3

And a block of memory is

100	7	2	4	9
101	1	5	8	2
102	6	1	3	6
103	2	0	8	4

What will be the contents of E_D after the following instructions are executed?

```
ENI    1,3
SET    10B
ADE    400B,3
```

Answer: (a) $M = m + (B^3)$

$= 400 + 1 = 401$

Add to E_D 8 character the least significant of which will be

$M + (D - 1)$

$= 401 + 7$

$= 410$

E_D =	0	000	000	876	543
+	0	000	024	915	826
Final E_D =	0	000	025	792	369

14.2.9 Subtract from E_D

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SBE	m,3

23 – 18	17	16 – 00
67	b	m

b = index designator
    If b = 0, m is the unmodified address, i.e., M = m
    If b = 1, m is modified by (B^3) only, $M = m + (B^3)$
m = storage address (character address)

Description: As for ADE, except that the field of up to 12 BCD digits is subtracted from the E_D register.

14.3 BCD TRAPPED INSTRUCTIONS

All BCD instructions may be used in any 3200 Computer, regardless of the model of the processor. Where the processor lacks the BCD hardware package necessary for direct processing of BCD instructions, the implementation of these instructions is carried out by a special software package. The instructions are then known as "trapped" instructions.

(It should be noted that where the software package is used, the contents of the Ed register cannot be displayed on the console, because the Ed register hardware does not exist.)

The B.C.D. instructions are detected by a translator as they appear in the Function register, and trapped. They are processed like interrupts, and the following action takes place

(a) P + 1 is stored in the lower 15 bits of address 00010

(b) The upper 6 bits of the Function register are stored in the lower 6 bits of 00011 - the upper 18 bits of 00011 remain unchanged.

(c) Program control is transferred to 00011, and a RNI cycle is executed.

Chapter 15

COMPASS PSEUDO INSTRUCTIONS

15.1 CONCEPTS OF PSEUDO INSTRUCTIONS

A better name would be "Assembly-Control" instructions. They are simply instructions from the programmer to the assembler.

They will be used during assembly only. Program execution can make no use of them.

e.g. BSS 4 is an instruction to the assembler to set aside 4 words of storage somewhere in the storage area. The 4 words are set up during assembly and then the function and usefulness of the BSS instruction is finished.

15.2 PROGRAM DEFINITION

15.2.1 IDENT Instruction

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	IDENT	m

Description: The Location field is blank. However if a symbol is written in it, COMPASS will ignore it. COMPASS picks up 8 or less alphanumeric characters from the address field, the first of which must be alphabetic. The Address field terminates at the first blank or the eighth alpha-numeric character, whichever is the first encountered. A period may appear in m.

m = PROGRAM NAME

This will appear on the top of each page of the assembly listing.
The IDENT card must be the first card in the program or the job will be terminated.

Examples: (a)
```
IDENT         TEST FØR  ILLEGAL SYMBØLS
.
.
END
```

Program name will be TEST

(b)
```
IDENT         CØNTINUØUS TESTING ØF TAPES
.
.
.
END
```

Program name will be CØNTINUØ

15.2.2 END Instruction

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	END	m

Description: The location field should be blank. If a symbol is present, it is ignored by COMPASS.
The END instruction terminates the sub program. The final instruction in a COMPASS Sub-program must be an END instruction.

Symbolic Transfer Address

The "m" signifies a symbol in the address field of some subroutine which has declared it to be an entry point. This address is called the Symbolic Transfer Address and need not be in the subroutine terminated by this END card.

Examples: (i) A program of one subprogram.

The symbolic transfer address must appear, and the symbol must be defined within the subprogram as an entry point.

e.g.
```
          IDENT    TEST
          ENTRY    FIRST
FIRST     UJP      **
           .
           .
          END      FIRST
```

(ii) A program of more than one Compass subprogram

The symbolic transfer address must appear in one of the END statements, and be defined as an entry point as before.

Example:

```
        IDENT   TEST
        ENTRY   FIRST
FIRST   UJP     **
        .
        .
        .
        .
        END

        IDENT   WRITER
        .
        .
        .
        .
        .
        .
        END     FIRST
```

Note that this program could have appeared as follows:

```
        IDENT   TEST
        ENTRY   FIRST
FIRST   UJP     **
        .
        .
        .
        .
        END     FIRST

        IDENT   WRITER
        .
        .
        .
        .
        .
        .
        END
```

(iii) A program of COMPASS and FORTRAN subprograms.

A symbolic transfer address should not appear in any END statement in the program, if the FORTRAN program is the main program.

15.2.2 (cont.2)

Example:

```
PRØGRAM  TEST
CALL ØNE
CALL TWØ
END

IDENT    ØNE
.
.
.
.
END

IDENT    TWØ
.
.
.
.
END
```

If the FORTRAN is a subroutine of a COMPASS subprogram a transfer address should appear in the END statement in the COMPASS subprogram.

TRA Card diagnostic

Where an error occurs in using symbolic transfer addresses, the error is flagged by the Loader when the program is loaded, and execution is not attempted.

The flag "TR" is shown (after the Load card is listed) on the standard output unit.

15.2.3 FINIS Instruction

LOCATION	OPERATION.MODIFIERS	ADDRESS FIELD
	FINIS	

Description: Symbols in the location and address fields are ignored. The instruction tells the assembler that it has reached the end of the assembly, and that all sub-programs have been assembled. If the FINIS card is put in out of order, the assembly will be terminated when it is reached. Control is returned to SCOPE when the FINIS card is read.

Example:

```
IDENT          TYPØUT
.
.
.
END
IDENT          SØUT
.
.
.
END
IDENT          TYPIN
.
.
END
FINIS
```

Where FORTRAN and COMPASS subprograms are used in the one subprogram, the FINIS card is used to indicate the end of each group of subprograms.

Example:

```
7
9FØRTRAN,L,X
    PRØGRAM    ØNE
    .
    .
    .
    .
    END

    SUBRØUTINE    TWØ
    .
    .
    .
    .
    END
    FINIS

7
9CØMPASS.L,X
    IDENT      THREE
    .
    .
    .
    END
    FINIS
```

15.3 ASSEMBLY AREAS

15.3.1 Introduction

There are 3 areas in any sub program assembly

(a) Subprogram Area.

In this area all normal parts of the subprogram are assembled.

(b) COMMON Area

Parts of the program declared to be in common are assembled in this area.

(c) DATA Area.

Parts declared to contain Data are assembled in this area.

Three counters are used at assembly time to put parts of program in sequential places in the areas above. These counters are incremented to give the current address of the instruction being assembled in the particular area in which the assembly is taking place.

15.3.2 DATA Area

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	DATA	

Description: Information may be put into the Data area at assembly time.

~~There may be no reference to an external symbol, nor can any symbol in the DATA area be an entry point for the subprogram in which it occurs.~~
The instruction specifies that all information following is to be stored or identified as part of the DATA area, until PRG or COMMON or END occurs. Any instruction or pseudo instruction may follow DATA. The DATA area is shared by all subprograms at execution time.
The Location and Address fields should be blank.

Example:

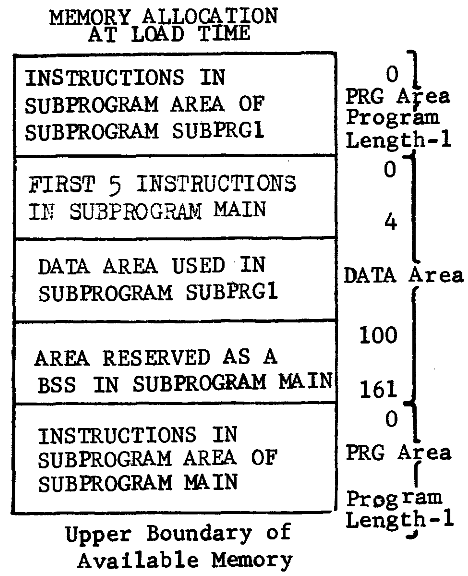
```
          IDENT   BINBCD
          .
          .
          .
          DATA
          BSS     2

DATA      ØCT     273
          .
          .
          .
          END
```

NOTE: The total DATA area must be defined in the first subprogram loaded.

15.3.2 (cont.)

Example:

```
          IDENT     MAIN
          DATA
          .  )
          .  )
          .  )5 INSTRUCTIONS
          .  )
          .  )
          ØRGR      100B
          BSS       50
          PRG
          .
          .
          .
          END       MAIN
          IDENT     SUBPRG1
          .
          .
          .
          .
          DATA
          ØRGR      5
          .
          .
          .
          .
          PRG
          .
          .
          .
          END
```



15.3.3 Return Assembly Control to Subprogram PRG Area

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	PRG	

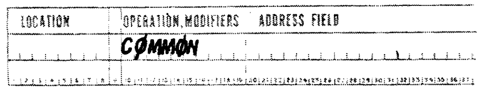
Description: All instructions that follow are to be assembled in the subprogram area.

The PRG instruction may be used to signal the end of the DATA or the COMMON areas.

Example:

```
          IDENT     BLØCKER
          DATA
SCALEF    ØCT       273
          ØCT       -0
          CØMMØN
INBUFF    BSS       100
          PRG
          .
          .
          .
          .
          END
```

15.3.4 COMMON Area



Description: The instruction labels and reserves space in the common area.

No information can be put into the area at assembly time. If this is attempted, an error listing is given. COMPASS assumes that a PRG card had been included before the instruction and resumes assembly in the subprogram area.

The COMMON area is shared by all subprograms at execution time.

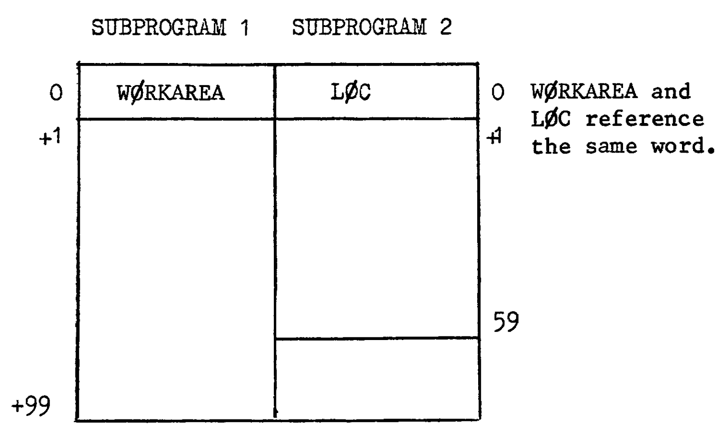
Note: COMMON is the same for all subprograms. If it is desired to have separate areas, ORGR instructions must be used to separate them.

Example:

```
          IDENT   TEST
          .
          .
          .
          CØMMØN
WØRKAREA  BSS     100
          .
          .
          .
          END
          IDENT   SUBEDIT
          .
          .
          .
          CØMMØN
LØC       BSS     60
          .
          .
          .
          END
```

In this program, the common area will be overlapped by the two subprograms.

COMMON



This can be used to reference the same words in common in two subprograms.

Example: Setting up common area in 2 subprograms

```
             IDENT      MAX
             CØMMØN
TEMP         BSS        10
CTABLE       BSS,C      6
             PRG
             .
             .
             .
             END
             IDENT      SUBPRØG
             .
             .
             .
             .
             CØMMØN
QTØTAL       BSS        12
FLAGS        BSS,C      4
             PRG
             .
             .
             .
             END
```

The area will be set up as follows:

TEMP					QTØTAL
TEMP+1					QTØTAL+1
TEMP+2					QTØTAL+2
TEMP+3					QTØTAL+3
TEMP+4					QTØTAL+4
TEMP+5					QTØTAL+5
TEMP+6					QTØTAL+6
TEMP+7					QTØTAL+7
TEMP+8					QTØTAL+8
TEMP+9					QTØTAL+9
	CTABLE	CTABLE+1	CTABLE+2	CTABLE+3	QTØTAL+10
	CTABLE+4	CTABLE+5	not used by MAX		QTØTAL+11
	FLAGS	FLAGS+1	FLAGS+2	FLAGS+3	FLAGS

15.3.4 (cont.2)

Note: The only instructions which can be used in the COMMON area are as follows,

BSS	ØRGR
BSS, C	IFT
EQU	IFN
EXT	IFF
ENTRY	IFZ

COMMON is terminated by PRG
DATA
or END

15.3.5 ORGR Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ØRGR	m

Description: This instruction controls the relocatable address for storage of instructions, constants, or the reservation of space in any of the three storage areas.
The location field is ignored by COMPASS, but printed on the listing.
Any symbol used in the address field must have been previously defined in the storage area being referenced. If COMPASS is assembling into one area, and an ORGR occurs with a different area relocatable symbol in the address field, an error results. COMPASS ignores the ORGR, but puts an error flag on the listing.

Example:

```
            IDENT      ØRGRT
            DATA
            BSS         2
DTAG        ØCT        227
            .
            .
            .
            PRG
            .
            .
            .
A           ØRGR       DTAG+1
            .
            .
            .
            END
```

Note: the error flag "A" set to show the error in the address field. DTAG is in the DATA area, and cannot be used in an ORGR statement in the SUBPROGRAM area.

ii)

```
        IDENT     HARRY
        ØRGR      100B
        LDA       CIT
          .
          .
          .
        END
```

The first instruction (LDA CIT) will be assembled in Location 100, and the rest will be stored following it.

iii)

```
                 IDENT     ØRGRTEST
                 ENTRY     START           STØRAGE ADDRESS
                 ØRGR      50
     START       UJP       **               00062
                 LDA       CIØ
                 STA       CIØBLØCK
                 .
                 .
                 .
                 .
                 UJP       02010B
     CØNTABLE    ØCT       0,-1             00076 and 77
                 ØRGR      *+50
     INPFLAG     ØCT       0                00162
                 ØRGR      INPFLAG+20
     ØNE         ØCT       1                00206
                 END       START
```

15.4 STORAGE RESERVATIONS

This is made in the area currently being used. The address field will determine the number of words or character positions to be reserved.

15.4.1 Word Block

LOCATION	OPERATION.MODIFIERS	ADDRESS FIELD
	BSS	m

m = a constant, a symbol, or an address expression.

Description: (i) The instruction reserves and labels a block of word storage. A symbol in the location field is the 15-bit, relocatable word address of the first word in the block of storage.

(ii) The address field specifies the number of locations to be reserved. It may be

(a) a constant

```
Example:    STATUS      BSS     2
            DISKBUFF    BSS     745
```

(b) a symbol

```
Example:    VARINP      EQU     5
            INPAREA     BSS     VARINP
```

Note that the symbol must not be a relocatable address, or an error results:

```
            VARINP      ØCT     5
      A     INPAREA     BSS     VARINP
```

(The "A" indicates the address field error.)

(c) An address expression which results in a non relocatable value.

```
Example:    VARINP      EQU     5
            INPAREA     BSS     VARINP+7
```

If the symbol is a relocatable address, an error results.

```
            VARINP      ØCT     5
      A     INPAREA     BSS     VARINP-2
```

(The "A" indicates the address field error).

(iii) The double asterisk is illegal

```
i.e.    PRINTBUF    BSS     **
```

Description: (Continued)

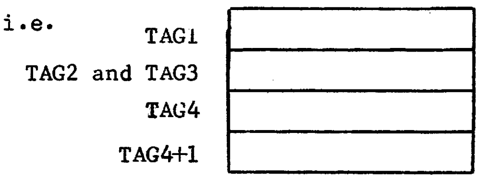
(iv) If an address field is zero or in error, the symbol is defined, but no storage is reserved.

Example:

```
TAG1    BSS    1
TAG2    BSS    **
TAG3    BSS    1
TAG4    BSS    2
```

The second instruction is illegal, and no location will be reserved for TAG2, but TAG2 is defined. It will reference the same word as TAG3.

i.e.



(v) All symbols used in the subprogram must have storage allocated to them:

```
        IDENT   MATRIX
        LDA     CØUNT
        INA
        STA     CØUNT
          .
          .
          .
          .
          .
          .
CØUNT   BSS     1
          .
          .
          .
          .
          .
          .
        END
```

(vi) NOTE: Where no symbol is used, storage is reserved but not labelled. It may be referenced from other labelled locations.

Example:

```
TAG1    ØCT    4
        BSS    3
TAG2    ØCT    27
        BSS    3
TAG3    ØCT    14
```

15.4.1 (cont.2)

Description: (Continued)

The block of storage set up will be:

TAG1	00 00 00 04
***	
TAG2	00 00 00 27
TAG3	00 00 00 14

The location marked *** may be referenced as:

TAG1+2

or TAG2-2

or TAG3-6

15.4.2 Character Block

LOCATION	OPERATION.MODIFIERS	ADDRESS FIELD
	BSS,C	m

Description: Reserves and labels a block of character storage in the area currently in use.

(i) A symbol in the location field is the 17 bit, relocatable character address of the first character in the block.

(ii) The address field specifies the number of characters to be reserved. It may contain

(a) a constant

Example: CTAG1 BSS,C 6
CTAG2 BSS,C 2

Storage will be reserved as follows:

CTAG1	CTAG1+1	CTAG1+2	CTAG1+3
CTAG1+4	CTAG1+5	CTAG2	CTAG2+1

(ii) Continued

(b) a symbol

```
Example:  SIZE       EQU      5
          PARLIST    BSS,C    SIZE
```

Note that the symbol must not be a relocatable address or an error results.

```
          SIZE       OCT      5
    A     PARLIST    BSS,C    SIZE
```

(The "A" indicates the address field error).

(c) an address expression which results in a non-relocatable value.

```
Example:  SIZE       EQU      15
          PARLIST    BSS,C    SIZE-3
```

(iii) If a BSS,C instruction is followed by a BSS 0 instruction, it forces any following character reservation to a new word, even if the last character word is not filled.

```
Example:        INPFLAGS    BSS,C    6
                            BSS      0
                ØUTFLAGS    BSS,C    2
```

Storage is reserved as follows:

INPFLAGS	INPFLAGS+1	INPFLAGS+2	INPFLAGS+3
INPFLAGS+4	INPFLAGS+5	Not Used	
ØUTFLAGS	ØUTFLAGS+1	Not Used	

15.5 ENTRY AND EXTERNAL INSTRUCTIONS

15.5.1 ENTRY Pseudo Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ENTRY	$m_1,m_2,m_3,----m_n$

Description The location field should be blank, but if a symbol does appear, it will be ignored by COMPASS. The address field contains one of more location names separated by commas. No blanks may occur. The field terminates at the first blank, or at Column 73. If there are more entry points to be defined than will fit on one card, a second card can be used.

Each of the address field location names contains a symbol defined as a subprogram relocatable word address by appearance in a location field elsewhere in the subprogram.

Example:

```
         IDENT      ØNE
         ENTRY      START,INTØ
START    UJP        **
         ENA        0
         .
         .
         .
INTØ     UJP        **
         .
         .
         .
         END        START
```

Note that more than one entry card can be used.

```
         IDENT      TWØ
         ENTRY      START
         ENTRY      INTØ
START    UJP        **
         .
         .
         .
INTØ     UJP        **
         .
         .
         .
         END        START
```

15.5.2 EXTERNAL Pseudo Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EXT	$m_1,m_2,m_3,------m_n$

Description: The location field should be blank. Any symbol appearing there will be ignored by COMPASS. The address field contains one or more location names up to Column 73. These must be separated by commas. No blanks may occur. A symbol in the address field may not be defined in the subprogram in which the EXT instruction appears.

The EXT instruction can only reference location names in the subprogram area of another subprogram. It cannot reference DATA or CØMMØN areas.

Example:

```
             IDENT    MAIN
             ENTRY    NUMBER
               .
               .
               .
    NUMBER   ØCT      37
               .
               .
               .
             END
             IDENT    SUBPRØG
             EXT      NUMBER
               .
               .
               .
             LDA      NUMBER
               .
               .
               .
             END
```

All subprograms within a main program are assembled independently, and all symbols in a subprogram are local to that program only, unless declared as external symbols in another subprogram, and as entry points in the former program.

Example:

```
             IDENT    DRIVER01
               .
               .
               .
             LDA      TAG
               .
               .
               .
    TAG      ØCT      14
             END
             IDENT    DRIVER02
               .
               .
               .
             LDA      TAG
               .
               .
               .
    TAG      ØCT      27B
             END
```

The two Symbols (TAG) are not linked in any way. Each will be referenced only by the subprogram in which it appears.

BUT: If they refer to the same symbol, the Program could appear as follows:

```
            IDENT     EDIT
            EXT       CARDBUFF
            .
            .
            .
            LDA       CARDBUFF
            .
            .
            .
            END

            IDENT     READ
            ENTRY     CARDBUFF
            .
            .
            .
            LDA       CARDBUFF
            .
            .
            .
CARDBUFF    ØCT       24
            .
            .
            .
            END
```

Address arithmetic is not permissible with external symbols

```
e.g.    LDA     CARDBUFF+2
```

But, address modification is permissible

```
e.g.    LDA     CARDBUFF,3
```

15.5.3 SCOPE Loading of Subprograms

The Assembler establishes links between the subprogram as directed by the EXT and ENTRY instructions. These linkages are then set up by the Loader (a part of the SCOPE monitor) when the assembled program is loaded prior to execution.

If an external is referenced in a subprogram, but there is no ENTRY for it in any other subprogram, SCOPE will look through the Library Tape to see if it can find a Library Routine to enter.

```
IDENT     QUAD
EXT       SQRTF
.
.
.
RTJ       SQRTF
.
.
.
END

IDENT     DISC
.
.
.
END
```

If it can find no Library routine of the same name, it will give an error symbol, and terminate the run. (This is done at Load Time, not in Assembly). The error symbol appears on the listing after the LOAD card print out e.g.

```
LOAD, 56
DISC    UD    SQRTF
```

The COMPASS assembly listing of a subprogram containing external symobl references will have the usual format, except that the address field will be prefaced by an X.

Example:

```
00010   00 1 X00003
```

The digits following the X are the reloctable word address of a previous instruction in the subprogram area which references the external symbol. The first (or only) reference to the external symbol will contain X77777 in the address field. COMPASS thus produces a "threaded list" of instructions referencing the external symbol.

Example:

```
        Program                 Listing

IDENT       TEST
EXT         CIØ
.
.
.
ENA         10B                 00000   14 6   00010
.
.
.
RTJ         CIØ                 00010   00 7   X77777
.
.
.
RTJ         CIØ                 00030   00 7   X00010
.
RTJ         CIØ                 00050   00 7   X00030
.
END
```

The address of the last instruction referencing the external is placed by COMPASS into the XNL Loader Card to begin the backward threaded list. When the loader loads the program, it enters the actual address of the external symbol into the address portion of each instruction referencing the external. It does this by saving the address portion of the last instruction referencing the external symbol, it then replaces the address with the actual address of the external symbol. The loader then, repeats the process using the saved address as the new last instruction address referencing the external symbol. The process continues until the address of the next instruction in the list is 77777, which indicates all instructions referencing this external symbol have been modified.

Thus, if CIØ is loaded at address 00106, the program will be loaded into storage as:

```
00000   14600010      (ENA    10B)
           .
           .
           .
00010   00700106      (RTJ    CIØ)
           .
           .
           .
00030   00700106      (RTJ    CIØ)
           .
           .
           .
00050   00700106      (RTJ    CIØ)
```

15.6 SYMBOL DEFINITION BY EQUIVALENCING

15.6.1 Introduction

A symbol may be defined by equivalencing it to another symbol, a constant, or an expression. The symbol may be defined as an absolute value, a relocatable word or relocatable character address. The symbol in the location field is equivalenced to the value of the address field. A symbol which is declared an entry point must not be equated to a symbol which is declared external. When symbols are equivalenced they are identical and interchangeable.

All symbols in the address field of an equivalence must have been previously defined by the appearance in the location field of a preceeding instruction, or in an EXT pseudo instruction.

15.6.2 Word Equating

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	EQU	m

<u>Description:</u> The symbol is equivalenced to another symbol, a 15-bit word address, or a 15-bit value. The symbol in the location field will be non-relocatable or relocatable, as determined by the address field.

If the location field is blank, an error occurs. The address field may contain

(i) An integer, modulo $2^{15}-1$ (15 bits or less)
(ii) A symbol, previously defined
(iii) An address expression containing symbols previously defined.

If a symbol in the address is defined as relocatable in a given area, the symbol in the location field will also be relocatable in that area.

<u>Examples:</u>

```
SYMBØL   EQU   57641B
DATE     EQU   27B
TEMP     BSS   1
SYM      EQU   TEMP
TEMP2    EQU   SYM+6
```

Assembled as follows:

	SYMBØL	57641
	DATE	00027
00165	TEMP	Storage reserved
	SYM	00165
	TEMP2	00173

TEMP, SYM and TEMP2 are relocatable.

15.6.3 Character Equating

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	EQU,C	m

Description: The symbol is equivalenced to a 17-bit address, a 17-bit value or another symbol. The symbol will be nonrelocatable, or relocatable, as determined by the address field. If the location field is blank, an error occurs.
The address field may contain

(i) An integer, Modulo $2^{17}-1$(17 bits or less)

Example: ABADD EQU,C 372B

ABADD is equivalenced to the 17-bit character address 372, which is word 76, character 2. This word address is shown on the listing:

```
000762   ABADD   EQU,C   372B
00027    DATE    EQU     27B
```

(ii) A symbol previously defined

Example:
```
SYM      BSS,C   1
NDFLAG   EQU,C   SYM
```

If the address of SYM is 00013, the value of NDFLAG will be 13 also.

(iii) An address expression, containing symbols already defined.

Example: NDFLAG EQU,C SYM-4

If the address of SYM is 00013, the value of NDFLAG will be 50.

```
Word address 13 = character address 54
                                   - 4
         NDFLAG = character address 50
```

15.7 COMPASS OUTPUT LISTING CONTROL

The programmer can control output listings under CØMPASS with these instructions. They are written in the same way as any other instruction.

15.7.1 REMarks

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	REM	

Description: Any remark may be inserted into the source program, to appear on the output listing. All columns except 9-13 may be used.

```
                      |9|10     13|
Example:    THIS IS   | |REM      |A REMARK INSTRUCTION
```

15.7.2 NO LIST Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	NØLIST	

Description: The instruction suppresses listing of the subprogram until the instruction LIST is encountered.
However, if lines containing errors are encountered, they will be printed out, regardless of the NØLIST instruction.
The instruction will not appear on the output listing.

15.7.3 Resume LISTing Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	LIST	

Description: The instruction resumes output listing after a NOLIST instruction
If LIST occurs without a proceeding NØLIST statement it is ignored.

15.7.4 SPACE Instruction

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	SPACE	m

Description: The instruction instructs the printer to skip m lines of print, or go to the top of the next page, whichever is the less.
m is an unsigned decimal integer.

Examples: (i) SPACE 2

2 lines are skipped on the printer

(ii) If only 3 lines remain in the page,

SPACE 10

will cause the printer to skip to a new page and begin in line 1 of the page.

15.7.5 New Page EJECT Instruction

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	EJECT	

Description: The page being printed is fed through the printer, and the line following the EJECT instruction will be the first line of listing on the new page.
The address field must be blank or an error will occur, although comments may be inserted from column 41.

15.7.6 TITLE Instruction

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	TITLE	title to be used

Description: Normally the name of the subprogram will appear at the top of each page of listing of the subprogram.
If another title is required instead, it can be inserted using this instruction. The heading obtained from the IDENT or previous TITLE instruction is replaced, and the first page following the TITLE instruction will have the new heading.
If the new heading is to be inserted immediately, the instruction EJECT should immediately follow TITLE.
If the new title is to be used on the first page of the listing, the TITLE instruction must immediately follow IDENT.
The title must be contained in columns 20-72 of the address field.

Examples:

(i)
```
IDENT    TEST
TITLE    TEST FØR ILLEGAL CHARACTERS
.
.
.
```

This will cause the full title to be printed on the first and subsequent pages of the listing of the subprogram.

(ii)
```
IDENT    TEST
TITLE    TEST FØR ILLEGAL CHARACTERS
.
.
.
TITLE    PRINT ØUT CHARACTERS FØUND
EJECT
.
.
.
END
```

The first title will be printed on all pages until the second TITLE instruction is found. A new page will be begun by the EJECT instruction, and it will bear the new title.

15.7.7 Comments

When CØMPASS detects a card with an asterisk in column 1, it prints the content of the card as a comment. No other action is performed.
Note: The asterisk itself is not printed. (See also Section 2.2.3.1)

SCOPE ORGANIZATION OF INPUT/OUTPUT

Chapter 16

16.1 INTRODUCTION

Under SCOPE, Input/Output devices are specified by Logical Unit Numbers (LUN's) which are organized according to function. The programmer or operator assigns the logical unit to a particular type or unit of hardware, through SCOPE control.

Logical Units may be specified as

(i) Programmer units,

(ii) Scratch units,

or (iii) System units.

16.1.1 Programmer Units

They are for general purpose use by the programmer, and they are unrestricted as to use in any run in a job.

Once defined, the definition of the programmer unit is fixed for the whole job. They are released by SCOPE at the end of the job, unless saved by the programmer by the use of a SCOPE unload card.

Programmer units are numbered 1-49.

16.1.2 Scratch Units

Scratch units must be defined for each run, and are released at the end of the run. They are assigned and used by Library programs, and may be accessed by the programmer for temporary use.

Scratch units are numbered 50-55.

They cannot be saved by the programmer.

16.1.3 Systems Units

Systems units are assigned to specific physical equipment within SCOPE, but these assignments may be altered by the operator. They are used for certain common functions, and may be protected by SCOPE from input-output requests which might destroy their contents.

Systems units are numbered 56-63, as follows:

56 Load and Go (for storage of object decks from assembly, prior to Loading and Execution)

57 Accounting

58 Comments from operator (only read requests allowed)

59 Comments to operator (only write requests allowed)

60 Standard Input (protected against writing, etc.)

61 Standard Output - holds listable output

62 Standard punch - output from COMPASS, etc.

63 Library.

16.2 CENTRAL INPUT/OUTPUT ROUTINE

16.2.1 Introduction

Input/Output requests in COMPASS programs are written as calling sequences for monitor routines controlled by a central Input/Output routine called CIO.

CIO performs the following functions:

(i) Selects an available channel

(ii) Rejects requests if

(a) the unit is not available (e.g. due to an operator error).

(b) no access channel is available

(c) an illegal instruction (function code) is given.

(iii) Provides the current status for all requests.

(iv) Initiates all I/O operations, and then returns control to the main program so that processing may continue while the I/O operation is carried out.

(v) Responds to external interrupts, and transfers control to a routine specified by the programmer.

16.2.2 Calling Sequences

Input/Output operations are specified by entering an octal function code and other parameters into a calling sequence. The function codes are

Function Code	Request
01 02	Read Write
03 04	Read backwards Rewind
05 06	Unload Backspace
07 10	Space forward past 1 EØF Space backwards past 1 EØF
11 12	Write EØF Erase
13 14	Status Format

There are 4 operations performed with CIO

(i) I/O operations

(ii) Tape control operations

(iii) Unit Status operations

(iv) Format selection operations.

16.2.3 Input/Output Operations

The function codes used by Input/Output operations are:

(a) 01 READ n words, starting at FWA (First word address)
(b) 02 WRITE n words, starting from FWA
(c) 03 READ BACKWARDS, n words, and store backwards, starting at FWA+n-1.

Calling Sequence:

Input/Output operations are requested by the following sequence of instructions.

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD	COMMENTS
(L)	RTJ	CIØ	
(L+1)	Function Code	Logical Unit Number, Interrupt Indicator	
(L+2)	UJP	Reject Address	
(L+3)	Mode	First Word Address	
(L+4)		Number of Words	
(L+5)		Interrupt Address	
(L+6)	FIRST INSTRUCTION EXECUTED UPON RETURN FROM CIØ		
	Note: CIØ must be declared external somewhere in the subprogram		
	also if Interrupt Indicator = 0,		
		no Interrupt Address is specified and the	
		first instruction to be executed upon return	
		from CIØ should be located at L+5 instead	
		of L+6.	

Notes: (a) The logical unit number (LUN) is defined by an EQUIP card, and may be 1-63, depending on function code.

(b) The function code is an octal number, 1-14 as defined previously.

(c) The interrupt indicator selects an interrupt on normal or abnormal end of operation when set.

0 = no interrupt

1 = interrupt on ABNORMAL end of operation only (end of tape, EOF mark, load point, parity error, lost data for mag. tape.)

2) interrupt on an end of operation, whether normal
3) or abnormal.

(d) JUMP is any legitimate jump to the reject address.

(e) Interrupt address is the address of a closed subroutine to which control goes when the specified interrupt occurs.

(f) Reject address is a symbolic address to which control goes in the event of CIO rejecting the calling routine. In the event of a reject because a channel or a unit is not available the A register will contain zero. If the reject is due to an illegal function code, the A register will contain a non-zero quantity. For both types of rejects, the Q register will contain the status of the unit.

(g) The mode designates the method of recording, and is given as an octal number.

If no mode is designated, binary mode is assumed and density is under the control of the operator.

Code	Density	Parity
00	Do not select a new mode	
40	none	even
41	none	odd
50	low	even
51	low	odd
60	medium	even
61	medium	odd
70	high	even
71	high	odd

(h) First Word Address (FWA) is the symbolic address of the first word in the input or output area.

(i) Number of words (n) is the decimal number of words to be transmitted.

(j) If no interrupt is specified, the normal return is written in location L+5.

(k) On interrupt, before control is passed to the interrupt address, SCOPE saves A, Q and the 3 index registers. On completion of the interrupt subroutine, the programmer must return control to SCOPE, which will then restore the A, Q and Index registers to their original values. Note that no values obtained in the subroutine can be returned to the main program in these registers.

Example:

Write at 556 bpi in BCD on a magnetic tape that has previously been defined as LUN 20, a 27 word block of data commencing at the symbolic address ORIGIN.

After successfully initiating the write operation, jump to the symbolic address PROCESS and continue the execution of the program.

In the event of an abnormal end of operation, go to the symbolic address ABANDON; and if the write request is rejected, jump to PAUSE.

Answer:

OPERATION MODIFIERS	ADDRESS FIELD
RTJ	CIØ
02	20, 1
UJP	PAUSE
60	ØRIGIN
	27
	ABANDØN
UJP	PRØCESS

Use of interrupt facility (See also Section 21.3)

If an interrupt address is specified, and the interrupt indicator is non zero, control transfers to the interrupt address at the end of the operation, or upon an abnormal condition interrupt.

Before giving control to the interrupt address, SCOPE saves the contents of the A, Q and three index registers. It then enters the current condition and status of the unit in the A and Q registers respectively.

C = Condition of unit
- 0 = dynamic
- 1 = static

LF = Last function code (other than 13) given for the unit

TCA = Terminating character address of data transmission contained in the Buffer Control Register.

LS = Logical Status of the Unit

- 00 = (a) if a status request, unit is static, channel is available
  (b) for reject return, hardware reject
  (c) for normal return, unit is dynamic
- 01 = Channel is not available for any requests
- 10 = previous operation is incomplete
- 11 = previous operation is complete, but an interrupt request is being processed.

LC = Last channel to which the unit was connected (or is still connected).

R = Retention code (from standard 3200 tape label)
- 0 = tape may be used for output
- 1 = contents of tape should not be destroyed.

STATUS See following chart.

UNIT STATUS TABLE

STATUS BIT	MT	CR	CP	PR	PT	TY
00	Ready	Ready	Ready	Ready	Ready	Ready
01	Busy	Busy	Busy		Busy	Busy
02	Write enable					
03	File mark	EØF				
04	Load point					
05	EØT	Hopper empty			Tape supply low	
06	DENSITY 00 = low					
07	01 = med. 10 = high					
08	Lost data	Fail to read	Fail to feed			
09	End of operation					
10	Parity error	Reader error	Compare error			Parity error
11	Binary mode	Binary card	Binary mode		Binary mode	
12		Stacker full or jammed				
13						
14						
15						
16						

NOTES: (a) Density is signified by combinations of 2 bits - bits 6 and 7 - as shown.

(b) Bits 13-16 are not used.

Control transfers to the interrupt address by a return jump instruction established by SCØPE within the CIO routine.

The interrupt address should therefore be an unconditional jump instruction to enable control to return to CIO after the interrupt has been processed

```
e.g.  INTERUPT     UJP     **
```

The programmer must transfer control to SCØPE from the interrupt routine by returning through linkage established by the return jump instruction

```
e.g.  INTRUPT      UJP     **
                   .
                   .
                   .
                   .
                   .
                   UJP,I   INTRUPT
```

Upon regaining control, SCØPE restores the A, Q and Index registers, and then returns control to the running program.

Note that values placed in A, Q or the index registers in the Interrupt routine will be lost when the return to CIO is made. Values to be returned should therefore be stored before the transfer of control is carried out.

An example of this appears on the following page.

Example;

Read 500 words from tape LUN 3 into a buffer commencing at BUFF. When the Operation has been initiated, continue program execution. When the operation is complete, set location FLAG to a non-zero value. If the read request is rejected because of an illegal code, jump to ABANDON. If it is rejected due to channel or unit not being available, jump to PAUSE.

Answer:

```
        RTJ     CIO
        01      3,2
        01      REJ
        51      BUFF
                500
                INTER
        LDA
        .
        .
        .
INTER   UJP     **
        ENA     1111B
        STA     FLAG
        UJP     INTER
REJ     AZJ,EQ  PAUSE
        UJP     ABANDON
```

16.2.4 Tape Control Operations

The codes used in tape control calling sequence are

04	REWIND
05	UNLOAD
06	BACKSPACE
07	SPACE FORWARD PAST ONE EØF MARK
10	SPACE BACKWARDS PAST ONE EØF MARK
11	WRITE EØF
12	ERASE

The calling sequence:

Location L	RTJ	CIO
L+1	function code	LUN, INTERRUPT INDICATOR
L+2	JUMP	REJECT ADDRESS
L+3		INTERRUPT ADDRESS
L+4	NORMAL RETURN	

Note: (a) If no interrupt is requested, the normal return is written in Location L+3.

(b) The notes for I/O control apply here also.

Examples:

(i) To rewind logical unit 56

```
RTJ        CIO
04         56
UJP        *-2
normal return
```

(ii) To write an end-of-file on LUN 20

```
RTJ        CIO
11         20
UJP        *-2
normal return
```

(iii) To space forward past an end-of-file mark on LUN 17

```
RTJ        CIO
07         17
UJP        *-2
normal return
```

Notes: (i) The direction of tape motion following a BACKSPACE request depends upon whether the last operation was a READ or a READ BACKWARDS operation -

(a) If the last operation was a READ operation, the tape will move backwards.

(b) If it was a READ BACKWARDS operation, the tape will move forward one record.

Other motion requests indicate the true direction of the tape and are not affected by READ BACKWARDS.

(ii) Tape control operations require the channel only during initiation of the function. They do not cause the channel to be busy while the function is carried out. However, if an interrupt at the end of operation is requested, CIO considers the channel to be busy until the interrupt occurs.

16.2.5 Unit Status Requests

For codes returned as status replies, see table on (cont.3) of section 16.2.3.

The calling sequence:

Location L	RTJ	CIO
L+1	13	LUN, Dynamic flag
L+2	NØRMAL	RETURN

NOTES: (a) The function code in L+1 is always 13.

(b) SCØPE provides the status in the Q register, and the current condition in the A register (A is negative if the unit is static, positive if it is dynamic).

(c) Dynamic flag:

If this is non-zero, the unit is interrogated for status unconditionally. (Status is given if unit is busy or not). If the flag is zero:

(i) If it is not busy, the status of the last completed operation is given.

(ii) If the unit is busy, the current status is returned.

16.2.6 Format Selection

The codes used in this sequence are -

1 = BCD

2 = BINARY

3 = LOW

4 = MEDIUM

5 = HIGH

The calling sequence:

```
RTJ       CIO
14        LUN, FORMAT CODE (as above)
JUMP      REJECT ADDRESS
NØRMAL    RETURN
```

16.2.7 Page Control of the Line Printer

The first character of the output buffer is used to position the paper prior to and after printing. This is accomplished by the following sequence of events.

(a) The first character is removed and replaced with a blank.

(b) The corresponding function code is found and selected.

(c) The output buffer is printed.

The character codes used in Page Control are:

User Character	Action Before Print	Action After Print
1	Skip to channel 8	Space 1 line
2	Skip to channel 7	Space 1 line
3	Skip to channel 6	Space 1 line
4	Skip to channel 5	Space 1 line
5	Skip to channel 4	Space 1 line
6	Skip to channel 3	Space 1 line
7	Skip to channel 2	Space 1 line
8	Skip to channel 1	Space 1 line
A	No space	Skip to channel 8
B	No space	Skip to channel 7
C	No space	Skip to channel 6
D	No space	Skip to channel 5
E	No space	Skip to channel 4
F	No space	Skip to channel 3
G	No space	Skip to channel 2
H	No space	Skip to channel 1
blank	No space	Space 1
0	Space 1	Space 1
-	Space 2	Space 1
*	No space	No space
other	No space	Skip to channel 1

Examples:

(a) To advance paper to the top of the new page

```
          RTJ     CIØ
          02      61
          RTJ     REJX
          00      PAGE
          00      1


PAGE      BCD     1,1
```

(b) To advance one line

```
            RTJ     CIØ
            02      61
            RTJ     REJX
            00      DS
            00      1


   DS       BCD     1,
```

Note: If unit 61 is assigned to tape by the operator and the tape is listed later or is listed off-line, trouble may develop because of the short print record (4 chars). Therefore it is recommended that all records be at least 24 characters so that they won't be considered 'noise' records by tape input routines.

STUDENT NOTES

SCOPE CONTROL CARDS

Chapter 17

17.1 INTRODUCTION

SCØPE control cards have a 7,9 punch in column one. There must be no other punchings in column 1.

Columns 2 through 80 contain Hollerith information or blanks. The first information on each card must be the statement name, followed by a comma.

e.g. $^{7}_{9}$RUN,

$^{7}_{9}$JØB,

17.2 SEQUENCE CARD

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
$^{7}_{9}$SEQUENCE, j		

The sequence statement assigns a number (j) to the job which it precedes. j must lie between 1 and 999. This card is normally supplied by the operating staff.

An EØF must precede each SEQUENCE statement except the first on input.

When a SEQUENCE statement is detected, the statement is typed out on the console typewriter, and listed on the standard output unit. SCØPE writes an EØF on the standard output tape (when tape is being used), and on the punch tape (if assigned), and releases all programmer units held from the last job.

SCØPE also closes off the last job's accounting, and opens a new accounting record for the new job.

If the sequence card is not followed by a JØB card, the job is terminated, and SCØPE searches forward until it finds an EØF. The following statement must be a SEQUENCE, ENDREEL or ENDSCØPE. If it is a SEQUENCE followed by a JØB card, SCØPE proceeds normally.

After SEQUENCE is read, SCØPE pauses for comments from operator to be typed in on the console typewriter. These enable the operator to specify the services for program execution (e.g. special EQUIP statements). This is the only opportunity the operator has to enter such statements.

Note: If the column following "j" contains a comma, comments may follow.

Example:

$^{7}_{9}$SEQUENCE,027,   COMMENT

17.3 JOB CARD

LOCATION	OPERATION, MODIFIERS ADDRESS FIELD
$^{7}_{9}$JØB,c,i,	t,$\overset{NS}{\underset{NP}{\text{or}}}$,ND

The symbols used in the statement are interpreted as follows:

c   charge number, 0-8 characters

i   programmer identification, 0-4 characters

t   time limit in minutes for the entire job, including all operator setting up, idle time, etc.

NS   indicates a single non stacked job. If NS is specified, NP is implied also.

All system units are rewound and unloaded, making all I/O units available to the programmer.

NP   Suppresses system I/O protection for stacked job.

ND   Suppresses the normal post execution dump in octal of the non system part of memory should abnormal termination of the job occur.

The c, i, and t fields are mandatory. If a field is blank, the comma showing this must appear.

e.g. $^{7}_{9}$JOB,c,,t

The job card is written on the standard output unit, and also on the CTØ (comments to operator) if the job is part of a stack. It must be immediately preceded by a SEQUENCE card or the run will be terminated.

17.4 ENDSCØPE STATEMENT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^7_8$ENDSCØPE		

This indicates that a SCØPE run is to be terminated. On the standard input unit, it should follow the EØF terminating the last in the stack. <u>This card is normally supplied by the operations staff</u>.

The card is listed on the CTØ unit and on ØUT, and the standard input unit is unloaded, if magnetic tape.

The library tape is rewound, and the accounting file is closed off.

A double EØF and one BCD word, consisting of ER$_{\wedge\wedge}$ are written on the standard output tape (when tape is used), which is then unloaded. If the punch tape is assigned, it is treated in the same way.

When all action is completed, the computer stops.

17.5 ENDREEL STATEMENT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^{7}_{9}$ENDREEL		

The statement terminates a reel of magnetic tape containing a job stack. (Normally it will be placed in a card job stack by the operations staff during card to tape operations preparing a tape for use as a standard input tape.)

SCØPE requires an EØF both immediately <u>before</u> and <u>after</u> ENDREEL.

When the statement is detected, SCØPE prints a message on the CTØ unit requesting the operator to mount the next reel of input, and halts the computer until the operator takes the action.

17.6 CTØ STATEMENT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^7_9$CTØ,statement		

The programmer may provide instruction~~s~~ or messages to the operator. The message is punched in Hollerith.

Examples: $^7_9$CTØ,PLEASE UNLØAD TAPE TWØ.

$^7_9$CTØ,SNAP DUMPS WILL ØCCUR.

The message is printed on the CTØ, and also listed on ØUT. CTØ cards may be placed in the deck where SCØPE control cards may appear, except as follows:

(i) Before or after SEQUENCE, ENDSCØPE or ENDREEL.

(ii) After CØMPASS or FØRTRAN.

(iii) Between RUN and last data card.

17.7 REWIND STATEMENT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^7_9$REWIND,U_1,U_2, ... ,U_n		

The magnetic tapes specified are rewound to load point. U is the logical unit number, and may be 1 through 57 or 63. The statement is copied onto the standard output unit, and on the CTØ unit.

If U is not 1-57,63 or not a magnetic tape unit, the request is ignored for that unit, but the rest of the units on the card are processed.

Example: $^7_9$REWIND,21,42,01,55

17.8 UNLØAD STATEMENT

LOCATION	OPERATION, MODIFIERS ADDRESS FIELD
${}^{7}_{9}$UNLØAD,	$U_1, U_2, \ldots, U_n$

The Logical units, U (1-57), may be unloaded by the programmer. The statement acts similarly to the REWIND, except that the unit is unloaded after rewinding.

Example: ${}^{7}_{9}$UNLØAD,21,42,01,55

17.9 EQUIP. STATEMENTS

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
${}^7_9$EQUIP, X_1=d_1,X_2=d_2,.....etc		

Where X = the logical unit number

d = a declaration about the unit.

17.9.1 Hardware definition

${}^7_9$EQUIP,X_1=hh_1,X_2=hh_2,........etc.

hh is a hardware type mnemonic

X is a L.U.N.

Mnemonic	Type
MT	Magnetic Tape
CR	Card Reader
PR	Printer
CP	Card Punch
TY	Console typewriter
PT	Paper tape station
DP	Disk Pack

SCØPE assigns the LUN to an available equipment of the specified type.

If no equipment is available, a diagnostic is given, and the job is terminated.

Examples: ${}^7_9$EQUIP,51=MT

${}^7_9$EQUIP,51=MT,43=PR,26=PT

17.9.2 Equating Logical Units

Logical units are equated by this statement

${}^7_9$EQUIP,X_1=X_2

A system unit (57-63) may not be specified on the left hand side of the statement. If it is, the job is terminated.

Examples: ${}^7_9$EQUIP,43=60 is permissable

but ${}^7_9$EQUIP,60=43 is illegal

${}^7_9$EQUIP,22=MT
${}^7_9$EQUIP,23=22

) Here both LUNS 22 and 23 will reference the same magnetic tape.

17.9.3 Physical Unit Assignment

$^{7}_{9}\text{EQUIP,X=hhC}_{c}\text{E}_{e}\text{U}_{uu}$

c = channel number (0-7), prefixed by C

e = equipment number (controller), prefixed by E

uu = unit number (device), prefixed by U

Example:

$^{7}_{9}$EQUIP,15=MTCOE2U03

It is possible to omit some parameters in the statement.

The following table sets out permissable combinations.

hh	C_c	E_e	U_{uu}
x			
x	x		
x	x	x	
x	x	x	x
	x	x	x
	x	x	

Use of non-existant c, e or uu, will cause a diagnostic and termination of the job.

Example:

Assign PUN (LUN 15) and LGO (Load and Go, 56) to the physical unit on channel 0, Equipment 1, and unit 7.

Answer:

$^{7}_{9}$EQUIP,15=MTCOE1U07

$^{7}_{9}$EQUIP,56=15

or $^{7}_{9}$EQUIP,15=MTCOE1U07,56=15

17.10 TRANSFER STATEMENT

LOCATION	OPERATION, MODIFIERS ADDRESS FIELD
${}^{7}_{9}$XFER,U	

U = Magnetic Tape Unit,
defined as 1-56,
or undefined.

Description: SCØPE transfers all the information following the XFER statement from the Standard input unit (INP) to the magnetic tape LUN U, until another SCØPE statement is encountered.

The records must be binary records and they are written on LUN U in odd parity. When the next SCOPE statement is found, an EOF is written on the tape, and SCOPE then backspaces over the EOF.

Uses:

(i) Programmer binary data cards* may be transferred from INP to a magnetic tape unit. A card with a ${}^{7}_{9}$ punch in column 1 is sufficient to terminate the XFER operation.

(ii) Binary object subprograms may similarly be stored on another magnetic tape for future use. The unit must be rewound before the LØAD operation if it is a programmer or scratch unit.

Example:

```
7
9XFER,03
   .
   .
Binary Data*
   .
   .
   .
7
9
```

The data is written on unit 3; when the ${}^{7}_{9}$ card is found, SCØPE writes EØF and backspaces over it.

---

*Data cards must be binary data cards where column 1 has a ${}^{7}_{9}$ punch plus at least one punch in the + - 0 1 2 or 3 position. The data used is usually a subprogram binary deck.

17.11 LOAD STATEMENT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^{7}_{9}$LØAD, U_1, U_2, U_3		

(U_1, U_2 and U_3 are Mag. tape units, previously defined by EQUIP statements as LUN 1-56. If omitted, SCØPE will try to load from the INP unit 60)

Description: Not more than 3 units can be specified, and the loading is done in the order indicated. Unit U_1 will be loaded until an EØF is found. Then U_2 is loaded until EØF, and finally U_3 is loaded. If there are 3 parts on one unit, each terminated by an EØF, the unit number can be repeated:

$^{7}_{9}$LØAD,23,23,23

When the units designated have been loaded, the Standard input unit is examined to see if binary object subprograms follow the LØAD card.

NOTE: If the LGØ unit is being used, the LØAD card must be of the form:

$^{7}_{9}$LØAD,56

The LØAD statement calls the loader to load binary subprograms into memory from programmer units, scratch units, LGØ or INP. Only one LØAD statement may appear in a run.

If 56 (LGØ) is specified, it will first be rewound by SCØPE. Other units must be rewound by rewind statements before loading is attempted.

Example:

$^{7}_{9}$LØAD,56,3,25

LGØ is rewound by SCØPE and loaded until EØF is found. Units 3 and 25 are then loaded to EØF marks.

NOTE: If only binary object programs are to be loaded (on INP), no LØAD card is necessary.

Example:

$^{7}_{9}$JØB,11121156,404,2

Binary object deck

$^{7}_{9}$RUN,1

$^{77}_{88}$

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
$^{7}_{9}$CØMPASS,	I, P, L, X, R	

Description: The CØMPASS library program is called in and loaded into memory, so that source programs in CØMPASS may be assembled and executed.

The parameter letters are free field, and may thus appear in any order. Each parameter must start with the character shown.

I = INPUT (the source subprogram input unit)

Specified as I = u, when u = LUN, when a source subprogram is to be loaded from a unit other than INP.

If the I parameter is absent, input is assumed to be from unit 60 - INP.

Example:

```
7
9EQUIP,MT=23
   .
   .
   .
   .
7
9CØMPASS,I=23,etc.
```

P = PUNCH-UNIT

Specified as P = u, where the punch unit is to be assigned to an output device.

If P only occurs, punching is on the binary punch unit (PUN) - unit 62.

If the parameter is absent, no binary output is produced.

X = EXECUTE (X = u)

Assigns the Load-Go unit (LGØ) to logical unit U, which must have been previously defined as a MT unit.

If absent, no LGØ tape will be produced, and the program will be assembled and listed only.

If only X appears, output will be put on the standard LGØ unit (56).

L = LIST OPTION (L = u)

Output is listed on unit u, which must have been previously defined.

If L only appears, listing will be done on the OUT unit (61).

If the parameter is absent, no listing of the program is given.

R = REFERENCE

When R appears, a symbol reference list is produced on the assembly listing. This is an alphabetic list of all symbols used in the program, with the address, or the value, of the symbol shown. The symbol list appears immediately following the listing of the assembled program.

Example:

A	77777		P00013	
ABNORMAL		EXTERNAL	P00001	
B	00020		P00013	
JOHN	P00002		P00011	
NAME	P00011		P00013	
X	00057		P00012	P00013

SYMBOLS NOT REFERENCED

ABLE	P00013	LOC	P00007	START	P00000

Note that X is referenced at two different locations in the program (12 and 13).

Character addresses are shown as follows:

CAN	P00166 0
BILL	P00156 1

17-Bit non-relocatable symbols are shown

TØM	00076 2

17.13 RUN STATEMENT

LOCATION	OPERATION MODIFIERS ADDRESS FIELD
$^{7}_{9}$RUN,t,NM	

t = execution time in minutes

May be in the range 0 through 999.

The time is not used by SCØPE, but is entered in the installation accounting file.

If not specified, maximum time is assumed.

NM = NO MEMORY MAP

If NM appears, it suppresses the memory map that would otherwise be written on ØUT, before program is executed. (All absolute memory allocations are given in the map).

Examples:

(i) $^{7}_{9}$RUN,2

(the execution time is assumed to be two minutes. The memory map will appear on ØUT.)

(ii) $^{7}_{9}$RUN,727,NM

(the execution time is assumed to be 727 minutes, and no memory map will appear on OUT).

(iii) $^{7}_{9}$RUN

(maximum execution time is assumed. Map will be printed).

(iv) $^{7}_{9}$RUN,,NM

(maximum execution time assumed, and no map will be listed on ØUT).

17.14 DIAGRAMMATIC DECK

```
7
9SEQUENCE,001

7
9JØB,3200,STØRMA,10

7
9EQUIP,56=MT

7
9FØRTRAN,(Parameters)

          PRØGRAM MAIN
               .
               .
               .
               .
               .
          CALL START                           FØRTRAN Main Program
               .
               .
               .
               .
               .
          END

               FINIS

7
9CØMPASS,(Parameters)
               IDENT      TWØ

               ENTRY      START

START          UJP        **                   CØMPASS Subprogram
                .
                .
                .
                .
                .
               END

               FINIS

7
9LØAD,56

7
9RUN,5

               data deck

77
88            (End-of-File Card)

7
9ENDSCØPE

77
88
```

STUDENT NOTES

SCOPE DEBUGGING AIDS

Chapter 18

18.1 ØCTAL CORRECTION CARDS

$^{7}_{9}$ØCC,location,octal correction,----------,octal correction.

Description: Octal corrections may be made to binary object subprograms after loading, using this instruction.

The parameters are free field.

If a period is used to terminate the card, comments may follow it.

The statement may be used to -

(i) define corrections

(ii) enter corrections

(iii) enter additions to a subprogram by establishing a program extension area after the subprogram area.

18.1.1 Location Symbols

(i) (Program name) k

Corrections on this card are loaded beginning with relative address "k" in the named subprogram. The subprogram name must appear in parentheses.

Examples:

$^{7}_{9}$ØCC,(TEST)15,01000000

$^{7}_{9}$ØCC,(BUFFIN)107,20

Example of use:

```
                IDENT    TWØ
                ENTRY    START
0     START     UJP      **
                 .
                 .
                 .
10              ENA      20B
                 .
                 .
                END
```

To change ENA 20B to ENA 30B

$^{7}_{9}$ØCC,(TWØ)10,14600030

(ii) Data Area Corrections

Dk

Corrections are loaded beginning with location "k" in the Data area.

Example: $^{7}_{9}$ØCC,D70,14000000

18.1.1 (cont.)

(iii) Program Extension Area

Xk

(a) First occurrence:

Defines a program extension area of length k words. Corrections on this card are ignored.

(b) Subsequent occurrences:

Corrections are loaded beginning at location k of the program extension area.

Example: $^{7}_{9}$ØCC,X30

$^{7}_{9}$ØCC,X3,14000010,14000250

(iv) Continuation Cards

+k

Increment k locations from the last location plus 1, corrected by the previous ØCC card. k must be octal.

$^{7}_{9}$ØCC,(TEST)136,00000100

$^{7}_{9}$ØCC,+5,14000600

Location 136 in Subprogram TEST, and location 144 in TEST are changed.

18.1.2 Octal Corrections

(i) Corrections may be of up to 8 digits, and are in the form of machine instructions.

(ii) Each correction is separated from the preceding correction by a comma.

(iii) Leading zeros may be omitted. Each value is stored right justified with zero fill, in successive computer words.

(iv) Locations may be omitted for correction by using commas to indicate the omissions -

e.g. $^{7}_{9}$ØCC,(TEST)10,140,,162,,10014100

Location 10 is altered to 140
11 is unchanged
12 is altered to 162
13 is unchanged
14 is altered to 10014100

18.1.3 Relocation Factors

(i) none given - the quantity specified is absolute.

(ii) (Subprogram name) - the address field of the correction is relative to the subprogram's first location.

(iii) Data area - D

Relocate the word address portion of the Octal correction relative to the DATA area.

(iv) Common Area - C

Relocate the word address portion of the Octal correction relative to the CØMMØN area.

(v) Program Extension Area - X

Relocate relative to Prog. Ext. Area.

(vi) Last subprogram area referred to - *

Relocate relative to the last subprogram named in this or a preceding ØCC or SNAP statement.

Example: $^7_9$ØCC,(TWØ)30,20000040(TWØ)

Correction made to location 30 in subprogram TWØ, with the address part of the correction relocated by the factor by which TWØ itself is relocated.

(i.e., if subprogram TWØ itself is relocated by 1000, the actual correction loaded would be 2001040).

Note: The above example could also have been written:

$^7_9$OCC,(TWØ)30,20000040*

18.1.4 Error Indicators

Errors in ØCC cards prevent execution of the program.

If the extension area is incorrectly defined, the following message is printed on ØUT:

***Xnnn

where nnn is the 3-digit octal length of the SCØPE defined extension area.

The format for all other errors is:

*mn COL nn

where mn = error mnemonic

nn = column number on the card.

18.1.4 (cont.)

The following table sets out the error mnemonics used.

Mnemonic	Meaning
PN	Program name
BS	Common or data storage is undefined and referenced
AD	Address or location field begins with an illegal character
8F	Octal field contains a non-octal character
XA	Program extension area error
WR	Wrap around of location field address - exceeds core size
AN	Antecedent reference to a program or loading address
RL	Relocation factor error

18.2 SNAP DUMPS

SCØPE provides selective memory dumps during execution, using this statement.

${}^{7}_{9}$SNAP,(Parameters)

The statement must appear after the program is loaded and before the RUN card is encountered.

The dump is carried out by the library routine SNAPSHØT, which must be defined in the program as an external. (If it is not declared as external, the routine is not loaded into storage at load time. A diagnostic of this is given on the ØUT listing as follows:

***	NØSD
RUN	ABØRTED

The job is terminated.)

Snap statement parameters define

(a) Where the dump is to be taken
i.e. when execution reaches a predetermined point, the dump is taken.

(b) The area to be dumped.

(c) The format of the dump.

The SNAP statement is of the following form:

${}^{7}_{9}$SNAP,location,beginning address,ending address,mode, identification,comments.

Each parameter is separated by commas.

Program names are always enclosed in parentheses.

18.2.1 Errors

If there is an error in any subfield, the following diagnostic is given.

*mn,	COL	nn
	mn =	error mnemonic
	nn =	the card column number, in which the error occurs.

The error mnemonics are set out in the table on the following page.

18.2.1 (cont.)

Mnemonic	Meaning
PN	Program name
BS	Common or data storage is undefined
AD	Address or location field begins with illegal character
8F	Octal field contains a non-octal character
XA	Program extension area is undefined or too small
WR	Location field address wrap around - exceeds core size
OV	Overflow of memory will recur if this SNAP is loaded
IM	Illegal mode
RG	Range to be snapped has FWA greater than LWA

When an error occurs, the SNAP statement is ignored, and execution continues as if no SNAP statement had been given.

18.2.2 Location

(i) (Subprogram name) k

Replace location k in the subprogram with a RTJ to SNAP calling sequence.

(ii) Program extension area - Xk

Replace location k in the P.EXT area by a RTJ to SNAP calling sequence.

(iii) Data area - Dk

Replace statement k in the DATA area by a RTJ to the SNAP calling sequence.

18.2.3 First and Last Word Addresses

The ending address must always be greater than the beginning address, or the SNAP statement is ignored.

The address can be

(i) Dk - dump begins or ends with word k in the DATA area.

(ii) Ck - dump begins or ends with word k in the CØMMØN area.

(iii) Xk - dump begins or ends with word k in the Program Extension Area,

(iv) (Subprogram name) k - dump begins or ends with the location k in the specified subprogram.

(v) *k - dump begins with the location k in the last named subprogram in a preceding ØCC or SNAP statement.

18.2.4 Mode

The dump may be in one of 3 formats, and may include the Register file or not, as specified.

O = octal

C = 6-Bit Characters

F = Floating point

If the register file is to be included, R is used. Thus ØR will give the dump printed out in ØCTAL, plus the register file contents.

18.2.5 Identification

0 to 4 BCD characters will be printed out on the SNAP output to identify the dump. (Used if several dumps are to be made).

18.2.6 Note

If the location specified is in a loop, the contents of the area will be dumped out each time the location is encountered in the loop.

18.2.7 Example

Dump after the execution of the 5th instruction of subprogram SUB1 (assuming the first location of the subprogram is the entry point and is entered by a RTJ). Dump from location 441 in SUB1 to location 465 in SUB1 in OCTAL, with the Register File also, and identify the dump as ØNE.

Answer: $^{7}_{9}$SNAP,(SUB1)6,*441,*465,ØR,ØNE

*441 could also be written (SUB1)441

18.2.8 Rules for Using SNAP

(1) DON'T specify SNAP for an instruction using more than one word,

e.g. SRCE
SRCN
MOVE

(2) DON'T SNAP jumps or tests, e.g., AQJ,EQ. - The jumps will not be executed correctly.

(3) DON'T SNAP indirectly addressed instructions.

(4) DON'T SNAP instructions which will be modified by program execution.

(5) AVOID using SNAP instruction in a loop.

(6) DON'T modify the location at which the SNAP occurs by an ØCC statement.

(7) DON'T specify SNAP for the following instructions:

MEQ
MTH
SSH
CPR
CON
SEL
EXS
INS
INTS
PAUS

(8) DON'T specify SNAP for any SKIP Instruction
e.g. ISI, ASE, QSG, etc.

(9) DON'T specify SNAP for INPUT/ØUTPUT instructions.

18.3 OTHER DEBUGGING AIDS

18.3.1 Memory Map

The programmer may secure a map of memory allocated to a loaded program at the time the run card is encountered. This map may be suppressed by a parameter of the RUN control statement (NM).

The map contains the following information:

(1) Absolute address of the first location in each subprogram loaded.

(2) All entry point symbols and their absolute addresses.

(3) The absolute addresses of the first and last locations in the common area.

(4) The absolute address of the first location in the data area.

(5) The absolute address of the first location in the program extension area.

18.3.2 Abnormal Termination Dump

If a job is terminated abnormally, a post execution dump of all the non system part of memory is written on the standard output unit, unless the programmer has specified in the job card that it be suppressed (ND parameter).

The dump consists of the console conditions, the register file, and all the non-system part of memory.

Should the contents of words making up a line of print be exactly the same as both the last word on the preceding line, and the first word on the following line, the line is not printed, and the word "GAP" appears instead.

e.g. If all the locations between 10010 and 10017 are the same as both 10007 and 10020, the line will not be printed, and GAP will indicate the omission.

18.4 CØMPASS ERROR CODES

A Format error in address field.

C Attempt to assemble information into CØMMØN.
(Instructions are processed as if a PRG was encountered.)

D Doubly defined symbol.
(The first time the symbol is used it is legal, and no flag is issued. Subsequent errors are flagged, and the instructions using the symbol are assembled as if no symbol occurred.)

F Full symbol table.
(All F flagged symbols are undefined, and reference to them in address fields of other instructions will produce U errors.)

L Location field error.

M Modifier error.

O Operation code error. (The field is assembled as zeros.)

U Undefined symbol.

T Truncation error.
(A symbol defined as a 17-bit character address is used in a subfield of only 15 bits. The 2 least significant bits are lost in truncation, and the flag indicates this loss.)

COMPASS ASSEMBLY OF CONSTANTS

Chapter 19

19. CØMPASS ASSEMBLY OF CONSTANTS

Constants may be

(i) stated as octal, decimal or character in the source language.

(ii) single, double or variable precision.

(iii) fixed or floating point format.

(iv) placed into bit positions of variable length fields.

19.1 ØCTAL CONSTANT PSEUDO INSTRUCTIONS

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ØCT	$m_1, m_2, ----m_n$

<u>Description</u>: The instruction expresses constants as signed or unsigned octal constants. The octal integer may consist of 8 or less digits.

As many constants as can be contained on a card may be expressed in the address field, separated by commas. No blanks may appear between constants. The field terminates at the first blank or at Column 73.

The octal constants are assembled, right justified, in consecutive locations. The symbol in the location field is the 15 bit word address of the first constant in the field.

<u>Example</u>: CVTABLE ØCT -17,32,12345670,5742,-361

CVTABLE	7 7 7 7 7 7 6 0
	0 0 0 0 0 0 3 2
	1 2 3 4 5 6 7 0
	0 0 0 0 5 7 4 2
	7 7 7 7 7 4 1 6

<u>Binary Scale factor</u>:

An optional binary scale factor may be stated by suffixing the constants by B, and expressing the scale factor as a signed or unsigned decimal integer of not more than 2 digits. The magnitude of the constant after scaling must be less than 2^{24}. The scaling factor is used to save space in coding

e.g. CVTABLE ØCT 200000 could be written as
CVTABLE ØCT 2B15

<u>Examples</u>: (i) CVTABLE ØCT 72B2

72 = 111 010 in binary

= 111 010 00 scaled by 2 (shift binary point 2 places right)

= 11 101 000 regrouped

= 3 5 0

(CVTABLE) = $\boxed{0000\ 0350}$

(ii) LØC ØCT 36B3,4B12,270B-2

$$36 = 011\ 110_2$$
$$= 011\ 110\ 000 \text{ (scaled)}$$
$$= 3\ 6\ 0_8$$
$$4 = 100_2$$
$$= 100\ 000\ 000\ 000\ 000_2 \text{ (scaled)}$$
$$= 40000_8$$
$$270 = 010\ 111\ 000_2$$
$$= 010\ 111\ 0_2 \text{ (scaled - 2)}$$
$$= 56_8$$

LØC	0000 0360
	0000 4000
	0000 0056

(iii) NUMBER ØCT 2416,311B16,3417B-8,-372

NUMBER	0000 2416
	6220 0000
	0000 0007
	7777 7405

Note: In negative scaling, digits are discarded from the right. If the number after scaling is greater than 2^{24}-1, the field is set to zero and the A flag is set.

Example: ØCT 6666B20

Assembled as A = 00000000

19.2 DECIMAL CONSTANTS, FIXED POINT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	DEC	$d_1, d_2, \cdots\cdots d_n$

<u>Description</u>: The instruction expresses constants as single precision fixed point binary constants. The constant may consist of a sign, and not more than 7 digits, with a magnitude of less than 2^{23}. The symbol in the location field is the address of the first constant in the field. The address field may contain as many constants separated by commas as the card may contain. The field terminates at first blank or Column 73.

<u>Example</u>: LØC DEC 1,82,-38

LØC	0 0 0 0 0 0 0 1	$(1_8 = 1_{10})$
	0 0 0 0 0 1 2 2	$(122_8 = 82_{10})$
	7 7 7 7 7 7 3 1	$(-46_8 = -38_{10})$

<u>Scaling Factors</u>:

Both decimal and/or binary scaling factors may be stated by suffixing the constant with D and/or B, and expressing the scale factor as signed or unsigned decimal integers. The magnitude of the constant after scaling must be less than 2^{23}.

<u>Steps in the conversion</u>:

(i) Decimal integer is converted to binary.

The result must be less than 2^{23}.

<u>Example</u>: $36_{10} = 44_8$

$= 100\ 100$

(ii) Binary integer is multiplied or divided by 10^d, where d is the scaling factor.

The result must be less than 2^{23}.

<u>Example</u>: 36_{10} D2 $= 36 \times 100$

$= 44_8 \times 144_8$

$= 100100 \times 001100100$

$= 111000 \times 010\ 000$

$= 7020_8$

(iii) Shift the result the number of bits specified by the binary scaling factor.

Negative factor = RIGHT shift

Positive factor = LEFT shift

<u>Example</u>:

36_{10} D2 B2

36_{10} D2 $= 111000010000$

$= 11100001000000 = 34100_8$

19.3 DOUBLE PRECISION AND/OR FLOATING POINT CONSTANTS

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	DECD	$d_1, d_2, \ldots\ldots d_n$

Description: Decimal values may be stored as double precision fixed point constants, or as floating point constants. Either format requires 48 bits for storage (2 consecutive words). Up to 14 decimal digits may be specified, and the value of the expression must be less than 2^{47}.

Decimal and binary scaling factors may be used, as in the DEC instruction.

The signed 48-bit result is stored in two consecutive computer words.

Example: SYM.TAG DECD 32,64D2B4

SYM.TAG	00 00 00 00
	00 00 00 40
	00 00 00 00
	00 31 00 00

$64_{10} = 100_8$

$D^2 = 10^2 = 100 = 144_8$

$100_8 \times 144_8 = 1\ 44\ 00_8$

$= 001100100000000$

$= 11001000\ 000\ 000\ 000$

$= 3\ 1\ 0\ 0\ 0\ 0$

Floating Point Constants:

1. Floating point constants contain a decimal point.

   Examples: 300.246
   2.040117321
   .111
   1765122.1

2. They are stored in two consecutive 24 bit words as a 12 bit characteristic (exponent) and a 36-bit mantissa (coefficient).

WORD 1	BIASED EXP	COEFF
WORD 2	COEFF	

3. A floating point constant may contain not more than 14 decimal digits and a decimal point.

4. Binary scaling is not permitted, but decimal scaling is.

5. The result after scaling must not exceed the capacity of the hardware ($10^{\pm 308}$)

   Example: SYM.TAG DECD 17643.463214

   17643.463214_{10}

   $= 42353.3551246_8$

   $= .423533551246_8 \times 2^{15}$

   =

2017	4235
3355	1246

19.4 BCD CONSTANTS

LOCATION	OPERATION.MODIFIERS	ADDRESS FIELD
	BCD	$n, c_1 c_2 \ldots c_{4n}$

Description: Characters are assembled for store into consecutive computer words as 6-bit BCD character codes, in addressable character positions. The code used is internal BCD.

The decimal integer n = the number of words to be used.

The maximum number of characters to be stored would be 4 x n.

The instruction reserves "n" words of storage, and any character positions not filled from the instruction are filled with blanks.

Characters specified in excess of (4 x n) are treated as comments.

The symbol in the location field is the 15-bit address of the first word.

Example: (i) ERRØRMSG BCD 3,I/Ø ERRØR

ERRØRMSG

I	/	Ø	60
E	R	R	Ø
R	60	60	60

3 words reserved, therefore the maximum number of characters is 12. Here only 9 appear before the end of message, so all are included.

(ii) ERRØRMSG BCD 2,I/Ø ERRØR

ERRØRMSG

I	/	Ø	60
E	R	R	Ø

2 words reserved, therefore the maximum number of characters is 8. Here 9 appear, therefore the last one is treated as a comment and discarded.

19.5 BCD CHARACTER CONSTANTS

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	BCD,C	$n, c_1c_2 \ldots\ldots c_n$

Description: Characters are assembled into consecutive character positions. n signifies the number of character positions to be reserved, and must be an integer less than 2^{15}. Characters in excess of n are treated as comments; positions reserved but not used are filled with blanks.

The symbol in the location field is the 17-bit address of the first character.

Storage

If the line of coding before BSS,C assigns character storage, the character string begins in the next available character position. If not, it begins with the first character position in the first available word.

If the number of characters specified does not exactly fill the last word, the rest of the word is zero filled. However, if the next instruction in the program which consumes space is a BCD,C instruction, it will fill up the remaining character positions in the last word.

Examples:

(i) MSG BCD,C 9,TEST PRØG

MSG	T	E	S	T
	60	P	R	Ø
	G	0	0	0

(ii) MSG BCD,C 6,TEST PRØG

MSG	T	E	S	T
	60	P	0	0

(iii) MSG BCD,C 10,TEST PRØG
BCD,C 4,END

MSG	T	E	S	T
	60	P	R	Ø
	G	60	E	N
	D	60	0	0

(Note: 60 = blank read after PRØG above.)

(iv) Example of actual listing of assembled BCD and BCD,C constants:

```
 Assembled
 Constants                  Instruction

31 61 46 60          BCD          2,I/Ø ERRØR
25 51 51 46
31 61 46 60          BCD          3,I/Ø ERRØR
25 51 51 46
51 60 60 60
63 25 62 63          BCD,C        9,TEST PRØG
60 47 51 46
27
   63 25 62          BCD,C        6,TEST PRØG
63 60 47
         63          BCD,C        10,TEST PRØG
25 62 63 60
47 51 46 27
60
   25 45 24          BCD,C        4,END
60 00 00 00
```

19.6 VARIABLE FIELD CONSTANTS

19.6.1 Introduction

The general form of the instruction is:

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	VFD	Mn/v,.....,Mn/v

where M = mode indicator

n = positive decimal integer denoting the number of bit positions in the variable field specified by this subfield. (NOTE: the range of values of n varies with the mode M).

v = the content of the field. This varies according to the mode and is restricted by the declared length.

As many address subfields as may be contained on a single card are allowed. Each subfield is terminated by a comma, except the last, which is terminated by a blank.

Use:

The instruction is used to enter information in one of the following modes into a field of a designated bit-length.

(i) octal numbers

(ii) character codes (BCD)

(iii) relocatable addresses (either word or character addresses)

or (iv) constants.

It enables information to be packed into computer words during assembly time.

Packing:

(i) Values are entered right adjusted in the field, with sign extension.

(ii) Character strings are entered left adjusted, with blank fill.

e.g. A B X is a character string.
If entered in a 24-bit character
VFD, it will be entered as:

$\boxed{21\ 22\ 69\ 60}$

Relocation:

If relocatable addresses are entered into a field, the addresses will be relocated when the assembled subprogram is loaded. (The listing will show only the assembled fields.)

19.6.2 Octal Mode

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	VFD	Øn/v

where Ø indicates the octal mode.

n indicates the number of bit positions in the field.
It may be in the range 1-24 inclusive.

v indicates the octal information to be entered into the field. It may be 1-8 octal digits, and may be signed. (If v is negative, the filled content is stored in one's complement form). The information is entered right justified in the field, zero filled if positive, one-bit filled if negative.

A binary scale factor, similar to that used with the OCT pseudo instruction, may be specified.

Example: VFD Ø24/24B6

Assembled as 00002400

Examples: (i) VFD Ø24/30502

Assembled as 00030502

(ii) VFD Ø24/-30502

Assembled as 77747275

(iii) VFD Ø15/30502

Assembled as 30502000

(Unused portions of the word are zero filled)

Errors:

If the value v exceeds the field length n,or is not octal, the error is flagged and the field is set to zero. (The CØMPASS address field error flag A appears on the listing.)

Example: VFD Ø15/30502,Ø15/2030502

Assembled as: 30502000 in word 1,
word 2 not shown on the listing.
"A" error flag set against the line.

(Note: the program will not be executed.)

Note:

If an error occurs in any field on the card, subsequent fields in that card are not listed, although space is reserved for them.

Example: VFD Ø10/12345,Ø15/24,Ø15/60,Ø24/1021

Word 1 is set to zero because the field is too small.
Words 2 and 3 are not listed.
Program listing resumes at word 4 with next card.

19.6.3 Hollerith Mode

LOCATION	OPERATION MODIFIERS	ADDRESS FIELD
	VFD	Hn/v

Here n must be a multiple of 6 to enable storage of Hollerith information as 6-bit internal BCD character codes. The address subfield terminates with a blank or a comma. If the field is too small for the number of characters specified, an error results.

Example: LØC VFD H18/ABC = $\boxed{21}\boxed{22}\boxed{23}\boxed{00}$

LØC VFD H12/ABC is illegal. (Address field flag "A" is set).

19.6.3 (cont.)

If the field is longer than the number of characters specified, the work is blank filled. Characters are stored LEFT justified in the field.

Example: LØC VFD H18/AB =

21	22	60	00

19.6.4 Word Address Arithmetic Mode

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	VFD	An/v

The address field v may be:

(i) A constant

(ii) A symbol

(iii) An expression formed by the rules of address field arithmetic.

If the expression yields a relocatable word address, the programmer must arrange so that it will be right justified on bit 0 in a word, and be contained in 15 bits. If it is not relocatable, the full 24 bits can be used.

Examples: (i) ALØC VFD A24/A+3

If A is a relocatable word address, previously defined, then answer must be 15 bits stored Right justified in word on bit 0.

If A is an absolute value, 24 bits can be stored.

(ii) Using relocatable word address

```
VFD     Ø9/010,A15/BUFR
```

where BUFR is a symbol, address 00002 in the program.

Assembled as 01000002

(iii) Using non relocatable symbol

```
A       EQU     77777B
B       EQU     57B
C       EQU     20B
        VFD     A21/A-B+C
```

Assembled as 777740 in the designated 21 bits.

19.6.5 Character Address Mode

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	VFD	Cn/v

A minimum of 17 bits is required for character addressing.

n must therefore not be less than 17.

If the address is relocatable, the field must be right justified on bit 0 in the word.

```
Examples:  (i)   VFD          C24/237B
                      Assembled as  00000237

                 VFD          C24/237
                      Assembled as  00000355

          (ii)  Suppose NAME is assembled at location 00025 in
                the subprogram, and is a word address.

                 VFD          C24/NAME
                      Assembled as  00000124

                 (Note:  124 is the character address of
                         word address 25)

         (iii)   CADR        EQU,C     237B
                 ØPAD        VFD       Ø7/04,C17/CADR

                   CADR:  is assembled as a 17-bit character address
                          = 000237
                          = Word 47, character position 3
                          = 000473 on the listing.

                   ØPAD:  is assembled as a 24-bit word
                          = 02000237

                          04 is entered right justified in a 7-bit
                          field
                          = 0000100
                          = 000 010 0
                          CADR is the 17-bit character address
                          000237
                          = 00 000 000 010 011 111

          (iv)  Suppose TMPC is assembled as character 0 in
                word 20 in the subprogram
                   JAC      VFD       Ø7/4,C17/TMPC
                   Assembled as 02000100
                   (100 is character address of TMPC)
```

19.6.6 Example of VFD instruction

If NAME is located at address 00011 in the assembled program, what will be assembled as a result of:

```
A      EQU     77777B
X      EQU     57B
B      EQU     20B
       VFD     Ø12/-737,A21/A-X+B,H24/HA3,A15/NAME+2,H12/BQ
```

Answer:

70	40	77	77
74	03	02	10
36	00	00	13
22	50	00	00

INPUT/OUTPUT WITHOUT CIO

20.1 INPUT/OUTPUT CHARACTERISTICS

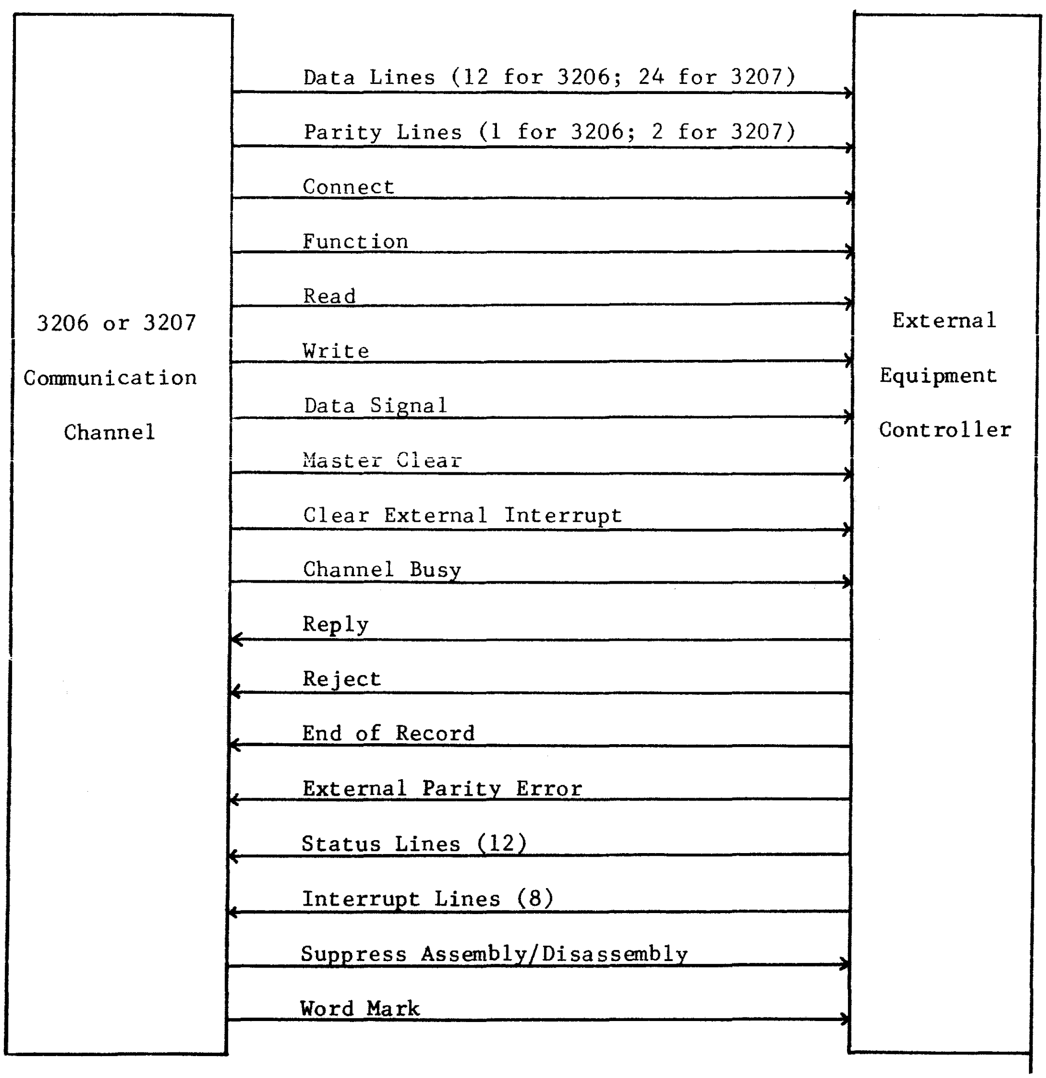
20.1.1 Introduction

The Input/Output section of the computer is responsible for transferring data to and from the computer and to and from an external device. Data is transferred between a 3200 Computer and its associated external equipment via a 3206 or 3207 Communication Channel. For programming purposes, the eight possible 3206 channels in a system are designated by numbers 0 through 7. A 3207 replaces the 3206 type I/O channels 2 and 3 in expanded systems. It is programmed as channel 2.

20.1.2 Interface signals

Up to eight external equipment controllers may be attached in parallel to each 3206 Communication Channel. The following chart shows the principal signals which flow between a 3206 and its external equipment. The 12 status lines are active only between the channel and the controller to which it has been connected by the CON (77.0) instruction*.

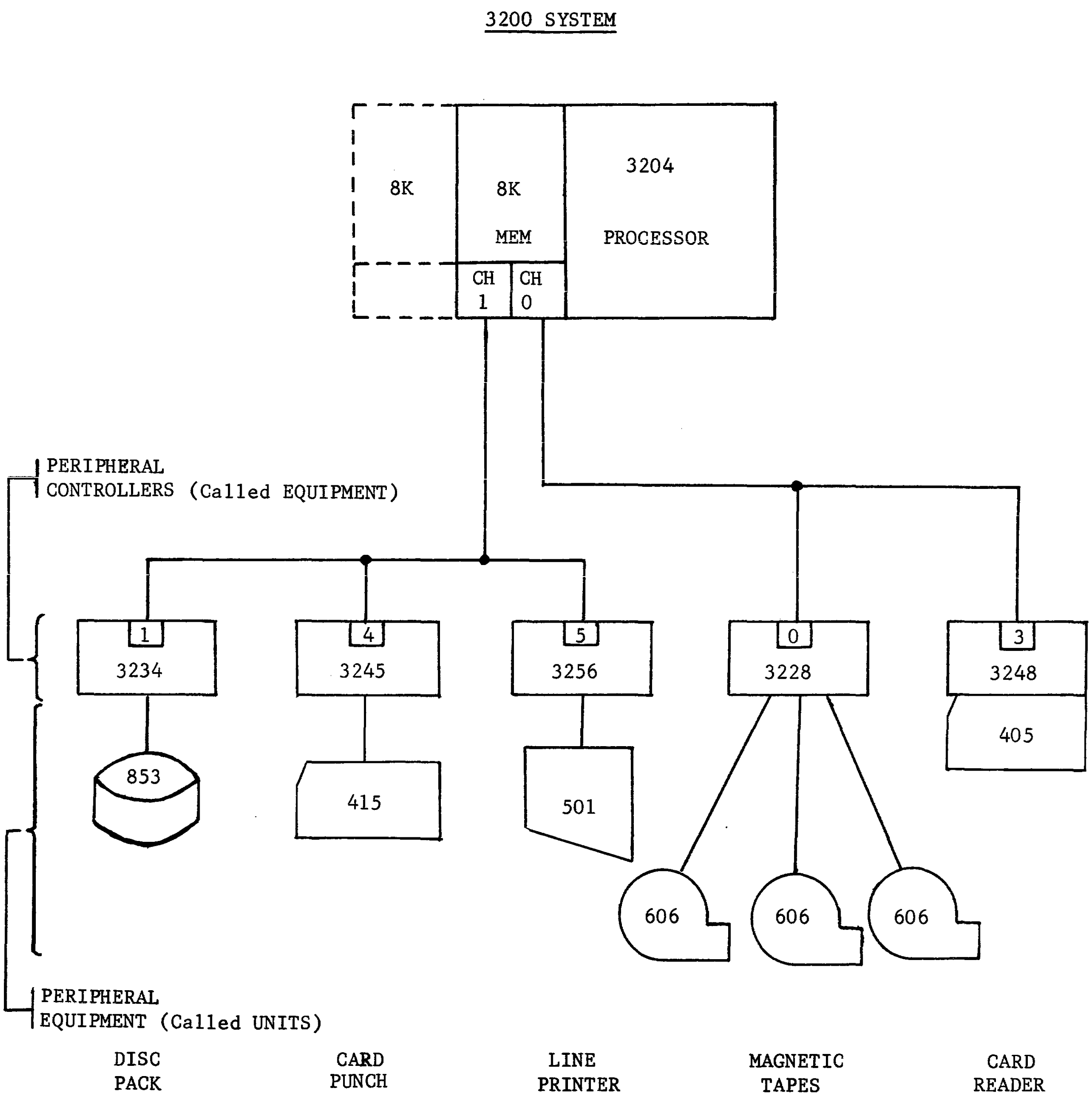
The eight interrupt lines, designated 0-7, connect to all eight controllers attached to a channel. These lines match the Equipment Selector switch setting on each controller. For a complete description of the I/O interface signals as well as an I/O timing chart, refer to the 3000 Series I/O Specification, publication number 60048800.



* The connect instruction selects one of eight controllers which may be attached to the channel.

20.1.3 System configuration

A typical configuration is:



20.1.4 Logical Sequence of Events for Initiating INPUT/OUTPUT Operations

Execute a connect instruction which will indicate the channel, controller and unit which is to receive or transmit the data.

Sense the status of the controller to determine if the unit is available and capable of performing the function and/or data transmission ("PRE-STATUS").

Send the appropriate select functions. Select functions are used to format the INPUT/OUTPUT device.

Execute the data transmission instructions.

At end of operation, sense the status of the controller to determine if the function and/or data transmission was successful ("POST-STATUS" check).

20.2 CONNECT

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	CØN	x,ch

23 — 18	17 — 15	14 — 12	11 — 00
77	0	ch	x

ch = I/O channel designator, 0-7
x = 12 bit connect code. Bits 09-11 select one of eight controllers which may be attached to channel ch. Bits 00-08 select the peripheral units connected to the controller.

Description: This instruction sends a 12-bit connect code along with a connect enable to an external equipment controller on I/O channel 'ch'. If a Reply is received from the controller within 100 usec, the next instruction is read from address P + 2. If a Reject is received or there is no response within 100 usec, a reject instruction is read from address P + 1. If the I/O channel is busy, a reject instruction is read immediately from address P + 1.

Once the connect is successful (RNI at P + 2) it will remain in effect until another connect is attempted on the same channel or a clear function is performed.

Examples:

```
CØN        1001B,2
```

This instruction connects controller number 1 and unit 1 on channel 2.

The reject instruction coded at P + 1 is usually a jump back to the connect to cause the computer to wait until the connect is successful.

```
e.g.  CØN        1001B,2
      UJP        *-1
```

20.2 (cont.)

In the following example, which controllers and units will be connected on channel 1 and 2 when the computer stops. Assume all connects can be made.

```
CØN    2004B,1
UJP    *-1
CØN    3004B,2
UJP    *-1
CØN    5B,1
UJP    *-1
UCS
```

Answers:
Channel 1 = Equip 0, Unit 5
Channel 2 = Equip 3, Unit 4

20.3 SELECT

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	SEL	x,ch

23–18	17–15	14–12	11–00
77	1	ch	x

ch = I/O channel designator, 0-7
x = 12-bit function code. Each piece of external equipment has a unique set of function codes to specify operations within that device. Refer to the 3000 Series Computer Systems Peripheral Equipment Codes publication No. 60113400 for a complete list of function codes.

Description: This instruction sends a 12-bit function code along with a function enable to the unit connected to I/O channel 'ch'. If a Reply is received from the unit within 100 usec, the next instruction is read from P + 2. If a Reject is received or there is no response within 100 usec, a reject instruction is read from address P + 1. If the I/O channel is busy, a reject instruction is read immediately from address P + 1.

The following conditions or combination of conditions will result in a Reject:

1) No Unit or Equipment Connected: The referenced device is not connected to the system and cannot recognize a Function instruction. If no response is received within 100 usec, the Reject signal is generated automatically by the I/O channel.

2) Undefined Code: When the Function code x is not defined for the specific device, a Reject may be generated by the device. However, in some cases an undefined code will cause the device to generate a Reply although no operation is performed. (Refer to the reference manual for the specific device.)

3) Equipment or Unit Busy or Not Ready: The device cannot perform the operation specified by the function code x without damaging the equipment or losing data. For example, a Write End of File code is rejected by a tape unit if the tape unit is rewinding.

4) Channel Busy: The selected data channel is currently performing a Read or Write operation.

20.3 (cont.)

The function codes for magnetic tape and card reader are:

MAGNETIC TAPE CONTROLLERS FUNCTION CODES	
0000	Release
0001	Binary
0002	Coded
0003	556 BPI
0004	200 BPI
0005	Clear
0006	800 BPI
0010	Rewind
0011	Rewind Unload
0012	Backspace
0013	Search Forward to File Mark
0014	Search Backward to File Mark
0015	Write File Mark
0016	Skip Bad Spot
0020	Interrupt on Ready and Busy
0021	Release Interrupt on Ready and Busy
0022	Interrupt on End of Operation
0023	Release Interrupt on End of Operation
0024	Interrupt on Abnormal End of Operation
0025	Release Interrupt on Abnormal End of Operation
0040	Clear Reverse Read
0041	Set Reverse Read

3248 CARD READER CONTROLLER FUNCTION CODES	
0001	Negate Hollerith to Internal BCD Conversion
0002	Release Negate Hollerith to Internal BCD Conversion
0004	Set Gate Card
0005	Clear
0020	Interrupt on Ready and Busy
0021	Release Interrupt on Ready and Busy
0022	Interrupt on End of Operation
0023	Release Interrupt on End of Operation
0024	Interrupt on Abnormal End of Operation
0025	Release Interrupt on Abnormal End of Operation

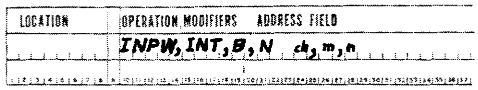
Example:

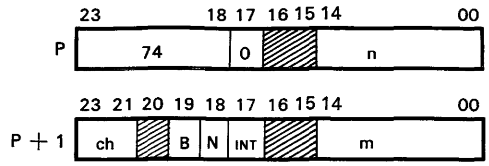
```
CØN    2B,1     Connects Controller 0 Unit 2 on channel 1
UJP    REJX
SEL    10B,1    Rewinds Tape Unit 2 to Load Point
UJP    REJX
SEL    3B,1     Sets the Density to 556 bpi
UJP    REJX
SEL    1B,1     Sets the Mode to binary
UJP    REJX
 .
 .
 .
UCS
```

Exercise: What does the following group of select function codes for Tape Unit 6 accomplish?

```
CØN    6B,0
UJP    REJX
SEL    6B,0     ______________________________
UJP    REJX
SEL    13B,0    ______________________________
UJP    REJX
 .
 .
 .
UCS
```

20.4 WORD ADDRESSED INPUT TO STORAGE





B = "1" for backward storage
ch = I/O channel designator, 0-7
INT = "1" for interrupt upon completion
N = "0" for 12- to 24-bit assembly
= "1" for no assembly
m = first word address of I/O data block; becomes current address as I/O operation progresses
n = last word address of input data block, plus one (minus one, for backward storage)

Description: This instruction transfers a word-addressed data block from an external equipment to storage. Transferring 12-bit bytes or 24-bit words depends upon the type of I/O channel used. The 3206 utilizes 12-bit bytes and the 3207 uses 24-bit words.

During forward storage and 12- to 24-bit assembly, the first byte of a block of data is stored in the upper half of the memory location specified by the storage address. Conversely, during backward storage, the first byte is stored in the lower half of the memory location.

This instruction is an initiate type instruction, which means all the foregoing actions will occur only if the instruction executes normally. And RNI will be at P + 3. However, if the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Examples: (i)

```
CØN     1001B,1
RTJ     REJX
SEL     2B,1
RTJ     REJX
SEL     3B,1
RTJ     REJX
INPW    1,INBUFF,INBUFF+50
RTJ     REJX
```

This example initiates an Input from tape unit 1, controller 1 on channel 1. The tape is written in BCD mode at 556 bpi.

(ii) A block of memory is as shown:

INBUFF	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777

And the contents of a data card is:

ABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABC

What will be the contents of memory as a result of the following coding examples?

(1)
```
CØN        3000B,0
UJP        REJX
INPW       0,INBUFF,INBUFF+20
UJP        REJX
```

(2)
```
CØN        3000B,0
UJP        REJX
INPW,B     0,INBUFF+19,INBUFF-1
UJP        REJX
```

(3)
```
CØN        3000B,0
UJP        REJX
INPW,N     0,INBUFF,INBUFF+40
UJP        REJX
```

(4)
```
CØN        3000B,0
UJP        REJX
INPW,B,N   0,INBUFF+39,INBUFF-1
UJP        REJX
```

20.4 (cont.2)

Answers:

(1)

```
INBUFF   21222324
         25262730
         31414121
         22232425
         26273031
         41422122
         23242526
         27303141
         42212223
         24252627
         30314142
         21222324
         25262730
         31414221
         22232425
         26273031
         41422122
         23242526
         27303141
         42212223
```

(2)

```
INBUFF   22334221
         31412730
         25262324
         21224142
         30312627
         24252223
         42213141
         27302526
         23242122
         41423031
         26272425
         22234221
         31412730
         25262324
         21224142
         30312627
         24252223
         42213141
         27302526
         23242122
```

(3)

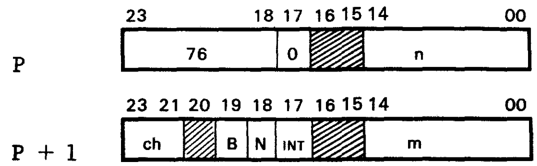
```
INBUFF   77772122
         77772324
         77772526
         77772730
         77773141
         77774221
         77772223
         77772425
         77772627
         77773031
         77774142
         77772122
         77772324
         77772526
         77772730
         77773141
         77774221
         77772223
         77772425
         77772627
         77773031
         77774142
         77772122
         77772324
         77772526
         77772730
         77773141
         77774221
         77772223
         77772425
         77772627
         77773031
         77774342
         77772122
         77772324
         77772526
         77772730
         77773141
         77774221
         77772223
```

(4)

```
INBUFF   77772223
         77774221
         77773741
         77772730
         77772526
         77772324
         77772122
         77774142
         77773031
         77772627
         77772425
         77772223
         77774221
         77773141
         77772730
         77772526
         77772324
         77772122
         77774142
         77773031
         77772627
         77772425
         77772223
         77774221
         77773141
         77772730
         77772526
         77772324
         77772122
         77774142
         77773031
         77772627
         77772425
         77772223
         77774221
         77773141
         77772730
         77772526
         77772324
         77772122
```

20.5 WORD ADDRESSED OUTPUT FROM STORAGE

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ØUTW,INT,B,N	ch,m,n



B = "1" for backward storage
ch = I/O channel designator
INT = "1" for interrupt upon completion
N = "0" for 24- to 12 bit disassembly
= "1" for straight 24-bit (no disassembly) data transfer
m = first word address of I/O data block; ecomes current address as I/O operation progresses
n = last word address of output data block, plus one (minus one, for backward output)

Description: This instruction transfers a word-addressed block of data consisting of 12-bit bytes or 24-bit words, from storage to an external equipment.

With no disassembly, 12 or 24-bit transfer capability depends upon whether a 3206 or 3207 I/O channel is used. If an attempt is made to send a 24-bit word over a 3206 I/O channel, the upper byte will be lost.

This instruction is an initiate type instruction, which means all the foregoing actions will occur only if the instruction executes normally. And RNI will be at P + 3. However, if the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Examples: A block of memory is as shown:

	Numerical Value	Alphabetical Representation
ØUTBUFF	21222324	A B C D
	25262730	E F G H
	31414221	I J K A
	22232425	B C D E
	26273031	F G H I
	41422122	J K A B
	23242526	C D E F
	27303141	G H I J
	42212223	K A B C
	24252627	D E F G
	30314142	H I J K
	21222324	A B C D
	25262730	E F G H
	31414221	I J K A
	22232425	B C D E
	26273031	F G H I
	41422122	J K A B
	[illegible]3242526	C D E F
	27303141	G H I J
	42212223	K A B C

20.5 (cont.)

What will be printed on the line printer as a result of the following coding examples?

```
(1)    CØN        5000B,1
       UJP        REJX
       ØUTW       1,ØUTBUFF,ØUTBUFF+20
       UJP        REJX


(2)    CØN        5000B,1
       UJP        REJX
       ØUTW,B     1,ØUTBUFF+19,ØUTBUFF-1
       UJP        REJX


(3)    CØN        5000B,1
       UJP        REJX
       ØUTW,N     1,ØUTBUFF,ØUTBUFF+20
       UJP        REJX


(4)    CØN        5000B,1
       UJP        REJX
       ØUTW,B,N   1,ØUTBUFF+19,ØUTBUFF-1
       UJP        REJX
```

Answers:

(1)

ABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABC

(2)

BCKAIJGHEFCDABJKHIFGDEBCKAIJGHEFCDABJKHIFGDEBCKAIJGHEFCDABJKHIFGDEBCKAIJGHEFCDAB

(3)

CDGHKADEHIABEFIJACFGJKCDGHKADEHIABEFIJBC

(4)

BCIJEFABHIDEKAGHCDJKFGBCIJEFABHIDEKAGHCD

20.6 CHARACTER ADDRESSED INPUT TO STORAGE

INPC,INT,B,H ch,r,s

P

23–18	17	16–00
73	0	s

P + 1

23–21	20	19	18	17	16–00
ch		B	H	INT	r

B = "1" for backward storage
ch = I/O channel designator, 0-3
H = "0" for 6- to 24-bit assembly
  = "1" for 12- to 24-bit assembly
INT = "1" for interrupt upon completion
r = first character address of I/O data block; becomes current address as I/O operation progresses
s = last character address of input data block, plus one (minus one, for backward storage)

Description: This instruction transfers a character-address block of data, consisting of 6-bit characters or 12-bit bytes, from an external equipment to storage. During 12- to 24-bit assembly, the lowest bit of each character address is forced to remain a "0" in register OX. This ensures that assembled bytes are in either the upper or the lower half of the word being stored.

This instruction is an initiate type instruction, which means all the foregoing actions will occur only if the instruction executes normally. And RNI will be at P + 3. However, if the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Examples: A block of memory is as shown:

INBUFF	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777
	77777777

And the contents of a data card is:

ABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABC

20.6 (cont.)

What will be the contents of memory as a result of the following coding examples?

(1)

```
CØN      3000B,0
UJP      REJX
INPC     0,INBUFF,INBUFF+80
UJP      REJX
```

(2)

```
CØN      3000B,0
UJP      REJX
INPC,B   0,INBUFF+79,INBUFF-1
UJP      REJX
```

(3)

```
CØN      3000B,0
UJP      REJX
INPC,H   0,INBUFF,INBUFF+80
UJP      REJX
```

(4)

```
CØN      3000B,0
UJP      REJX
INPC,B,H 0,INBUFF+79,INBUFF-1
UJP      REJX
```

Answers:

(1)	(2)
21222324	23222142
25262730	41313027
31414221	26252423
22232425	22214241
26273031	31302726
41422122	25242322
23242526	21424131
27303141	30272625
42212223	24232221
24252627	42413130
30314142	27262524
21222324	23222142
25262730	41313027
31414221	26252423
22232425	22214241
26273031	31302726
41422122	25242322
23242526	21424131
27303141	30272625
42212223	24232221

(3) Same as #1

(4) Same as #2

20.7 CHARACTER ADDRESSED OUTPUT FROM STORAGE

```
ØUTC,INT,B,H   ch,r,s
```

P

23–18	17	16–00
75	0	s

P + 1

23–21	20	19	18	17	16–00
ch		B	H	INT	r

B = "1" for backward storage
ch = I/O channel designator, 0-3
H = "0" for 24- to 6-bit disassembly
= "1" for 24- to 12-bit disassembly
INT = "1" for interrupt upon completion
r = first character address of I/O data block; becomes current address as I/O operation progresses
s = last character address of output data block, plus one (minus one, for backward output)

Description: This instruction transfers a character-addressed block of data, consisting of 6-bit characters or 12-bit bytes, from storage to an external equipment.

This instruction is an initiate type instruction, which means all the foregoing actions will occur only if the instruction executes normally. And RNI will be at P + 3. However, if the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Examples: A block of memory is as shown:

	Numerical Value	Alphabetical Representation
ØUTBUFF	21222324	A B C D
	25262730	E F G H
	31414221	I J K A
	22232425	B C D E
	26273031	F G H I
	41422122	J K A B
	23242526	C D E F
	27303141	G H I J
	42212223	K A B C
	24252627	D E F G
	30314142	H I J K
	21222324	A B C D
	25262730	E F G H
	31414221	I J K A
	22232425	B C D E
	26273031	F G H I
	41422122	J K A B
	23242526	C D E F
	27303141	G H I J
	42212223	K A B C

20.7 (cont.)

What will be printed on the line printer as a result of the following coding examples?

```
(1)     CØN         5000B,1
        UJP         REJX
        ØUTC        1,ØUTBUFF,ØUTBUFF+80
        UJP         REJX

(2)     CØN         5000B,1
        UJP         REJX
        ØUTC,B      1,ØUTBUFF+79,ØUTBUFF-1
        UJP         REJX

(3)     CØN         5000B,1
        UJP         REJX
        ØUTC,H      1,ØUTBUFF,ØUTBUFF+80
        UJP         REJX

(4)     CØN         5000B,1
        UJP         REJX
        ØUTC,B,H    1,ØUTBUFF+79,ØUTBUFF-1
        UJP         REJX
```

Answers:

(1)

ABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABCDEFGHIJKABC

(2)

CBAKJIHGFEDCBAKIJHGFEDCBAKJIHGFEDCBAKJIHGFEDCBAKJIHGFEDCBAKJIHGFEDCBAKJIHGFEDCBA

(3)

Sames as Number 1

(4)

Same as Number 2

20.8 INPUT/OUTPUT TO AND FROM THE A REGISTER

20.8.1 Input Character to A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INAC,INT	ch

	23–18	17	16–00
P	73	1	

	23–21	20–18	17	16–00
P + 1	ch	0	INT	

Bits 00-16 at P and P+1 should be loaded with 0's

ch = I/O channel designator, 0-7
INT = "1" for interrupt upon completion
"0" for do not interrupt upon completion

Description: This instruction transfers a 6-bit character from an external equipment into the lower 6-bits of the A register. A is cleared prior to loading and the upper 18-bits remain cleared.

Main control is stalled until the character is received from the external equipment. At that time it resumes reading instructions and RNI's from P + 3. If the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Example:

```
CØN     3000B,1
UJP     *-1
INAC    1
UJP     *-2
```

This example inputs 6-bits from controller 3, unit 0 on channel 1 into the lower 6-bits of the A register. A is cleared prior to loading and the upper 18-bits remain cleared.

20.8.2 Input Word to A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INAW, INT	ch

	23–18	17	16–00
P	74	1	

	23–21	20–18	17	16–00
P + 1	ch	0	INT	

Bits 00-16 at P and P+1 should be loaded with 0's

ch = I/O channel designator, 0-7
INT = "1" for interrupt upon completion
"0" for do not interrupt upon completion

Description: This instruction transfers a 12-bit byte into the lower 12-bits of A or a 24-bit word into all of A from an external equipment. Transferring 12 or 24 bits depends upon whether a 3206 or 3207 I/O channel is used. (A) is cleared prior to loading and, in the case of a 12-bit input, the upper 12 bits remain cleared.

20.8.2 (cont.)

Main control is stalled until the byte (word) is received from the external equipment. At that time it resumes reading instructions and RNI's from P + 3. If the input/output control for the specified channel in Block Control is busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Note: Bits 18, 19 and 20 are all zeros when a 3206 data channel is used. If the operation with A involves the use of a 3207, these bits take on the following significance:

Bit 20 = always a "0"
Bit 19 = If bit 18 = "1", the state of bit 19 is of no consequence.
If bit 18 = "0", a "1" in bit 19 signifies backward operation. A "0" in bit 19 signifies a forward operation.

Examples: If the connect code for the card reader is 3000B and a data card has ABCD in the first four columns, what will be the contents of the A register as a result of the following coding examples? Assume a 3206 data channel.

```
CØN     3000B,0
UJP     REJX
INAW    0
UJP     REJX
```

Answer: (A) = 00002122 Also, this is all the information that is available from that card. Another input to A would cause the next card to be read.

20.8.3 Output Character from A

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	ØTAC,INT	ch

P

23–18	17	16–00
75	1	

P + 1

23–21	20–18	17	16–00
ch	0	INT	

Bits 00-16 at P and P+1 should be loaded with 0's

ch = I/O channel designator, 0-7
INT = "1" for interrupt upon completion
"0" for do not interrupt upon completion

Description: This instruction transfers a character from the lower 6-bits of A to an external equipment. The original contents of A are retained.

After outputting the character, main control proceeds immediately and RNI's at P + 3. Should the input/output control for the specified channel in Block Control be busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Example: If the connect code for the external device is 3002B, it is connected to channel 4, and it requires a data output of 21B to perform a certain task, what coding is necessary to perform the task.

```
Ans:  CØN      3002B,4
      UJP      *-1
      ENA      21B
      ØTAC     4
      UJP      *-2
```

The data sent to the external device is 0021B accompanied by a suppress assembly/disassembly control signal. This latter informs the device to ignore the upper 6 bits and recognize the 21B only.

20.8.4 Output Word from A

```
ØTAW,INT ch
```

P

23–18	17	16–00
76	1	

P + 1

23–21	20–18	17	16–00
ch	0	INT	

Bits 00-16 at P and P+1 should be loaded with 0's

ch = I/O channel designator, 0-7
INT = "1" for interrupt upon completion
"0" for do not interrupt upon completion

Description: This instruction transfers a 12-bit byte from the lower 12 bits of A (or all 24-bits of A) to an external equipment depending upon the type of I/O channel (3206 or 3207) that is used. The contents of A is not disturbed and is retained.

After outputting the information, main control proceeds immediately and RNI's at P + 3. Should the input/output control for the specified channel in Block Control be busy, the instruction will act as a double NOP and RNI from P + 2. The instruction at that location is termed the 'Reject Instruction'.

Note: Bits 18, 19 and 20 are all zeros when a 3206 data channel is used. If the operation with A involves the use of a 3207, these bits take on the following significance:

Bit 20 = always a "0"
Bit 19 = If bit 18 = "1", the state of bit 19 is of no consequence.
If bit 18 = "0", a "1" in bit 19 signifies backward operation. A "0" in bit 19 signifies a forward operation.

Example: Assuming a remote typewriter connected to a data channel (not to be confused with the console typewriter) has a connect code of 5000B and is connected to channel 2, what code is necessary to cause that typewriter to perform a carriage return tab sequence of operations? The code for a carriage return is 77B and for the tab is 75B.

20.8.4 (cont.)

```
Answer:  CØN     5000B,2
         UJP     *-1
         ENA     7775B
         ØTAW    2
         UJP     *-2
```

The data transmitted to the typewriter is 7775B.

20.9 SENSING INSTRUCTIONS

20.9.1 Sense External Status

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	EXS	x,ch

23 — 18	17 — 15	14 — 12	11 — 00
77	2	ch	x

ch = I/O channel designator, 0-7
x = external status sensing mask code

Description: When a peripheral equipment controller is connected to an I/O channel by the CØN (77.0) instruction, the EXS instruction can sense conditions within that controller. Twelve status lines run between each controller and its I/O channel. Each line may monitor one condition within the controller, and each controller has a unique set of line definitions. To sense a specific condition, a "1" is placed in the bit position of the status sensing mask that corresponds to the line number. When this instruction is recognized in a program, RNI at address P + 1 if an external status line is active when its corresponding mask bits are "1". RNI at address P + 2 if no selected line is active.

Status Codes: Following are the status response codes for magnetic tape and card reader:

	MAGNETIC TAPE STATUS CODES
XXX1	Ready
XXX2	Channel and/or Read/Write Control and/or Unit Busy
XXX4	Write Enabled
XX1X	File Mark Read
XX2X	At Loadpoint
XX4X	End-of-Tape Read
X1XX	Density 2^0 bit**
X2XX	2^1 bit**
	** 00 = 200 bpi 01 = 556 bpi 10 = 800 bpi 11 = undefined
X4XX	Lost Data
1XXX	End of Operation
2XXX	Vertical or Longitudinal Parity Error
4XXX	Reserved by another control (multiple channel controllers only)

	3248 CARD READER STATUS CODES
XXX1	Ready
XXX2	Busy
XXX4	Binary Card
XX1X	File Card Read
XX2X	Fail to Feed, Stacker Full or Jam
XX4X	Input Tray Empty
X1XX	Input Tray Empty and End of File Switch On
X2XX	Ready and not Busy Interrupt Present
X4XX	End of Operation Interrupt Present
1XXX	Abnormal End of Operation Interrupt Present
2XXX	Read Compare, Preread Error or Illegal Suppress Assembly

20.9.1 (cont.)

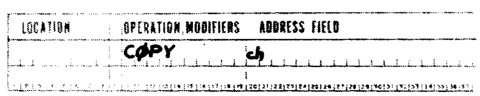
Comments: Refer to the 3000 Series Computer Systems Peripheral Equipment Codes manual, publication no. 60113400 for a complete list of status response codes.

Example: The example below accomplishes the following:

a) Connects the card reader on channel 0.
b) Checks the status of the card reader. If busy it waits until it becomes not busy.
c) Initiates reading of a card at the card reader and transfer of the data read to memory.
d) Waits until the INPUT is complete.

```
CØN     3000B,0                CONNECT CARD READER
UJP     *-1
EXS     2B,0                   SENSE BUSY
UJP     *-1                    LOOP IF BUSY'
INPW    0,INBUFF,INBUFF+20     INITIATE INPUT
UJP     *-2
EXS     2B,0                   SENSE BUSY
UJP     *-1                    LOOP UNTIL DONE
 .
 .
 .
UCS
```

20.9.2 Copy External Status and Interrupt Mask Register



23–18	17–15	14–12	11–00
77	2	ch	0000

ch = I/O channel designator, 0-7

Description: This instruction performs the following functions:

(1) The external status code from I/O channel ch is loaded into the lower 12 bits of A. See EXS instruction.

(2) The contents of the Interrupt Mask register are loaded into the upper 12 bits of A.

(3) RNI from address P + 1.

Examples: If the INTERRUPT MASK REGISTER is 0032_8, and the external status on channel 1 = 1004_8, what will be in A after execution of the following instruction?

```
CØPY    1
```

Answer:

(a) A is cleared.

(b) Contents of INTERRUPT MASK REGISTER put in upper 12 bits of A.

(c) External status on channel 1 put in lower 12 bits of A.

(A) = 00321004

20.9.3 Sense Interrupt

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	INTS	x,ch

23–18	17–15	14–12	11–00
77	4	ch	x

ch = I/O channel designator, 0-7
x = Interrupt sensing mask code

Description: Sense for the interrupt conditions listed in the following table. RNI from P + 1 if an interrupt line is active corresponding to any "1" bit in the mask. If none of the selected lines are active, RNI from P + 2. Internal interrupts are cleared as soon as they are sensed. External interrupts are cleared by connecting the unit and executing one of the SEL functions controlling peripheral interrupts.

INTERRUPT SENSING MASK BIT ASSIGNMENTS

Mask Bit Position	Mask Code x	Interrupt Condition Represented	
00	0001	I/O Equip # 0 on designated channel	External Interrupts
01	0002	1	
02	0004	2	
03	0010	3	
04	0020	4	
05	0040	5	
06	0100	6	
07	0200	7	
08	0400	Real-time Clock	Internal Interrupts
09	1000	Exponent Overflow/Underflow (flt pt) and BCD Fault	
10	2000	Arithmetic Overflow and Divide Fault (integer)	
11	4000	Search/Move Completion	

Examples: i) If there is an interrupt line active on channel 2, which instruction will be executed after executing the INTS instruction in the following section of code?

```
INTS    4B,2
UJP     INTADD
UJP     NØINT
```

Answer: UJP INTADD if equip. nr. 4 generated the interrupt, else UJP NØINT

ii) The contents of the A register = 37777777 and the instruction executed is:

```
INA     1
```

An arithmetic overflow is generated. What code is necessary to sense this fact?

Answer: INTS 2000B

```
UJP     overflow-routine                      (P+1)
normal non-overflow next instruction          (P+2)
```

Note: The "ch" designator is required only when sensing external interrupts originating on a channel.

20.9.4 Sense Internal Status

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	INS	x,ch

23–18	17–15	14–12	11–00
77	3	ch	x

ch = I/O channel designator, 0-7
x = Internal Status Sensing Mask Code

Description: Sense for the internal conditions listed in the following table. RNI from P + 1 if an internal condition is present corresponding to any "1" bit in the mask. If none of the selected conditions are present, RNI from P + 2. Internal conditions are cleared as soon as they are sensed, except when they are related to channel "ch".

INTERNAL STATUS SENSING MASK BIT ASSIGNMENTS

Mask Bit Position	Mask Code x	Internal Condition Present	
00	0001	Parity Error	Channel Control
01	0002	Read Active	Channel Control
02	0004	Write Active	Channel Control
03	0010	External (controller) Reject	Channel Control
04	0020	Internal (no response) Reject	Channel Control
05	0040	Illegal Write	Main Control
06	0100	CØN or CØN and SEL executed and channel currently not busy	Channel Control
07	0200	Block Control Interrupt waiting Write: Buffer complete Read: Buffer complete or End of Record at peripheral	Channel Control
08	0400	Exponent Overflow/Underflow fault (flt pt option)	Main Control
09	1000	Arithmetic Overflow fault (main arithmetic section)	Main Control
10	2000	Divide fault (main arithmetic or flt pt opt)	Main Control
11	4000	BCD fault (BCD option)	Main Control

Example: The following coding example sums a table of 50 numbers. It detects and corrects for arithmetic overflow using the INS instruction.

```
        ENI     49,1        SET LØØP INDEX TØ MAX NR - 1
        ENA     0           CLEAR THE ACCUMULATØR
LØØP    ADA     TABLE,1     ADD NEXT ENTRY ØF TABLE TØ THE
*                            ACCUMULATØR
        INS     1000B,0     WAS THERE ARITHMETIC ØVERFLØW
        UJP     ØV          YES, JUMP TØ CØRRECT AT LØCATIØN
*                                ØV
        IJD     LØØP,1      AFTER LAST TIME THRØUGH LØØP -
*                            NØ DECREASE B1 BY 1 ØR JUMP
*                            TØ LØØP
FINIS   SHAQ    -24         CØNVERT 24 BIT SUM TØ 48 BITS
        ADAQ    SUM48       ADD CØNVERTED SUM TØ 48 BIT
*                            ACCUMULATØR
        UJP     EXIT
ØV      SHAQ    -24         CØRRECT FØR ARITHMETIC ØVERFLØW
        XØA,S   -0          BY CØMPLEMENTING THE SIGN
        ADAQ    SUM48       ADD CØNVERTED SUM TØ 48 BIT
*                            ACCUMULATØR
        STAQ    SUM48
        ENA     0           CLEAR 24 BIT ACCUMULATØR
        IJD     LØØP,1      DECREASE B1 AND JUMP TØ LØØP
        UJP     FINIS
SUM48   DECD    0
TABLE   BSS     50
```

20.9.4 (cont.)

Exercise: Assuming that data channel 5 is busy at the moment, determine if the operation in progress is a Read or a Write. Write the coding required to do this check.

20.9.5 Copy Internal Status and Interrupt Mask Register

LOCATION	OPERATION, MODIFIERS	ADDRESS FIELD
	CINS	ch

23–18	17–15	14–12	11–00
77	3	ch	0000

ch = I/O channel designator, 0-7

Description: The CINS instruction performs the following functions:

1) The internal status information (see table in Section 20.9.4) is loaded into the lower 12 bit positions of the A register.

2) The contents of the Interrupt Mask register are loaded into the upper 12 bit positions of the A register.

3) RNI from P + 1

Example: If the Interrupt Mask register contains 0121_8 and the internal status is 0111_8, what will be in the A register after execution of the following instruction?

```
CINS    1
```

Answer: a) The A register is cleared

b) The contents of the Interrupt Mask Register is copied in the upper 12 bits of A.

c) The current internal status is copied in the lower 12 bits of A.

$(A) = 01210111_8$

Exercises: i) If the Interrupt Mask register contains 7400_8 and a parity error has occurred on the channel for data channel 6 (called a "transmission parity error"), what will be in A after the execution of:

```
CINS    6
```

ii) If the Interrupt Mask register contains 0403_8 and the reject instruction following a SEL was executed, what coding would be necessary to determine the cause of the reject. (Remember there are three sources of SEL rejects 1) channel busy, 2) function illegal, and 3) function not recognized)

20.9.6 Comments on Internal Status and the Interrupt Mask Register

At first glance, it appears that the INTS and INS instructions perform essentially the same function with relation to internal conditions. However, there is one important difference and that is the INTS instruction needs both the condition and the interrupt mask bit set to get a match. The INS instruction senses the internal condition without the necessity of having the interrupt mask register bit set.

20.10 CONSOLE TYPEWRITER INPUT/OUTPUT

20.10.1 General Description

The 3192 Console Typewriter is an on-line input-output (I/O) device; i.e., it requires no connection to a communication channel and no function codes are issued. The typewriter receives output data directly from storage via the lower 6 bits of the Data Bus. Inputs to storage are handled in the same manner.

The console typewriter consists of an electric typewriter and a typewriter control panel mounted on a desk console.

Used in conjunction with block control and the Register File, the typewriter may be used to enter a block of internal binary-coded characters into storage and to print out data from storage. The two storage addresses that define the limits of the block must be stored in the register file prior to an input or output operation. Register 23* contains the initial character address of the block, and register 33 contains the last character address, plus one. Because the initial character address is incremented for each storage reference, it always shows the address of the character currently being stored or dumped. Output operations occur at the rate of 15 characters per second. Input operations are limited by the operator's typing speed.

*The upper seven bits of registers 23 and 33 should be "0".

20.10.2 Operation

The general order of events when using the console typewriter for an input or output operation is:

1) Set tabs, margins and spacing. Turn on typewriter.

2) Clear

3) Check status

4) Type out or type in

20.10.2.1 Set tabs, margins, and spacing

All tabs, margins, and paper spacing must be set manually prior to the input or output operation. A tab may be set for each space on the typewriter between margins.

20.10.2.2 Clear

There are three types of clears which may be used to clear all conditions (except ENCODE FUNCTION) existing in the typewriter control. These are:

1) Internal Clear or a Master Clear

   This signal clears all external equipment, the communications channels, the typewriter control, and sets the typewriter to lower case.

2) Clear Channel, Search/Move Control, or Type Control instruction (77.51).

   This instruction selectively clears a channel, the S/M control, or, by placing a "1" in bit 08 of the instruction, the typewriter control, and sets the typewriter to lower case.

3) Clear Switch on typewriter.

   This switch clears the typewriter control and sets the typewriter to lower case.

20.10.2.3 Status Checking

The programmer may wish to check the status of the typewriter before proceeding. This is done with the Pause instruction. Status response is returned to the computer via two status lines.

The typewriter control transmits two status signals that are checked by the Busy Comparison Mask using the Pause instruction. These status signals are:

Bit 09 Type Not Finish
Bit 10 Type Not Repeat

An additional status bit appears on sense line 08. This code is Type Busy, and is transmitted by block control in the computation section when a typewriter operation has been selected. If the programmer is certain of the status of the typewriter, this operation may be omitted.

20.10.2.4 Type In and Type Load

The Set Type In instruction or pressing the TYPE LOAD switch on the console or typewriter permits the operator to enter data directly into storage from the typewriter. When the TYPE LOAD indicator on the console or typewriter glows, the operator may begin typing. The Encode function switch must be depressed to enable backspace, tab, carriage return, and case shifts to be transmitted to the computer during a typewriter input operation.

Input is in character mode only. As each character is typed, the information is transmitted via the Data Bus to the storage address specified by block control. This address is incremented as characters are transmitted. When the current address equals the terminating address, the TYPE LOAD indicator goes off and the operation is terminated. Data is lost if the operator continues typing after the TYPE LOAD indicator goes off.

20.10.2.5 Type Out and Type Dump

The typewriter begins to type out when the computation section senses a Set Type Out instruction or the operator presses the TYPE DUMP switch on the console or typewriter. Single 6-bit characters are sent from storage to the typewriter via the lower 6 bits of the Data Bus. When the current address equals the terminating address, the TYPE DUMP indicator goes off and the operation is terminated.

During a Type Out operation, the keyboard is locked to prevent loss of data in the event a key is accidentally pressed.

20.10.3 Typewriter Console Switches and Indicators

The following table shows the function of each switch and indicator for the console typewriter.

Name	Switch (S) Indicator (I)	Description
HIGH TEMP	I	This indicator glows when the ambient temperature within the typewriter cabinet exceeds 110°F.
BUSY	I	This indicator shows that the TYPE LOAD or TYPE DUMP switch has been pressed and the operation is in progress.
POWER ON	I	This indicator shows that power is applied to the typewriter.
TYPE DUMP	S & I	This switch is in parallel with the TYPE DUMP switch on the main console and causes the computer to send data to the typewriter for print-out. It is a momentary contact switch that is illuminated until the last character in the block has been print printed or the CLEAR button is pressed.
TYPE LOAD	S & I	This switch is in parallel with the TYPE LOAD switch on the main console and allows the computer to receive a block of input data from the typewriter. The TYPE LOAD indicator remains on until either the FINISH, REPEAT or CLEAR button is pressed, or until the last character of the block has been stored. If the program immediately reactivates the typewriter, it may appear that the light does not go off.
REPEAT	S & I	This switch is pressed during a Type Load operation to indicate that a typing error occurred. This switch deactivates busy sense line 10 (see PAUS instruction). If the computer does not respond, this light remains on.
FINISH	S & I	This switch is pressed during a Type Load operation to indicate that there is no more data in the current block. This action is necessary if the block that the operator has entered is smaller than the block defined by registers 23 and 33. This switch also deactivates busy sense line 09. If the computer does not respond, this light remains on.
INTERRUPT	S & I	This switch is in parallel with the MANUAL INTERRUPT switch on the console and is used to manually interrupt the computer program.
ENCODE FUNCTION	S & I	This switch enables the typewriter to send to storage the special function codes for backspace, tab, carriage return, upper-case shift, and lower-case shift.
CLEAR	S & I	This switch clears the typewriter controls and sets the typewriter to lower case but does not cancel Encode Function.

20.10.4 Character Codes

The following table lists the internal BCD codes, typewriter print-out and upper- or lower-case shift that applies to the console typewriter. All character transmission between the computation section and the typewriter is in the form of internal BCD. The typewriter logic makes the necessary conversion to the machine code.

Note: Shifting to upper case (57) or lower case (32) is not necessary except on keyboard letters where both upper and lower case is available. The standard type set for the 3192 has two sets of upper case letters and no lower case letters. This eliminates the need for specifying a case shift.

Those characters that are strictly an upper or lower case character are not affected by the case currently selected. Case selection only affects those characters that may be printed in either upper or lower case.

CONSOLE TYPEWRITER CODES

Print-out	Case	Internal BCD Code	Print-out	Case	Internal BCD Code
0	L	00	-	L	40
1	L	01	J	U or L	41
2	L	02	K	U or L	42
3	L	03	L	U or L	43
4	L	04	M	U or L	44
5	L	05	N	U or L	45
6	L	06	O	U or L	46
7	L	07	P	U or L	47
8	L	10	Q	U or L	50
9	L	11	R	U or L	51
±	U	12	° (degree)	U	52
=	L	13	$	U	53
"	U	14	*	U	54
:	U	15	#	U	55
;	L	16	%	U	56
?	U	17	(Shift to UC)		57
+	U	20	(Space)		60
A	U or L	21	/	L	61
B	U or L	22	S	U or L	62
C	U or L	23	T	U or L	63
D	U or L	24	U	U or L	64
E	U or L	25	V	U or L	65
F	U or L	26	W	U or L	66
G	U or L	27	X	U or L	67
H	U or L	30	Y	U or L	70
I	U or L	31	Z	U or L	71
(Shift to LC)		32	&	U	72
.	U or L	33	,	U or L	73
)	U	34	(	U	74
'	L	35	(Tab)		75
@	U	36	(Backspace)		76
!	L	37	(Carriage Return)		77

20.10.5 Input/Output Instructions

20.10.5.1 Set Console Typewriter Input

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	CTI	

23 18	17 12	11 00
77	75	

Bits 00 - 11 should be loaded with zeros

Description: This instruction, like the TYPE LOAD switch, permits a block of data to be entered into storage as soon as the Type Load indicator lights. If a block of data smaller than the one defined by registers 23 and 33 is to be typed, the FINISH switch should be depressed when the typing is completed. If more data is entered than the defined block can hold, the excess data is lost. If a typing error occurs, the REPEAT button should be depressed, the typewriter input operation is terminated and the appropriate status bits (09 and 10) may be sensed with the PAUS instruction.

Example: The below example illustrates initiating a typewriter INPUT. The INPUT data is to be stored in address INBUFF through INBUFF + 12.

```
         ECHA     INBUFF
         TAM      23B        SET R.F. LØCA 23 TØ FCA
         INA      13
         TAM      33B        SET R.F. LØCA 33 TØ LCA+1
         CTI                 INITIATE TYPEWRITER INPUT
          .
          .
          .
         UCS
INBUFF   BSS,C    13
```

20.10.5.2 Set Console Typewriter Output

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	CTØ	

23 18	17 12	11 00
77	76	

Bits 00 - 11 should be loaded with zeros

Description: This instruction, like the TYPE DUMP switch, causes the typewriter to print out the block of data defined by the character addresses in registers 23 and 33.

Note: The CTI and CTO instructions are mutually exclusive. Any attempt to execute one while the other is being executed will be ignored by the computer. Typewriter busy should be checked before these instructions are used and before registers 23 and 33 are altered.

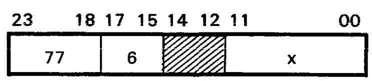
20.10.5.2 (cont.)

Example: The following example illustrates initiating a typewriter OUTPUT. The OUTPUT will be from address ØUTBUFF through ØUTBUFF+15.

```
         ECHA    ØUTBUFF
         TAM     23B          SET R.F. LØCA 23 TØ FCA
         INA     16
         TAM     33B          SET R.F. LØCA 33 TØ LCA+1
         CTØ                  INITIATE TYPEWRITER ØUTPUT
          .
          .
          .
         UCS
ØUTBUFF  BSS,C   16
```

20.10.5.3 Pause Instruction (as used with Console Typewriter Instructions)

LOCATION	OPERATION,MODIFIERS	ADDRESS FIELD
	PAUS	x



Bits 00 - 11 should be loaded with zeros

Description: This instruction allows the program to halt for a maximum of 40 ms if a condition (excluding typewriter-see note) defined by the pause sensing mask exists. If a "1" appears on a line that corresponds to a mask bit that is set, the count in P will not advance. If the advancement of P is delayed for more than 40 ms, a reject instruction is read from address P + 1. If none of the lines being sensed is active, or if they become inactive during the pause, the program immediately skips to address P + 2. If an interrupt occurs and is enabled during a PAUS, the pause condition is terminated, the interrupt sequence is initiated and the address of the PAUS instruction is stored as the interrupted address.

Note: If either bit 08, 09 or 10 (or any combination of these bits) is set and the sensed condition exists, a pause will not occur and the instruction at P + 1 is read up immediately. If these bits are set but the condition(s) does not exist, the program immediately skips to P + 2. For all other bits, the normal PAUS routine is followed.

PAUSE Sensing Mask Table

Mask Bit	Mask Code	Condition	Notes
00	0001	I/O channel 0 Busy	Channel Read or Write
01	0002	1	operation in progress,
02	0004	2	or the external Master
03	0010	3	Clear logic within the
04	0020	4	channel is set.
05	0040	5	
06	0100	6	
07	0200	7	
08	0400	Typewriter BUSY	Typewriter input or output in progress
09	1000	Typwrtr NOT FINISH	FINISH switch not depressed
10	2000	Typwrtr NOT REPEAT	REPEAT switch not depressed
11	4000	Search/Move control BUSY	Search or Move operation in progress

Examples: i) This example initiates and waits until a typewriter OUTPUT is complete.

```
           ECHA     ØUTBUFF
           TAM      23B           SET R.F. LØCA 23 TØ FCA
           INA      16B
           TAM      33B           SET R.F. LØCA 33 TØ LCA+1
           CTØ                    INITIATE TYPEWRITER ØUTPUT
           PAUS     400B          WAIT UNTIL ØUTPUT IS CØMPLETE
           UJP      *-1
            .
            .
            .
           UCS
ØUTBUFF    BCD,C    16, THIS IS THE END
```

ii) Study the following example and determine what it will do.

```
*
           PAUS     400B
           UJP      *-1
           ECHA     INBUF
           TAM      23B
           INA      80
           TAM      33B
           CTI
*
           PAUS     400B
           UJP      *-1
           ECHA     CR
           TAM      23B
           INA      1
           TAM      33B
           CTØ
*
           PAUS     400B
           UJP      *-1
           ECHA     INBUFR
           TAM      23B
           INA      10
           TAM      33B
           CTI
*
            .
            .
            .
           UJP      ELSE
*
INBUF      BSS,C    80
CR         ØCT      -0
INBUFR     BSS,C    10
            .
            .
            .
           etc.
```

It looks like the program will do an input, then a carriage return and then call for more input. If the first input is terminated by a REPEAT or FINISH, and 1) few or no characters were inputted or 2) if the operator is slow in getting his finger off the switch, then the second input will be terminated before he has a chance to type any further characters.

Verify this for yourself by studying the actions listed on the next page. The key is that the CTI can be initiated during the 50msec interval following the end of a type-out as the PAUS 400B senses buffer busy not typewriter busy.

Note: Some programs use the REPEAT and FINISH switches as self clearing sense switches. This use is possible but is not recommended except under controlled conditions. The reason for this will be evident when the actions of the REPEAT and FINISH switches and PAUS instruction are studied below.

REPEAT or FINISH switch depressed

Typewriter NOT busy and not in the 50msec interval following a type-out operation

Action: Set REPEAT or FINISH status bit, turn on light

Typewriter executing a type-out or in the 50msec interval following a type-out operation

Action: None

Typewriter waiting for type-in

Action: Set REPEAT or FINISH status bit, turn on light and terminate type-in.

End of 50msec interval at end of type-out operation and REPEAT or FINISH switch being held down

Typewriter not busy.

Action: Set REPEAT or FINISH status bit, turn on light

Typewriter busy with new output

Action: None

Typewriter busy with type-in

Action: Set REPEAT or FINISH status bit, turn on light and terminate type-in.

At any time when the REPEAT or FINISH light is on and status bit set and the REPEAT or FINISH switch is being held down.

REPEAT or FINISH being sensed by PAUS instruction

Action: Clear REPEAT or FINISH status bit and turn off light. (Switch must be released and depressed again to reset) RNI at P+2, where otherwise it would be P+1.

Exercise: Write a subroutine that will output a carriage return and then tab the console typewriter. Then initiate a type-in of 1 character and wait until that character is received or a NOT busy, repeat or finish condition arises. Clear repeat and/or finish if present.

STUDENT NOTES

INTERRUPTS

Chapter 21

21.1 INTERRUPTS USING CIC

Description: There are twelve groups of conditions for which, when one or more of these conditions occur, the programmer may wish to jump to a special sequence of coding, and upon completion of that task, resume processing in his original task. Processing in this manner is called "interrupt processing".

The twelve groups of conditions mentioned above are listed in the table "Interrupt Mask Register Bit Assignments" in Section 21.4 at the end of this discussion. This register (IMR) is set by the programmer.

In addition to the IMR, there are twelve flip-flops, each representing one of the conditions specified by the IMR. (Schematically, we may consider this as a 12-bit Interrupt Register.) When one of the 12 interruptible conditions occurs, the hardware sets the corresponding flip-flop in this Interrupt Register. If the corresponding bit has been set by the programmer in the IMR (and the interrupt system is enabled), interrupt processing will take place. The programmer must have previously placed the address of his interrupt routine in the CIT table.

Example: Add the integers in BUF thru BUF+99. If an arithmetic overflow occurs, jump to a routine to process the sum using double-precision (48-bit) integer arithmetic.

```
          EXT       CIT
SUM       ØCT       0,0
START     UJP       **
          ENA       INTADD         *STØRE ADDRESS
          ENI       7,1             ØF INTERRUPT RØUTINE AT CIT+7
          SWA       CIT,1           (SEE TABLE 21.5)
          SSIM      2000B          *SET IMR FØR ØVERFLØW CØNDITIØN
          EINT                     *ENABLE INTERRUPT SYSTEM
           .
           .
           .
           .
           .
          ENA       0
          ENI       99,1
LØØP      ADA       BUF,1          *ADDITIØN LØØP
          IJD       LØØP,1
*                                  *100 WØRD SUM IS COMPLETE, EXCEPT
          SHAQ      -24            *ADD 24-BIT SUM IN *A*
          ADAQ      SUM              TØ 48-BIT SUM IN *SUM*
          STAQ      SUM            *ALL DØNE
           .
           .
           .
           .
          UJP,I     START
*
INTADD    UJP       **
          ENA       INTADD         1
          SWA       CIT,1          2
          ENI       1,1            3
          LDA       CIT,1          4
          SHAQ      -24            5
          XØA,S     -0             6
          ADAQ      SUM            7
          STAQ      SUM            8
          ENA       0              9
          STA       CIT,1          10
          UJP,I     INTADD         11
```

Discussion of START+1 thru START+5 in the Example

Initialization to recognize an interrupt

(1) the programmer must store the address of his interrupt routine in the lower 15 bits of the proper CIT table entry (See Section 21.5) and
(2) the programmer must set the proper bit or bits in the IMR (See Section 21.4) and
(3) the programmer must enable the interrupt system.

Discussion of INTADD in the Example

Processing the interrupt

(1)* and (2)* CIC replaced the lower 15 bits of CIT+7 with the address of ABNORMAL. If we expect to get another overflow interrupt, we must again place the address of our routine in CIT+7. (Location CIT+7 applies only to overflow interrupts, see Section 21.5) Upon entry to an interrupt routine, CIT+(B^1) equals the CIT table location where the FWA of an Interrupt Routine must be placed to process the next interrupt of the type currently being processed.

(3)* and (4)* CIC stored the original contents (the "overflowed" sum) of the A register at CIT+1 and used the A register for its own purposes. We are merely reloading the original A register contents at the time of overflow so that we may process the overflow.

(4)*, (5)*, (6)*, (7)* & (8)* are processing the overflow condition into a 48-bit true sum.

(9)* and (10)* Since CIC will load the A register from CIT+1 before returning to our original sequence, we must place into CIT+1 whatever quantity we desire to be in the A register upon re-entry into our original sequence.

(11)* Returns us to CIC for housekeeping (explained later) before giving control to our original sequence.

Discussion of the Function of CIC

When an interruptible condition occurs, the Interrupt Register is compared to the IMR. If (a) any corresponding bits are set, and (b) the interrupt system has been enabled, then

(1) the interrupt system is disabled,
(2) the address of the instruction which would normally be executed next is stored in the lower 15 bits of absolute location 4,
(3) an identifying code is stored in the lower 12 bits of location 5 and,
(4) control is given to location 5.

Here are the contents of locations 4, 5 and 6 under SCOPE.

```
00004    UJP    **
00005    NØP    0
00006    UJP    CIC
```

*refers to card number in INTADD example

Since the hardware gives control to location 5 (which is a no operation instruction), we see that a jump is made to CIC (Central Interrupt Control). CIC saves the contents of A, Q, B^1, B^2 and B^3 at CIT+1 thru CIT+5. Since an identifying code (showing what condition caused the interrupt) is set in the lower 12 bits of location 00005, CIC knows which entry in CIT contains the address of the programmers interrupt routine.

CIC does a return jump to this location, and the programmer's interrupt routine (INTADD in this example) is executed. The interrupt routine does a UJP or UJP,I thru it's entry point to return to CIC when finished.

CIC restores the five registers, clears the flip-flop which was set by the interruptible condition (arithmetic overflow in the example), enables the interrupt system, and does an indirect jump through location 00004. The indirect jump gives control back to the instruction which was orginally interrupted.

21.2 INTERRUPTS WITHOUT USING CIC*

If the programmer does not wish to use CIC to help in the processing of his interrupt, then at location 00006 he must store a jump to the address to which he wishes control to be given. In his interrupt routine, he must save and restore his registers (if his routine uses them) if he wishes them to have their original contents upon return to the main coding. He must also clear the flip-flop in the Interrupt Register (with an INCL instruction) which signalled the interruptible condition. His last two instructions should be:

```
EINT
UJP,I      4
```

If the last instruction in the interrupt routine does not use an indirect reference to location 00004, the control may never return to the main program. This is because after an EINT he is assured of being able to execute only one more instruction before the interrupt system can recognize another interrupt. Hence, if he has programmed for interrupt on more than one condition and another is present, the computer will interrupt again and the address portion of the jump instruction at location 00004 will be changed before it can be executed. Since it will be changed to 00004, the computer will stall on a jump to location 00004 after completing the processing of the current interrupt.

*Since CIC is essential for SCOPE I/O, it is assumed that no I/O will be done or that SCOPE isn't being used.

21.3 I/O USING CIC (See also Section 16.2.3)

In programming for I/O interrupts using CIO, all the housekeeping is done by CIO. (The programmer does not EINT, SWA CIT+k, or set the IMR with an SSIM). CIO actually uses CIC in the same manner that we indicated, but the programmer does not have to attend to the details.

Example: Suppose that we wish to output 30 words from locations BUFF thru BUFF+29 onto logical unit 15. We wish to continue executing instructions while the output is going on. However, as soon as the output is finished, we wish to be "interrupted" and process a special sequence of code, then return to our original sequence.

21.3 (cont.)

Following is the code that will accomplish the task:

```
             EXT       CIØ
              .
START        UJP       **              ENTRY
              .
              .
              .
             ENA       0               SET BUFFER FLAG TØ BUSY
             STA       BFRBUSY
             RTJ       CIØ             GØ TØ CIØ TØ -
             02        15,2            WRITE WITH INTERRUPTS ØN LU 15
             UJP       REJECT          WRITE REJECTED IF WE GET HERE
             40        BUFF            START ØUTPUTTING FRØM LØCA *BUFF*
             0         30              ØUTPUT 30 WØRDS
             0         INTADD          WHEN INTRPT ØCCURS, GØ TØ INTADD
              .
              .
              .
              .
             SSH       BFRBUSY         NEED *BUFF* NØW, IS WRITE DØNE
             UJP       *-1             IF NØ, LØØP UNTIL FINISHED
                                       IF YES, CØNTINUE
              .
              .
              .
             UJP,I     START           PRØGRAM ALL DØNE, EXIT TØ SCØPE
*
INTADD       UJP       **              ENTRY PØINT ØF INTERRUPT RØUTINE
              .
              .                        } Interrupt Routine
              .                        } Special Sequence of Code
              .
              .
              .
             ENA,S     -0              SET BUFFER FLAG TØ NØT BUSY
             STA       BFRBUSY
             UJP,I     INTADD          EXIT TØ MAIN CØDE VIA CIC
*
BFRBUSY      ØCT       -0              +0 = BUSY, -0 = NØT BUSY
```

21.4 INTERRUPT MASK REGISTER BIT ASSIGNMENTS

Mask Bit Positions	Mask Codes (x)	Interrupt Conditions Represented
00	0001	I/O Channel 0 (includes interrupts generated within the channel and external equipment interrupts)
01	0002	1
02	0004	2
03	0010	3
04	0020	4
05	0040	5
06	0100	6
07	0200	7
08	0400	Real-time clock
09	1000	Exponent overflow/underflow & BCD faults
10	2000	Arithmetic overflow & divide faults
11	4000	Search/Move completion

21.5 CIT ASSIGNMENTS

Symbolic Location	Content	Explanation
CIT+0	Interrupt flag	If +0, no interrupt occurred. If -0, interrupt occurred.
+1	(A)	Contents of these registers when last interrupt occurred. Registers are restored from here on exit from CIC.
+2	(Q)	
+3	(B^1)	
+4	(B^2)	
+5	(B^3)	
+6	Real Time Clock	Initially contains UJP ABNØRMAL. Address of user interrupt routine stored in CIT by user main program when the corresponding interrupt is selected.
+7	Arithmetic Overflow	
+8	Divide Fault	
+9	Exponent Overflow	
+10	BCD Fault	
+11	Search/Move	
+12	Manual Interrupt	
+13	Associated Processor Interrupt	
+14	Channel 0	Initially contains UJP ABNØRMAL. Address is set by CIO when interrupt is selected. Table is extended for each pair of channels added to the hardware configuration*.
+15	Channel 1	
+16	Channel 2	
+17	Channel 3	
+18	Channel 4	
+19	Channel 5	
+20	Channel 6	
+21	Channel 7	

* The Central Interrupt Table (CIT) length varies from 15 to 21 entries and is dependent on the number of channels present in the system. The length of the table is specified at the time CIC is assembled under COMPASS prior to doing a PRELIB (Prepare library tape) of SCOPE.

SAMPLE COMPASS PROGRAMS

Appendix A

```
SEQUENCE,001
JOB,,,,
COMPASS,L,R
```

```
COMPASS-32    (2.1)              EXAMPLES                                      11/21/66  PAGE     1


  UNDEFINED SYMBOLS
      SAM
      SYM
      SYMBOL


  MULTIPLY-DEFINED SYMBOLS
      GEORGE


  EXTERNAL SYMBOLS
      BCDBOXS
      FDPBOXS


  LENGTH OF SUBPROGRAM        00372
  LENGTH OF COMMON            00000
  LENGTH OF DATA              00000
```

```
THIS IS A LISTING OF THE CDC 3200 INSTRUCTION SET

**********************************************************************
        --------  DEFINITION OF OPERATION CODE MODIFIERS  --------
**********************************************************************

        EQ         EQUAL
        NE         NOT EQUAL
        GE         GREATER THAN OR EQUAL TO
        LT         LESS THAN
        I          INDIRECT ADDRESSING
        S          SIGN EXTENSION
        INT        INTERRUPT
        B          BACKWARD
        H          HALF ASSEMBLY OR DISASSEMBLY
        N          NO ASSEMBLY OR DISASSEMBLY

**********************************************************************
        --------  DEFINITION OF TERMS AND SYMBOLS  --------
**********************************************************************

        A          THE ≠A≠ REGISTER
        Q          THE ≠Q≠ REGISTER
        AQ         48 BIT REG , (A AND Q COMBINED RESPECTIVELY)
        QA         48 BIT REG , (Q AND A COMBINED RESPECTIVELY)
        E          THE 48 BIT ≠E≠ REGISTER
        EL         LOWER 24 BITS OF ≠E≠
        EU         UPPER 24 BITS OF ≠E≠
        ED         THE 52 BIT (13 CHAR) ≠E DECIMAL≠ REGISTER. SAME AS
                   ≠E≠ BUT EXTENDED FROM 48 TO 52 BITS.
        AQE        96 BIT REG , (A,Q AND E COMBINED RESPECTIVELY)
        B          ANY ONE OF THE THREE INDEX REGISTERS
        B1         INDEX REGISTER ONE ONLY
        B2         INDEX REGISTER TWO ONLY
        B3         INDEX REGISTER THREE ONLY
        D          4 BIT ≠D≠ REGISTER
        IMR        INTERRUPT MASK REGISTER

        M          15 BIT WORD ADDRESS
        R          17 BIT CHARACTER ADDRESS
        FSCA       FIRST SOURCE CHARACTER ADDRESS
        FDCA       FIRST DESTINATION CHARACTER ADDRESS
        V          6 BIT REGISTER FILE ADDRESS
        Y          15 BIT OPERAND
        C          6 BIT SEARCH CHARACTER
        FL         4 BIT OPERAND  (BCD FIELD LENGTH)
        P          CURRENT INSTRUCTION ADDRESS AS INDICATED BY THE P REG

        (  )       CONTENTS OF
        (M)        24 BIT CONTENTS OF MEMORY LOCATION M
        (M,M+1)    48 BIT CONTENTS OF MEM LOCS M AND M+1 RESPECTIVELY
        (R)        6 BIT CONTENT OF MEMORY CHARACTER LOCATION R
        (V)        24 BIT CONTENTS OF REG FILE LOCATION V
```



```
        RNI        READ NEXT INSTRUCTION
                   WHERE DATA IS BEING STORED INTO PART OF A MEMORY
                   LOCATION , THE REMAINDER OF THAT LOCATION REMAINS
                   UNCHANGED

                   ALL POSSIBLE OPERATION MODIFIERS ARE SHOWN WITH EACH
                   MNEMONIC CODE , SEPARATED BY (,).
                   THERE IS NO ORDER , WHERE MULTIPLE MODFIERS ARE
                   POSSIBLE.
                   THE FOLLOWING MODIFIERS ARE OPTIONAL AND CAN BE
                   DROPPED BY ELEMINATING BOTH THE MODIFIER AND THE
                   PRECEDING COMMA.

                   I , S , INT , B , H , N ,


                   ON ALL CONDITIONAL JUMP AND SKIP INSTRUCTIONS ,
                   IF THE CONDITION IS NOT MET THEN RNI P+1
```

```
                                        ******************************************************************
                                                 --------  3200 INSTRUCTION SET  --------
                                        ******************************************************************

                                                       LOAD CLASS

      00000  20725252 20 1  25252 3          LDA,I      M,B            (M) TO A
      00001  21725252 21 1  25252 3          LDQ,I      M,B            (M) TO Q
      00002  22425253 22 1  05252 3          LACH       R,B1           (R) TO A 05-00 , A 23-06 CLEARED
      00003  23425253 23 1  05252 3          LQCH       R,B2           (R) TO Q 05-00 , Q 23-06 CLEARED
      00004  24725252 24 1  25252 3          LCA,I      M,B            (M)COMPLEMENT TO A
      00005  25725252 25 1  25252 3          LDAQ,I     M,B            (M,M+1) TO AQ
      00006  26725252 26 1  25252 3          LCAQ,I     M,B            (M,M+1)COMPLEMENT TO AQ
      00007  27725252 27 1  25252 3          LDL,I      M,B            (M)LM(Q) TO A , M AND Q UNCHANGE
      00010  54725252 54 1  25252 3          LDI,I      M,B            (M 14-00) TO B

                                                       STORE CLASS

      00011  40725252 40 1  25252 3          STA,I      M,B            (A) TO M
      00012  41725252 41 1  25252 3          STQ,I      M,B            (Q) TO M
      00013  42425253 42 1  05252 3          SACH       R,B2           (A 05-00) TO R
      00014  43425253 43 1  05252 3          SQCH       R,B1           (Q 05-00) TO R
      00015  44725252 44 1  25252 3          SWA,I      M,B            (A 14-00) TO M 14-00
      00016  45725252 45 1  25252 3          STAQ,I     M,B            (AQ) TO M,M+1
      00017  46725252 46 1  25252 3          SCHA,I     M,B            (A 16-00) TO M 16-00
      00020  47725252 47 1  25252 3          STI,I      M,B            (B) TO M 14-00

                                                     24 BIT ARITH CLASS

      00021  30725252 30 1  25252 3          ADA,I      M,B            (A)+(M) TO A
      00022  31725252 31 1  25252 3          SBA,I      M,B            (A)-(M) TO A
      00023  50725252 50 1  25252 3          MUA,I      M,B            (A)*(M) TO QA
      00024  51725252 51 1  25252 3          DVA,I      M,B            (AQ)/(M) TO A , REMAINDER TO Q

      00025  34725252 34 1  25252 3          RAD,I      M,B            (A)+(M) TO M , A IS UNCHANGED

                                                       48 BIT ARITH CLASS

      00026  32725252 32 1  25252 3          ADAQ,I     M,B            (AQ)+(M,M+1) TO AQ
      00027  33725252 33 1  25252 3          SBAQ,I     M,B            (AQ)-(M,M+1) TO AQ
      00030  56725252 56 1  25252 3          MUAQ,I     M,B            (AQ)*(M,M+1) TO AQE
      00031  57725252 57 1  25252 3          DVAQ,I     M,B            (AQE)/(M,M+1) TO AQ, REMDR TO E

                                                       FLOATING POINT ARITH CLASS

      00032  60725252 60 1  25252 3          FAD,I      M,B       FP(AQ) + FP(M,M+1) TO AQ
      00033  61725252 61 1  25252 3          FSB,I      M,B       FP(AQ) - FP(M,M+1) TO AQ
      00034  62725252 62 1  25252 3          FMU,I      M,B       FP(AQ) * FP(M,M+1) TO AQ
      00035  63725252 63 1  25252 3          FDV,I      M,B       FP(AQ) / FP(M,M+1) TO AQ
```



```
                                                       BCD CLASS

      00036  64425253 64 1  05252 3          LDE        FCA,B1 (FCA THRU FCA+(D)-1) TO ED RIGHT JUSTIFIED
      00037  65425253 65 1  05252 3          STE        FCA,B2 (ED) TO FCA THRU FCA+(D)-1 , RIGHT JUSTIFIED
      00040  66425253 66 1  05252 3          ADE        FCA,B3 (ED)+(FCA THRU FCA+(D)-1) TO ED
      00041  67425253 67 1  05252 3          SBE        FCA,B3 (ED)-(FCA THRU FCA+(D)-1) TO ED
      00042  70300014 70 0  00014 3          SFE        K,B     SHIFT ED , K DIGITS LEFT OR RIGHT (END OFF)

      00043  70700012 70 1  00012 3          SET        FL      FL TO D

      00044  70625252 70 1  25252 2          EOJ        M       RNI M IF ED OVERFLOW CHARACTER IS NONZERO
      00045  70425252 70 1  25252 0          EZJ,EQ     M       RNI M IF ED CONTAINS ZERO
      00046  70525252 70 1  25252 1          EZJ,LT     M       RNI M IF ED IS NEGATIVE

                                                     24 BIT INTER-REGISTER TRANSFER CLASS

      00047  53300000 53 0  00000 3          TIA        B              (B) TO A 14-00 , A 23-15 CLEARED
      00050  53700000 53 1  00000 3          TAI        B              (A 14-00) TO B
      00051  53010077 53 0  10077 0          TMQ        V              (V) TO Q
      00052  53410077 53 1  10077 0          TQM        V              (Q) TO V
      00053  53020077 53 0  20077 0          TMA        V              (V) TO A
      00054  53420077 53 1  20077 0          TAM        V              (A) TO V
      00055  53330077 53 0  30077 3          TMI        V,B            (V 14-00) TO B
      00056  53730077 53 1  30077 3          TIM        V,B            (B) TO V 14-00 , V 23-15 CLEARED

      00057  53040000 53 0  40000 0          AQA                       (A)+(Q) TO A
      00060  53340000 53 0  40000 3          AIA        B              (A)+(B) TO A
      00061  53740000 53 1  40000 3          IAI        B              (A)+(B) TO B

                                                     48 BIT INTER-REGISTER TRANSFER

      00062  55100000 55 0  00000 1          ELQ                       (EL) TO Q
      00063  55500000 55 1  00000 1          QEL                       (Q) TO EL
      00064  55200000 55 0  00000 2          EUA                       (EU) TO A
      00065  55600000 55 1  00000 2          AEU                       (A) TO EU
      00066  55300000 55 0  00000 3          EAQ                       (E) TO AQ
      00067  55700000 55 1  00000 3          AQE                       (AQ) TO E
```

STOP AND JUMP CLASS

```
00070  14000000 14 0  00000 0     NOP                            DO NOTHING

00071  00025252 00 0  25252 0     HLT      M                     STOP, RNI M
00072  77770000 77 1  70000 3     UCS                            STOP, RNI P+1

00073  01725252 01 1  25252 3     UJP,I    M,B                   RNI M

00074  00725252 00 1  25252 3     RTJ      M                     (P) TO M 14-00 , RNI M+1

00075  00125252 00 0  25252 1     SJ1      M                     RNI M IF KEY 1 IS SET
00076  00225252 00 0  25252 2     SJ2      M                     RNI M IF KEY 2 IS SET
00077  00325252 00 0  25252 3     SJ3      M                     RNI M IF KEY 3 IS SET
00100  00425252 00 1  25252 0     SJ4      M                     RNI M IF KEY 4 IS SET
00101  00525252 00 1  25252 1     SJ5      M                     RNI M IF KEY 5 IS SET
00102  00625252 00 1  25252 2     SJ6      M                     RNI M IF KEY 6 IS SET

00103  03025252 03 0  25252 0     AZJ,EQ   M                     RNI M IF (A) EQ + OR - ZERO
00104  03125252 03 0  25252 1     AZJ,NE   M                     RNI M IF (A) NE + OR - ZERO
00105  03225252 03 0  25252 2     AZJ,GE   M                     RNI M IF (A) POSITIVE
00106  03325252 03 0  25252 3     AZJ,LT   M                     RNI M IF (A) NEGATIVE

00107  03425252 03 1  25252 0     AQJ,EQ   M                     RNI M IF (A) EQ (Q)
00110  03525252 03 1  25252 1     AQJ,NE   M                     RNI M IF (A) NE (Q)
00111  03625252 03 1  25252 2     AQJ,GE   M                     RNI M IF (A) GE (Q)
00112  03725252 03 1  25252 3     AQJ,LT   M                     RNI M IF (A) LT (Q)

00113  02325252 02 0  25252 3     IJI      M,B    IF (B) NE 0 (B)+1 TO B AND RNI M, OW RNI P+1
00114  02725252 02 1  25252 3     IJD      M,B    IF (B) NE 0 (B)-1 TO B AND RNI M, OW RNI P+1
```

SKIP CLASS

```
                                  WITHOUT SIGN EXTENSION , ONLY THE LOWER 15 BITS OF A OR Q
                                  ARE COMPARED WITH Y.
                                  WITH SIGN EXTENSION , BIT 14 OF Y IS EXTENDED THRU BIT 23
                                  MAKING Y 24 BITS FOR COMPARISON WITH ALL OF A OR Q.

00115  04412345 04 1  12345 0     ASE,S    Y                     RNI P+2 IF (A) EQ Y , OW RNI P+1
00116  04512345 04 1  12345 1     QSE,S    Y                     RNI P+2 IF (Q) EQ Y , OW RNI P+1
00117  04312345 04 0  12345 3     ISE      Y,B                   RNI P+2 IF (B) EQ Y , OW RNI P+1
00120  04012345 04 0  12345 0     ISE      Y                     RNI P+2 IF Y EQ 0 , OW RNI P+1

00121  05412345 05 1  12345 0     ASG,S    Y                     RNI P+2 IF (A) GE Y , OW RNI P+1
00122  05512345 05 1  12345 1     QSG,S    Y                     RNI P+2 IF (Q) GE Y , OW RNI P+1
00123  05312345 05 0  12345 3     ISG      Y,B                   RNI P+2 IF (B) GE Y , OW RNI P+1

00124  10712345 10 1  12345 3     ISD      Y,B    IF (B) EQ Y CLEAR B AND RNI P+2. OTHERWISE
00125  10312345 10 0  12345 3     ISI      Y,B    IF (B) EQ Y CLEAR B AND RNI P+2. OTHERWISE
                                                  (B)+1 TO B AND RNI P+1
                                                  (B)-1 TO B AND RNI P+1
```


SHIFT CLASS

```
                                  POSITIVE SHIFT COUNT (K) INDICATES LEFT SHIFT. ALL LEFT
                                  SHIFTS ARE END AROUND.
                                  NEGATIVE SHIFT COUNT (K) INDICATES RIGHT SHIFT. ALL RIGHT
                                  SHIFTS ARE END OFF WITH SIGN EXTENDED.

00126  12300014 12 0  00014 3     SHA      K,B                   SHIFT (A) LEFT OR RIGHT K BITS
00127  12700014 12 1  00014 3     SHQ      K,B                   SHIFT (Q) LEFT OR RIGHT K BITS
00130  13300014 13 0  00014 3     SHAQ     K,B                   SHIFT (AQ) LEFT OR RIGHT K BITS

00131  13700014 13 1  00014 3     SCAQ     K,B                   SCALE (AQ)
```

ENTER CLASS

```
                                  WITHOUT SIGN EXTENSION , THE UPPER BITS OF A OR Q ARE CLEARED.
                                  WITH SIGN EXTENSION , BIT 14 OF Y (BIT 16 OF R) IS EXTENDED
                                  MAKING Y OR R 24 BITS FOR ENTRY INTO ALL OF A OR Q.

00132  14412345 14 1  12345 0     ENA,S    Y                     Y TO A 14-00
00133  14512345 14 1  12345 1     ENQ,S    Y                     Y TO Q 14-00
00134  14312345 14 0  12345 3     ENI      Y,B                   Y TO B
```

INCREASE CLASS

```
                                  WITH OR WITHOUT SIGN EXTENSION , Y WILL BE TREATED AS A 24 BIT
                                  VALUE WHEN ADDED TO A OR Q.
                                  WITHOUT SIGN EXTENSION , BITS 23-15 OF Y WILL BE ZERO.
                                  WITH SIGN EXTENSION , BIT 14 OF Y IS EXTENDED THRU BIT 23
                                  MAKING Y A 24 BIT VALUE.

                                  IF Y IS A NEGATIVE VALUE , THE REGISTER WILL BE DECREASED BY
                                  THAT AMOUNT.  ( MUST USE SIGN EXT IN THIS CASE FOR A AND Q)

00135  15412345 15 1  12345 0     INA,S    Y                     INCREASE (A) BY Y
00136  15512345 15 1  12345 1     INQ,S    Y                     INCREASE (Q) BY Y
00137  15312345 15 0  12345 3     INI      Y,B                   INCREASE (B) BY Y
```

```
                                                     LOGICAL INSTRUCTIONS WITHOUT STORAGE REFERENCE

                                             WITH OR WITHOUT SIGN EXTENSION , Y IS TREATED AS A 24 BIT
                                             VALUE.
                                             WITHOUT SIGN EXTENSION , BITS 23-15 OF Y ARE ZEROS.
                                             WITH SIGN EXTENSION , BIT 14 OF Y IS EXTENDED THRU BIT 23
                                             MAKING Y A 24 BIT VALUE FOR THE OPERATION.

00140  16412345 16 1  12345 0      XOA,S      Y                    SC (A) BY Y
00141  16512345 16 1  12345 1      XOQ,S      Y                    SC (Q) BY Y
00142  16312345 16 0  12345 3      XOI        Y,B                  SC (B) BY Y

00143  17412345 17 1  12345 0      ANA,S      Y                    LM (A) BY Y
00144  17512345 17 1  12345 1      ANQ,S      Y                    LM (Q) BY Y
00145  17312345 17 0  12345 3      ANI        Y,B                  LM (B) BY Y
                                                     LOGICAL INSTRUCTIONS WITH STORAGE REFERENCE

00146  35725252 35 1  25252 3      SSA,I      M,B                  SS (A) BY (M)
00147  36725252 36 1  25252 3      SCA,I      M,B                  SC (A) BY (M)
00150  37725252 37 1  25252 3      LPA,I      M,B                  LM (A) BY (M)
                                                     BUFFERED SEARCH AND MOVE CLASS

00151  71425261 71 1  05254 1      SRCE,INT   C,FCA,LCA+1          SEARCH (FCA THRU LCA) FOR EQ C
00152  23025253 23 0  05252 3
00153  01000151 01 0 P00151 0      UJP        *-2                 REJECT INSTRUCTION
00154  71425261 71 1  05254 1      SRCN,INT   C,FCA,LCA+1          SEARCH (FCA THRU LCA) FOR NE C
00155  23425253 23 1  05252 3
00156  01000154 01 0 P00154 0      UJP        *-2                 REJECT INSTRUCTION
00157  72425653 72 1  05352 3      MOVE,INT   FL,FSCA,FDCA         MOVE (FSCA THRU FSCA+FL-1) TO
00160  05025253 05 0  05252 3
                                                                   FDCA THRU FDCA+FL-1
00161  01000157 01 0 P00157 0      UJP        *-2                 REJECT INSTRUCTION
                                                     STORAGE TEST CLASS

00162  06225252 06 0  25252 2      MEQ        M,INTERVAL           MASKED EQUALITY SEARCH
00163  07225252 07 0  25252 2      MTH        M,INTERVAL           MASKED THRESHOLD SEARCH
00164  10025252 10 0  25252 0      SSH        M                    STORAGE TEST AND SHIFT
00165  52725252 52 1  25252 3      CPR,I      M,B                  COMPARE (M) WITH (A) AND (Q)
```



```
                                                     INPUT / OUTPUT

00166  77067007 77 0  67007 0      CON        CC,CH                CONNECT TO I/O EQUIPMENT
00167  01000166 01 0 P00166 0      UJP        *-1                 REJECT INSTRUCTION
00170  77160022 77 0  60022 1      SEL        FC,CH                SELECT FUNCTION ON I/O EQUIPMENT
00171  01000170 01 0 P00170 0      UJP        *-1                 REJECT INSTRUCTION

00172  73025261 73 0  05254 1      INPC,INT,B,H    CH,FCA,LCA+1    CHAR ADRS INPUT TO STORAGE
00173  63425253 63 1  05252 3
00174  01000172 01 0 P00172 0      UJP             *-2            REJECT INSTRUCTION

00175  73400000 73 1  00000 0      INAC,INT        CH              CHAR ADRS INPUT TO A
00176  60400000 60 1  00000 0
00177  01000175 01 0 P00175 0      UJP             *-2            REJECT INSTRUCTION

00200  74025322 74 0  25322 0      INPW,INT,B,N    CH,FWA,LWA+1    WORD ADRS INPUT TO STORAGE
00201  63425252 63 1  25252 0
00202  01000200 01 0 P00200 0      UJP             *-2            REJECT INSTRUCTION

00203  74400000 74 1  00000 0      INAW,INT        CH              WORD ADRS INPUT TO A
00204  60400000 60 1  00000 0
00205  01000203 01 0 P00203 0      UJP             *-2            REJECT INSTRUCTION

00206  75025261 75 0  05254 1      OUTC,INT,B,H    CH,FCA,LCA+1    CHAR ADRS OUTPUT FROM STORAGE
00207  63425253 63 1  05252 3
00210  01000206 01 0 P00206 0      UJP             *-2            REJECT INSTRUCTION

00211  75400000 75 1  00000 0      OTAC,INT        CH              CHAR ADRS OUTPUT FROM A
00212  60400000 60 1  00000 0
00213  01000211 01 0 P00211 0      UJP             *-2            REJECT INSTRUCTION

00214  76025322 76 0  25322 0      OUTW,INT,B,N    CH,FWA,LWA+1    WORD ADRS OUTPUT FROM STORAGE
00215  63425252 63 1  25252 0
00216  01000214 01 0 P00214 0      UJP             *-2            REJECT INSTRUCTION

00217  76400000 76 1  00000 0      OTAW,INT        CH              WORD ADRS OUTPUT FROM A
00220  60400000 60 1  00000 0
00221  01000217 01 0 P00217 0      UJP             *-2            REJECT INSTRUCTION

00222  77750000 77 1  50000 3      CTI                             CONSOLE TYPEWRITER INPUT
00223  77760000 77 1  60000 3      CTO                             CONSOLE TYPEWRITER OUTPUT
```

```
                                                              SENSING AND COPY CLASS

00224  77260000 77 0  60000 2          COPY     CH                     COPY EXTERNAL STATUS AND IMR TO A
00225  77360000 77 0  60000 3          CINS     CH                     COPY INTERNAL STATUS AND IMR TO A
00226  77267777 77 0  67777 2          EXS      X,CH                     SENSE EXTERNAL STATUS
00227  77367777 77 0  67777 3          INS      X,CH                     SENSE INTERNAL STATUS
00230  77467777 77 1  67777 0          INTS     X,CH                     SENSE INTERRUPT
00231  77607777 77 1  07777 2          PAUS     X                        PAUSE

                                                              CONTROL CLASS

00232  77507777 77 1  07777 1          INCL     X                        INTERRUPT CLEAR
00233  77517777 77 1  17777 1          IOCL     X                        INPUT/OUTPUT CLEAR

00234  77710000 77 1  10000 3          SFPF                              SET FLOATING POINT FAULT
00235  77720000 77 1  20000 3          SBCD                              SET BCD FAULT

                                                              INTERRUPT CLASS

00236  77527777 77 1  27777 1          SSIM     X                      SELECTIVELY SET IMR
00237  77537777 77 1  37777 1          SCIM     X                        SELECTIVELY CLEAR IMR

00240  77730000 77 1  30000 3          DINT                              DISABLE INTERRUPT SYSTEM
00241  77740000 77 1  40000 3          EINT                              ENABLE  INTERRUPT SYSTEM

00242  11425253 11 1  05252 3          ECHA,S   R                        R TO A 16-00
00243  77570000 77 1  70000 1          IAPR                              INTERRUPT ASSOCIATED PROCESSOR

                               -------------------  TABLE OF MASK BIT ASSIGNMENTS  -----------------

                               BIT CODE  SSIM
                                         SCIM   INCL    INTS     IOCL   PAUS           INS

                               00  0001  CH 0   CH 0    LINE 0   CH 0   CH 0 BUSY    PARITY ERR ON CH X
                               01  0002  CH 1   CH 1    LINE 1   CH 1   CH 1 BUSY    CH X BUSY READING
                               02  0004  CH 2   CH 2    LINE 2   CH 2   CH 2 BUSY    CH X BUSY WRITING
                               03  0010  CH 3   CH 3    LINE 3   CH 3   CH 3 BUSY    EXT REJECT ON CH X
                               04  0020  CH 4   CH 4    LINE 4   CH 4   CH 4 BUSY    NO RESP REJ ON CH X
                               05  0040  CH 5   CH 5    LINE 5   CH 5   CH 5 BUSY    * ILLEGAL WRITE
                               06  0100  CH 6   CH 6    LINE 6   CH 6   CH 6 BUSY    CH X PRESET CON/SEL
                               07  0200  CH 7   CH 7    LINE 7   CH 7   CH 7 BUSY    INTERNAL INT ON CH X
                               08  0400   REAL TIME CLOCK INT     TY    TY BUSY      *EXP OVFLW FAULT
                               09  1000  *EXP OVFLW/BCD FAULT    ----   NOT FINISH   *ARITH OVFLW FAULT
                               10  2000  *ARITH OVFLW/DIV FAULT  ----   NOT REPEAT   *DIVIDE FAULT
                               11  4000   SEARCH/MOVE COMPLETE   S/M    S/M BUSY     *BCD FAULT

                                 * INTERNAL FAULTS CLEARED BY SENSING
```



```
                               *******************************************************************
                                         --------  COMPASS CODING  TECHNIQUES  --------
                               *******************************************************************

                                                              ASSEMBLY OF CONSTANTS

00244           00000001               OCT      1,2,-2,50,-77
00245           00000002
00246           77777775
00247           00000050
00250           77777700
00251           00000001               DEC      1,2,50,-50,99,987654
00252           00000002
00253           00000062
00254           77777715
00255           00000143
00256           03611006
00257           00000000               DECD     1,-1,98,-1.,98.,9.8
00260           00000001
00261           77777777
00262           77777776
00263           00000000
00264           00000142
00265           57763777
00266           77777777
00267           20076100
00270           00000000
00271           20044714
00272           63146315
00273           44256262               BCD      2,MESSAGE
00274           21272560
00275           442562                 BCD,C    3,MES
002753                62               BCD,C    5,SAGE
00276           21272560
00277           77304643      HOLMSG   VFD      06/77,H18/HOL,09/0,A15/HOLMSG,C24/HOLMSG
00300           00000277
00301           00001374

                                                              STORAGE RESERVATION

00302                         TOM      BSS      3
00305                         TOMC     BSS,C    3
003053                        TOMC1    BSS,C    1

00306  20000302 20 0 P00302 0          LDA      TOM
00307  22001424 22 0 P00305 0          LACH     TOMC
00310  22001427 22 0 P00305 3          LACH     TOMC1
```

```
COMPASS-32     (2.1)              EXAMPLES                                           11/21/66  PAGE    12

                                                          ADDRESSING MODES

                                                                     ABSOLUTE

         00311  20000012 20 0  00012 0            LDA      10
         00312  20000010 20 0  00010 0  SYMB1     LDA      10B
         00313  20077740 20 0  77740 0  SYMB2     LDA      -37B
         00314  20000001 20 0  00001 0            LDA      SYMB2-SYMB1
         00315  20000025 20 0  00025 0            LDA      ADRS
                               00025      ADRS    EQU      25B

                                                                     RELOCATABLE

         00316  20000317 20 0 P00317 0            LDA      TEMP
         00317  20000321 20 0 P00321 0  TEMP      LDA      TEMP+2
         00320  20000317 20 0 P00317 0            LDA      TEMP1
                               00317      TEMP1   EQU      TEMP

                                                                     LITERALS

         00321  20000361 20 0 P00361 0            LDA      =D9
         00322  25000362 25 0 P00362 0            LDAQ     =2D9
         00323  25000364 25 0 P00364 0            LDAQ     =2D9.
         00324  20000360 20 0 P00360 0            LDA      =077777777
         00325  25000366 25 0 P00366 0            LDAQ     =207373737373737373
         00326  20000357 20 0 P00357 0            LDA      =HABCD
         00327  25000370 25 0 P00370 0            LDAQ     =2HABCDEFGH

                                                                     SPECIAL CHARACTERS

         00330  20000330 20 0 P00330 0            LDA      *
         00331  20000332 20 0 P00332 0            LDA      *+1
         00332  20000330 20 0 P00330 0            LDA      *-2
         00333  20077777 20 0  77777 0            LDA      **

                                                                     INTERCHANGE OF WORD AND CHARACTER ADDRESSES

                               00334      WORDADRS EQU     *
                               00334      CHARADR1 EQU,C   *
                               003343     CHARADR2 EQU,C   *+3

         00334  20000334 20 0 P00334 0            LDA      CHARADR1
       T 00335  20000334 20 0 P00334 0            LDA      CHARADR2            TRUNCATION ERROR
         00336  22001560 22 0 P00334 0            LACH     WORDADRS
```

```
COMPASS-32     (2.1)              EXAMPLES                                           11/21/66  PAGE    13

                                                                     SYMBOL EQUATIONS

                               25252      ADDRESS EQU      25252B
                               25252      M       EQU      ADDRESS
                               052523     R       EQU,C    M+1
                               00003      B       EQU      3
                               00001      B1      EQU      1
                               00002      B2      EQU      2
                               00003      B3      EQU      3
                               052523     FCA     EQU,C    R
                               05254      LCA     EQU,C    R+5
                               00014      K       EQU      12
                               00077      V       EQU      77B
                               12345      Y       EQU      12345B
                               053523     FUCA    EQU,C    FCA+256
                               052523     FSCA    EQU,C    FCA
                               00012      FL      EQU      12B
                               00006      CH      EQU      6
                               25252      FWA     EQU      M
                               25321      LWA     EQU      M+39
                               07777      X       EQU      7777B
                               07007      CC      EQU      7007B
                               00022      FC      EQU      22B
                               00002      INTERVAL EQU     2
                               00023      C       EQU      23B
```

```
COMPASS-32    (2.1)              EXAMPLES                                         11/21/66  PAGE    14

                                                  COMPASS ASSEMBLY ERRORS

   A 00337  20000000 20 0  00000 0            LDA      2BB                ADDRESS FORMAT ERROR

                                              COMMON
   C 00340  20000005 20 0  00005 0            LDA      5                  ATTEMPT TO ASSEMBLE INFO IN
     00341          00000007                  OCT      7                  THE COMMON AREA
                                              PRG

  DA 00342  20000343 20 0 P00343 0            LDA      GEORGE             MULTIPLY DEFINED SYMBOL
     00343          00000001        GEORGE    OCT      1
   D 00344          00000012        GEORGE    DEC      10

   L 00345  20000005 20 0  00005 0  123       LDA      5                  LOCATION FIELD ERROR

   M 00346  00000005 00 0  00005 0            LDA,1    5                  OPERATION MODIFIER ERROR

   O 00347  00000000 00 0  00000 0            LID      5                  OPERATION CODE ERROR

   U 00350  20000000 20 0  00000 0            LDA      SAM                UNDEFINED SYMBOL

   T 00351  20000352 20 0 P00352 0            LDA      CHAR               TRUNCATION ERROR
                       003523       CHAR      EQU,C    *+3

                                    ***************************************************************************
                                              LITERAL IN A CHARACTER ADDRESS INSTRUCTION
     00352  22001670 22 0 P00356 0            LACH     =012
                                    ***************************************************************************
                                    ***************************************************************************
                                              BLANK CHARACTERS IN SYMBOLS
   L 00353  20000353 20 0 P00353 0  SYM BOL   LDA      *
   U 00354  01000000 01 0  00000 0            UJP      SYM BOL
   U 00355  01000000 01 0  00000 0            UJP      SYMBOL
                                    ***************************************************************************
                                    ***************************************************************************


                                              END

 LITERALS
00356            00000012             00357          21222324             00360          77777777
00361            00000011
00362                 0000000000000011                00364                2004440000000000
00366                 7373737373737373                00370                2122232425262730

                                             NUMBER OF LINES WITH DIAGNOSTICS          13
```

```
COMPASS-32    (2.1)              EXAMPLES                                         11/21/66  PAGE     1

      ADDRESS        25252                         P25252
      ADRS           00025                         P00315
      B              00003                         P00000        P00001        P00004        P00005
                                                   P00006        P00007        P00010        P00011
                                                   P00012        P00015        P00016        P00017
                                                   P00020        P00021        P00022        P00023
                                                   P00024        P00025        P00026        P00027
                                                   P00030        P00031        P00032        P00033
                                                   P00034        P00035        P00042        P00047
                                                   P00050        P00055        P00056        P00060
                                                   P00061        P00073        P00113        P00114
                                                   P00117        P00123        P00124        P00125
                                                   P00126        P00127        P00130        P00131
                                                   P00134        P00137        P00142        P00145
                                                   P00146        P00147        P00150        P00165
      B1             00001                         P00002        P00014        P00036
      B2             00002                         P00003        P00013        P00037
      B3             00003                         P00040        P00041
      C              00023                         P00151        P00154
      CC             07007                         P00166
      CH             00006                         P00166        P00170        P00172        P00175
                                                   P00200        P00203        P00206        P00211
                                                   P00214        P00217        P00224        P00225
                                                   P00226        P00227        P00230
      CHAR          P00352 3                       P00351
      CHARADR1      P00334 0                       P00334
      CHARADR2      P00334 3                       P00335
      FC             00022                         P00170
      FCA            05252 3                       P00036        P00037        P00040        P00041
                                                   P00151        P00154        P00172        P00206
                                                   P05352        P05252
      FDCA           05352 3                       P00157
      FL             00012                         P00043        P00157
      FSCA           05252 3                       P00157
      FWA            25252                         P00200        P00214
      GEORGE        P00343      MULTIPLE-DEFINED   P00342
      HOLMSG        P00277                         P00277        P00277
      INTERVAL       00002                         P00162        P00163
      K              00014                         P00042        P00126        P00127        P00130
                                                   P00131
      LCA            05254 0                       P00151        P00154        P00172        P00206
      LWA            25321                         P00200        P00214
      M              25252                         P00000        P00001        P00004        P00005
                                                   P00006        P00007        P00010        P00011
                                                   P00012        P00015        P00016        P00017
                                                   P00020        P00021        P00022        P00023
                                                   P00024        P00025        P00026        P00027
                                                   P00030        P00031        P00032        P00033
                                                   P00034        P00035        P00044        P00045
                                                   P00046        P00071        P00073        P00074
                                                   P00075        P00076        P00077        P00100
                                                   P00101        P00102        P00103        P00104
                                                   P00105        P00106        P00107        P00110
```

```
COMPASS-32    (2.1)              EXAMPLES                                                          11/21/66  PAGE      2
                                                            P00111        P00112        P00113        P00114
                                                            P00146        P00147        P00150        P00162
                                                            P00163        P00164        P00165        P05252
                                                            P25252        P25321
     R              05252 3                                 P00002        P00003        P00013        P00014
                                                            P00242        P05252        P05254
     SAM            00000      UNDEFINED                    P00350
     SYM            00000      UNDEFINED                    P00354
     SYMB1          P00312                                  P00314
     SYMB2          P00313                                  P00314
     SYMBOL         00000      UNDEFINED                    P00355
     TEMP           P00317                                  P00316        P00317        P00317
     TEMP1          P00317                                  P00320
     TOM            P00302                                  P00306
     TOMC           P00305                                  P00307
     TOMC1          P00305 3                                P00310
     V              00077                                   P00051        P00052        P00053        P00054
                                                            P00055        P00056
     WORDADRS       P00334                                  P00336
     X              07777                                   P00226        P00227        P00230        P00231
                                                            P00232        P00233        P00236        P00237
     Y              12345                                   P00115        P00116        P00117        P00120
                                                            P00121        P00122        P00123        P00124
                                                            P00125        P00132        P00133        P00134
                                                            P00135        P00136        P00137        P00140
                                                            P00141        P00142        P00143        P00144
                                                            P00145
     LITERAL        P00366     7373737373737373             P00325
     LITERAL        P00360     77777777                     P00324
     LITERAL        P00362     0000000000000011             P00322
     LITERAL        P00361     00000011                     P00321
     LITERAL        P00356     00000012                     P00352
     LITERAL        P00364     2004440000000000             P00323
     LITERAL        P00370     2122232425262730             P00327
     LITERAL        P00357     21222324                     P00326

  SYMBOLS NOT REFERENCED

           BCDBOXS     EXT        FDPBOXS    EXT
```

```
COMPASS-32    (2.1)              EXAMPLE 20 (AVERAGE)                                              11/21/66  PAGE      1


  ENTRY-POINT SYMBOLS
      START            00000


  LENGTH OF SUBPROGRAM       00016
  LENGTH OF COMMON           00000
  LENGTH OF DATA             00000
```

```
COMPASS-32    (2.1)              EXAMPLE 20 (AVERAGE)                              11/21/66  PAGE     2
                                        THIS PROGRAM WILL COMPUTE THE AVERAGE OF THREE POSITIVE NUMBERS

                                            ENTRY     START
     00000  01077777 01 0  77777 0  START   UJP       **                    EXIT TO MONITOR PROGRAM
     00001  20000011 20 0 P00011 0          LDA       NUMB1                 LOAD FIRST NUMBER INTO A
     00002  30000012 30 0 P00012 0          ADA       NUMB2                 ADD SECOND NUMBER
     00003  30000013 30 0 P00013 0          ADA       NUMB3                 ADD THIRD NUMBER
     00004  13077747 13 0  77747 0          SHAW      -24                   CONVERT TO A 48 BIT VALUE
     00005  51000014 51 0 P00014 0          DVA       THREE                 DIVIDE BY THREE
     00006  40000015 40 0 P00015 0          STA       AVG                   STORE RESULT
     00007  77770000 77 1  70000 3          UCS                             STOP
     00010  01000000 01 0 P00000 0          UJP       START                 GO TO EXIT ON RESTART
     00011           00000100       NUMB1   OCT       100                   CONSTANT (100 OCTAL)
     00012           00000011       NUMB2   DEC       9                     CONSTANT (9 DECIMAL, 11 OCTAL)
     00013           00000020       NUMB3   OCT       20                    CONSTANT (20 OCTAL)
     00014           00000003       THREE   DEC       3                     CONSTANT (3)
     00015                          AVG     BSS       1                     RESERVED LOCATION FOR RESULT
                                            END       START

                                           NUMBER OF LINES WITH DIAGNOSTICS         0
```

```
COMPASS-32    (2.1)              EXAMPLE 20 (AVERAGE)                              11/21/66  PAGE     1

      AVG          P00015                        P00006
      NUMB1        P00011                        P00001
      NUMB2        P00012                        P00002
      NUMB3        P00013                        P00003
      START        P00000                        P00010
      THREE        P00014                        P00005
```

```
COMPASS-32    (2.1)              EXAMPLE 19A  (CR2PR)                         11/21/66  PAGE     1


  ENTRY-POINT SYMBOLS
      START           00000


  LENGTH OF SUBPROGRAM        00045
  LENGTH OF COMMON            00000
  LENGTH OF DATA              00000
```

```
COMPASS-32    (2.1)              EXAMPLE 19A  (CR2PR)                         11/21/66  PAGE     2
                                                ENTRY     START
                                      THIS PROGRAM WILL READ ONE HOLLERITH CARD AND COPY IT ON THE LINE PRINTER

       00000  01077777 01 0  77777 0  START    UJP       **
       00001  77012000 77 0  12000 0  REPEAT   CON       2000B,1                ESTABLISH CONNECTION TO CR
       00002  01000001 01 0 P00001 0           UJP       *-1                    REJECT INSTRUCTION
       00003  74000045 74 0 P00045 0           INPW      1,BUF,BUF+20           INITIATE INPUT OF ONE CARD
       00004  10000021 10 0 P00021 0
       00005  01000003 01 0 P00003 0           UJP       *-2                    REJECT INSTRUCTION
       00006  77310002 77 0  10002 3           INS       2,1                    SENSE TO SEE IF CHANNEL 1 IS BUSY
       00007  01000006 01 0 P00006 0           UJP       *-1                    BUSY - THEN KEEP CHECKING
       00010  77013000 77 0  13000 0           CON       3000B,1                NOT BUSY - THEN CONNECT TO PR
       00011  01000010 01 0 P00010 0           UJP       *-1                    REJECT INSTRUCTION
       00012  76000045 76 0 P00045 0           OUTW      1,BUF,BUF+20           INITIATE OUTPUT OPERATION
       00013  10000021 10 0 P00021 0
       00014  01000012 01 0 P00012 0           UJP       *-2                    REJECT INSTRUCTION
       00015  77310004 77 0  10004 3           INS       4,1                    SENSE TO SEE IF CHANNEL 1 IS BUSY
       00016  01000015 01 0 P00015 0           UJP       *-1                    BUSY - THEN KEEP CHECKING
       00017  77770000 77 1  70000 3           UCS                              NOT BUSY - THEN STOP
       00020  01000001 01 0 P00001 0           UJP       REPEAT                 REPEAT ON RESTART
       00021                          BUF      BSS       20
                                               END       START

                                             NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)            EXAMPLE 19A  (CR2PR)                    11/21/66  PAGE    1

      BUF         P00021                  P00003        P00003        P00012        P00012
      REPEAT      P00001                  P00020

   SYMBOLS NOT REFERENCED

          *START     P00000
```

```
COMPASS-32    (2.1)            EXAMPLE 21 (CODE)                       11/21/66  PAGE    1


   ENTRY-POINT SYMBOLS
        IN.OUT         00000


   LENGTH OF SUBPROGRAM        00014
   LENGTH OF COMMON            00000
   LENGTH OF DATA              00000
```

```
                                        ENTRY      IN.OUT
                              THIS PROGRAM WILL HANG IN A LOOP UNTIL THE SELECTIVE JUMP KEYS ARE
                              SET TO A CODE OF 35 OCTAL. PROGRAM REPEATS ON RESTART.

00000  01077777 01 0  77777 0  IN.OUT  UJP      **
00001  00100003 00 0 P00003 1  LOOP    SJ1      *+2                TEST BIT 0
00002  01000001 01 0 P00001 0          UJP      LOOP
00003  00200001 00 0 P00001 2          SJ2      LOOP               TEST BIT 1
00004  00300006 00 0 P00006 3          SJ3      *+2                TEST BIT 2
00005  01000001 01 0 P00001 0          UJP      LOOP
00006  00400010 00 1 P00010 0          SJ4      *+2                TEST BIT 3
00007  01000001 01 0 P00001 0          UJP      LOOP
00010  00500012 00 1 P00012 1          SJ5      *+2                TEST BIT 4
00011  01000001 01 0 P00001 0          UJP      LOOP
00012  00600001 00 1 P00001 2          SJ6      LOOP               TEST BIT 5
00013  00000001 00 0 P00001 0          HLT      IN.OUT+1           STOP
                                       END      IN.OUT

                                       NUMBER OF LINES WITH DIAGNOSTICS        0
```



```
IN.OUT    P00000              P00013
LOOP      P00001              P00002      P00003      P00005      P00007
                              P00011      P00012
```

```
COMPASS-32    (2.1)                EXAMPLE 22 (MEQ.TEST)                         11/21/66  PAGE     1


   ENTRY-POINT SYMBOLS
       START             00000


   LENGTH OF SUBPROGRAM        00014
   LENGTH OF COMMON            00000
   LENGTH OF DATA              00000
```

```
COMPASS-32    (2.1)                EXAMPLE 22 (MEQ.TEST)                          11/21/66  PAGE     2
                                               ENTRY     START
                                        THIS PROGRAM WILL COUNT THE NUMBER OF EVEN LOCATIONS IN MEMORY (8K)
                                        WITH 35 IN CHARACTER POSITION 2.

        00000  01077777 01 0  77777 0  START    UJP      **
        00001  14300000 14 0  00000 3           ENI      0,3                  CLEAR COUNTER (B3)
        00002  14117776 14 0  17776 1           ENI      17776B,1            SET B1 TO 17776B
        00003  14603500 14 1  03500 2           ENA      3500B                SET SEARCH PATTERN IN A
        00004  14707700 14 1  07700 3           ENQ      7700B                SET SEARCH MASK IN Q
        00005  06200000 06 0  00000 2  REENTER  MEQ      0,2                  *** SEARCH ***
        00006  01000011 01 0 P00011 0           UJP      STOP                 ** NOT FOUND ** THEN STOP
        00007  15300001 15 0  00001 3           INI      1,3                  ** FOUND ** THEN INCREASE COUNT
        00010  01000005 01 0 P00005 0           UJP      REENTER                          AND CONTINUE SEARCH
        00011  77770000 77 1  70000 3  STOP     UCS                           DISPLAY RESULTS IN B3
        00012  00100000 00 0 P00000 1           SJ1      START                EXIT IF JUMP KEY 1 IS SET
        00013  01000001 01 0 P00001 0           UJP      START+1              OTHERWISE REPEAT
                                                END      START

                                             NUMBER OF LINES WITH DIAGNOSTICS         0
```

```
     REENTER    P00005                     P00010
     START      P00000                     P00012          P00013
     STOP       P00011                     P00006
```



```
  ENTRY-POINT SYMBOLS
      TY.OUT          00000


  LENGTH OF SUBPROGRAM       00010
  LENGTH OF COMMON           00000
  LENGTH OF DATA             00000
```

```
COMPASS-32    (2.1)              EXAMPLE 23 (TY.OUT)                                         11/21/66  PAGE     2
                                              ENTRY      TY.OUT
                                       THIS IS A CLOSED SUBROUTINE FOR TYPING MESSAGE ON THE CONSOLE TY.

                                              CALLING SEQUENCE    ECHA       FCA (FIRST CHAR ADRS OF MSGE)
                                                                  ENQ        NUMB CHARS (LENGTH OF MESSAGE)
                                                                  RTJ        TY.OUT
                                                                  NEXT INSTRUCTION

                                              NOTE  TY.OUT MUST BE DECLARED EXTERNAL (EXT    TY.OUT)

      00000  01077777 01 0  77777 0  TY.OUT   UJP      **
      00001  77600400 77 1  00400 2           PAUS     400B                 IS TY CURRENTLY BUSY
      00002  01000001 01 0 P00001 0           UJP      *-1                  YES - THEN KEEP CHECKING
      00003  53420023 53 1  20023 0           TAM      23B                  NO - THEN PLACE FCA IN REG 23B
      00004  53040000 53 0  40000 0           AQA                           FORM LCA+1
      00005  53420033 53 1  20033 0           TAM      33B                  PLACE LCA+1 IN REG 33B
      00006  77760000 77 1  60000 3           CTO                           INITIATE OUTPUT
      00007  01000000 01 0 P00000 0           UJP      TY.OUT               RETURN TO USER
                                              END

                                             NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)              EXAMPLE 23 (TY.OUT)                                         11/21/66  PAGE     1

      TY.OUT       P00000                         P00007
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                   11/21/66  PAGE     1


   ENTRY-POINT SYMBOLS
       START          00000


   LENGTH OF SUBPROGRAM       00614
   LENGTH OF COMMON           00000
   LENGTH OF DATA             00000
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                   11/21/66  PAGE     2
                                                 ENTRY      START
       00000  01077777 01 0  77777 0  START      UJP        **

                                         THE FOLLOWING INSTRUCTIONS WILL INITIATE AN OUTPUT TO THE CONSOLE TY

       00001  11000034 11 0 P00007 0             ECHA       MSG                      FIRST CHAR ADRS TO  A
       00002  53420023 53 1  20023 0             TAM        23B                      THEN TO REG FILF LOC 23B
       00003  11003060 11 0 P00614 0             ECHA       MSGEND                   LAST CHAR  ADRS TO  A
       00004  53420033 53 1  20033 0             TAM        33B                      THEN TO REG FILF LOC 33B
       00005  77760000 77 1  60000 3             CTO                                 INITIATE TYPF OUT

       00006  00000000 00 0 P00000 0             HLT        START                    EXIT BACK TO SCOPE ON RESTART

                                         FOLLOWING IS THE MESSAGE

       00007           31602144          MSG     BCD,C      40,I AM A CONTROL DATA 3200 COMPUTER. I AM
       00010           60216023
       00011           46456351
       00012           46436024
       00013           21632160
       00014           03020000
       00015           60234644
       00016           47646325
       00017           51336031
       00020           60214460
       00021           77575757                  OCT        77575757
       00022           21602231                  BCD,C      44,A BINARY, FIXED WORD LENGTH, STORED PROGRAM,
       00023           45215170
       00024           73602631
       00025           67252460
       00026           66465124
       00027           60432545
       00030           27633073
       00031           60626346
       00032           51252460
       00033           47514627
       00034           51214473
       00035           77575757                  OCT        77575757
       00036           24312731                  BCD,C      16,DIGITAL COMPUTER
       00037           63214360
       00040           23464447
       00041           64632551
       00042           77775757                  OCT        77775757
       00043           63302562                  BCD,C      28,THESE ARE MY SPECIFICATIONS
       00044           25602151
       00045           25604470
       00046           60624725
       00047           23312631
       00050           23216331
       00051           46456260
       00052           77775757                  OCT        77775757
       00053           01330205                  BCD,C      36,1.25 MICRO SECOND MEMORY CYCLE TIME
       00054           60443123
       00055           51466062
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                  11/21/66  PAGE    3
        00056          25234645
        00057          24604425
        00060          44465170
        00061          60237023
        00062          43256063
        00063          31442560
        00064          77575757          OCT      77575757
        00065          10427360          BCD,C    40,8K, 16K, OR 32K  WORDS OF CORE STORAGE
        00066          01064273
        00067          60465160
        00070          03024260
        00071          60664651
        00072          24626046
        00073          26602346
        00074          51256062
        00075          63465121
        00076          27256060
        00077          77575757          OCT      77575757
        00100          02046022          BCD,C    20,24 BIT WORD LENGTH
        00101          31636066
        00102          46512460
        00103          43254527
        00104          63306060
        00105          77575757          OCT      77575757
        00106          03603145          BCD,C    20,3 INDEX REGISTERS
        00107          24256760
        00110          51252731
        00111          62632551
        00112          62606060
        00113          77575757          OCT      77575757
        00114          44644363          BCD,C    32,MULTI-LEVEL INDIRECT ADDRESSING
        00115          31404325
        00116          65254360
        00117          31452431
        00120          51252363
        00121          60212424
        00122          51256262
        00123          31452760
        00124          77575757          OCT      77575757
        00125          23302151          BCD,C    32,CHARACTER HANDLING INSTRUCTIONS
        00126          21236325
        00127          51603021
        00130          45244331
        00131          45276031
        00132          45626351
        00133          64236331
        00134          46456260
        00135          77575757          OCT      77575757
        00136          22642626          BCD,C    48,BUFFERED CHARACTER SEARCH AND MOVE OPERATIONS
        00137          25512524
        00140          60233021
        00141          51212363
        00142          25516062
        00143          25215123
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                  11/21/66  PAGE    4
        00144          30602145
        00145          24604446
        00146          65256046
        00147          47255121
        00150          63314645
        00151          62606060
        00152          77575757          OCT      77575757
        00153          23464562          BCD,C    20,CONSOLE TYPEWRITER
        00154          46432560
        00155          63704725
        00156          66513163
        00157          25516060
        00160          77575757          OCT      77575757
        00161          51252143          BCD,C    16,REAL TIME CLOCK
        00162          60633144
        00163          25602343
        00164          46234260
        00165          77775757          OCT      77775757
        00166          62632145          BCD,C    32,STANDARD ARITHMETIC CAPABILITIES
        00167          24215124
        00170          60215131
        00171          63304425
        00172          63312360
        00173          23214721
        00174          22314331
        00175          63312562
        00176          77776060          OCT      77776060
        00177          02046022          BCD,C    28,24 BIT  ADD, SUB, MULT + DIV
        00200          31636060
        00201          21242473
        00202          60626422
        00203          73604464
        00204          43636020
        00205          60243165
        00206          77576060          OCT      77576060
        00207          04106022          BCD,C    20,48 BIT  ADD + SUB
        00210          31636060
        00211          21242460
        00212          20606264
        00213          22606060
        00214          77775757          OCT      77775757
        00215          46476331          BCD,C    32,OPTIONAL ARITHMETIC CAPABILITIES
        00216          46452143
        00217          60215131
        00220          63304425
        00221          63312360
        00222          23214721
        00223          22314331
        00224          63312562
        00225          77776060          OCT      77776060
        00226          26476124          BCD,C    52,FP/DP PACKAGE     FLOATING POINT ADD, SUB, MULT +
        00227          47604721
        00230          23422127
        00231          25606060
```

```
        00232          60602643
        00233          46216331
        00234          45276047
        00235          46314563
        00236          60212424
        00237          73606264
        00240          22736044
        00241          64436360
        00242          20606060
        00243          77576060              OCT      77576060
        00244          60606060              BCD,C    48,                  DIVIDE AND FIXED POINT 48 BIT
        00245          60606060
        00246          60606060
        00247          60606060
        00250          60602431
        00251          65312425
        00252          60214524
        00253          60263167
        00254          25246047
        00255          46314563
        00256          60041060
        00257          22316360
        00260          77576060              OCT      77576060
        00261          60606060              BCD,C    28,                  MULT + DIV
        00262          60606060
        00263          60606060
        00264          60606060
        00265          60604464
        00266          43636020
        00267          60243165
        00270          77576060              OCT      77576060
        00271          22232460              BCD,C    52,BCD PACKAGE       BINARY CODED DECIMAL  ADD + SUB
        00272          47212342
        00273          21272560
        00274          60606060
        00275          60602231
        00276          45215170
        00277          60234624
        00300          25246024
        00301          25233144
        00302          21436060
        00303          21242460
        00304          20606264
        00305          22606060
        00306          77775757              OCT      77775757
        00307          31454764              BCD,C    28,INPUT/OUTPUT CAPABILITIES
        00310          63614664
        00311          63476463
        00312          60232147
        00313          21223143
        00314          31633125
        00315          62606060
        00316          77776060              OCT      77776060
        00317          02401060              BCD,C    20,2-8 DATA CHANNELS
```



```
        00320          24216321
        00321          60233021
        00322          45452543
        00323          62606060
        00324          77576060              OCT      77576060
        00325          01401060              BCD,C    44,1-8 EQUIPMENT CONTROLLERS PER DATA CHANNEL
        00326          25506431
        00327          47442545
        00330          63602346
        00331          45635146
        00332          43432551
        00333          62604725
        00334          51602421
        00335          63216023
        00336          30214545
        00337          25436060
        00340          77776060              OCT      77776060
        00341          60606060              BCD,C    40,    AVAILABLE EQUIPMENT           SPEEDS
        00342          21652131
        00343          43212243
        00344          25602550
        00345          64314744
        00346          25456360
        00347          60606060
        00350          60606060
        00351          60606247
        00352          25252462
        00353          77576060              OCT      77576060
        00354          60606060              BCD,C    48,      MAGNETIC TAPES              7.5KC - 120KC
        00355          60604421
        00356          27452563
        00357          31236063
        00360          21472562
        00361          60606060
        00362          60606060
        00363          60606060
        00364          60073305
        00365          42236040
        00366          60010200
        00367          42236060
        00370          77576060              OCT      77576060
        00371          60606060              BCD,C    48,      CARD READER                 1200 CARDS/MIN
        00372          60602321
        00373          51246051
        00374          25212425
        00375          51606060
        00376          60606060
        00377          60606060
        00400          60606060
        00401          60010200
        00402          00602321
        00403          51246261
        00404          44314560
        00405          77576060              OCT      77576060
```

```
COMPASS-32    (2.1)                EXAMPLE 24 (DEMO)                                 11/21/66  PAGE    7
      00406        60606060                 BCD,C     48,      CARD PUNCHES          150 - 250 CARDS/MIN
      00407        60602321
      00410        51246047
      00411        64452330
      00412        25626060
      00413        60606060
      00414        60606001
      00415        05006040
      00416        60020500
      00417        60232151
      00420        24626144
      00421        31456060
      00422        77576060                 OCT       77576060
      00423        60606060                 BCD,C     48,      PAPER TAPE STATIONS   350 - 1000 CPS  READ
      00424        60604721
      00425        47255160
      00426        63214725
      00427        60626321
      00430        63314645
      00431        62606003
      00432        05006040
      00433        60010000
      00434        00602347
      00435        44606051
      00436        25212060
      00437        77576060                 OCT       77576060
      00440        60606060                 BCD,C     48,                                  110 CPS  PUNCH
      00441        60606060
      00442        60606060
      00443        60606060
      00444        60606060
      00445        60606060
      00446        60606060
      00447        60606060
      00450        60600101
      00451        00602347
      00452        44606047
      00453        64452330
      00454        77576060                 OCT       77576060
      00455        60606060                 BCD,C     48,      LINE PRINTERS         150 - 1000 LINES/MIN
      00456        60604331
      00457        45256047
      00460        51314563
      00461        25516260
      00462        60606060
      00463        60606001
      00464        05006040
      00465        60010000
      00466        00604331
      00467        45256261
      00470        44314560
      00471        77576060                 OCT       77576060
      00472        60606060                 BCD,C     52,      DISC PACKS            97 MILLI SEC AVG ACCESS
      00473        60602431
```

```
COMPASS-32    (2.1)                EXAMPLE 24 (DEMO)                                 11/21/66  PAGE    8
      00474        62236047
      00475        21234262
      00476        60606060
      00477        60606060
      00500        60606011
      00501        07604431
      00502        43433160
      00503        62252360
      00504        21652760
      00505        21232325
      00506        62626060
      00507        77576060                 OCT       77576060
      00510        60606060                 BCD,C     48,                            71K CHAR/SEC AVG XFER
      00511        60606060
      00512        60606060
      00513        60606060
      00514        60606060
      00515        60606060
      00516        60606007
      00517        01426023
      00520        30215161
      00521        62252360
      00522        21652760
      00523        67262551
      00524        77576060                 OCT       77576060
      00525        60606060                 BCD,C     52,      DRUM STORAGE          17 MILLI SEC AVG ACCESS
      00526        60602451
      00527        64446062
      00530        63465121
      00531        27256060
      00532        60606060
      00533        60606001
      00534        07604431
      00535        43433160
      00536        62252360
      00537        21652760
      00540        21232325
      00541        62626060
      00542        77576060                 OCT       77576060
      00543        60606060                 BCD,C     48,                  250K - 2M CHAR/SEC DATA XFER
      00544        60606060
      00545        60606060
      00546        60606060
      00547        60606060
      00550        02050042
      00551        60406002
      00552        44602330
      00553        21516162
      00554        25236024
      00555        21632160
      00556        67262551
      00557        77576060                 OCT       77576060
      00560        60606060                 BCD,C     16,      PLOTTERS
      00561        60604743
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                         11/21/66  PAGE     9
         00562         46636325
         00563         51626060
         00564         77576060                  OCT       77576060
         00565         60606060                  BCD,C     20,        PAGE READER
         00566         60604721
         00567         27256051
         00570         25212425
         00571         51606060
         00572         77576060                  OCT       77576060
         00573         60606060                  BCD,C     24,        CRT DISPLAY UNITS
         00574         60602351
         00575         63602431
         00576         62474321
         00577         70606445
         00600         31636260
         00601         77576060                  OCT       77576060
         00602         60606060                  BCD,C     40,        AND MANY OTHER SPECIALIZED DEVICES
         00603         60602145
         00604         24604421
         00605         45706046
         00606         63302551
         00607         60624725
         00610         23312143
         00611         31712524
         00612         60242565
         00613         31232562
                             00614     MSGEND    EQU,C     *
                                                 END       START
                                                NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)              EXAMPLE 24 (DEMO)                                         11/21/66  PAGE     1

       MSG        P00007                            P00001
       MSGEND     P00614 0                          P00003
       START      P00000                            P00006
```

```
ENTRY-POINT SYMBOLS
    MTDRIVER        00000


LENGTH OF SUBPROGRAM        00101
LENGTH OF COMMON            00000
LENGTH OF DATA              00000
```



```
          ENTRY     MTDRIVER
THIS SUBPROGRAM IS AN I/O DRIVER DESIGNED TO HANDLE ALL MAG TAPE
OPERATIONS. USE OF THIS DRIVER WILL GREATLY REDUCE THE AMOUNT OF EFFORT
REQUIRED ON THE PROGRAMMER≠S PART WHEN WORKING WITH MAG TAPE. HE NEED
NOT EVEN BE CONCERNED WITH THE EQUIPMENT CONFIGURATION OF THE PARTICULAR
MACHINE IN USE, SINCE THIS IS HANDLED BY MTDRIVER.

          ---------- CALLING SEQUENCE ----------

                    1. SET PARAMETERS INTO  A + Q

                      (A)   A = TAPE UNIT NUMBER (0-7)
                      (B)   Q 23-18 = FUNCTION CODE
                      (C)   Q 14-00 = BUFFER FWA (NEEDED FOR I/O REQUEST ONLY)

                    2. RTJ  TO  MTDRIVER  (MTDRIVER MUST BE DECLARED EXTERNAL)

          ---------- OPERATIONS AVAILABLE ----------

                           OPERATION                    FUNCTION CODE (OCTAL)

                    1. READ 30 WDS IN BCD (120 CHARS)          01
                    2. READ 40 WDS IN BINARY                   02
                    3. WRITE 30 WDS IN BCD (120 CHARS)         03
                    4. WRITE 40 WDS IN BINARY                  04
                    5. REWIND                                  10
                    6. UNLOAD                                  11
                    7. BACKSPACE                               12
                    8. SEARCH FILE FORWARD                     13
                    9. SEARCH FILE BACKWARD                    14
                   10. WRITE FILE MARK                         15
                   11. SKIP BAD SPOT                           16

          ---------- ON RETURN ----------

                    1. B REGS ARE UNCHANGED.
                    2. IF REQUEST WAS I/O (FC 1-4), THE OPERATION WILL BE
                       COMPLETE.
                    3. A 11-00 = STATUS FROM THE TAPE AT END OF OPERATION
                                 IF REQUEST WAS I/O (FC 1-4).
                    4. A IS MEANINGLESS IF NOT I/O REQUEST.
                    5. Q IS MEANINGLESS.

          ---------- ERROR PROCEDURES ----------

                    1. IF TAPE UNIT IS FOUND ≠NOT READY≠ A DIAGNOSTIC
                       WILL BE TYPED (READY MT X), PROGRAM WILL CONTINUE
                       WHEN UNIT IS READY.
                    2. ALL REJECTS WILL LOOP.
```

```
COMPASS-32     (2.1)              EXAMPLE   25 (MTDRIVER)                         11/21/66  PAGE    3
      00000  01077777 01 0  77777 0  MTDRIVER UJP       **              LINKAGE BACK TO USER

                                  ******* INITIALIZING PROCEDURE ******

      00001  42000157 42 0 P00033 3           SACH      CONNECT+3       ESTABLISH CONNECT CODE
      00002  42000371 42 0 P00076 1           SACH      RDYMSG+9        SET TAPE NO. IN READY MESSAGE

      00003  14600000 14 1  00000 2           ENA       0               PLACE FUNCTION CODE
      00004  13000006 13 0  00006 0           SHAQ      6               IN  A 5-0.
      00005  42000400 42 0 P00100 0           SACH      FC              SAVE FUNCTION CODE
      00006  05600017 05 1  00017 2           ASG       17B             IS THIS AN
      00007  05600010 05 1  00010 2           ASG       10B             I/O REQUEST
      00010  01000013 01 0 P00013 0           UJP       INPOUT            YES - THEN  JUMP

      00011  42000247 42 0 P00051 3           SACH      SELECT+3          NO - THEN SET SELECT CODE AND
      00012  01000033 01 0 P00033 0           UJP       CONNECT                GO TO CONNECT PROCEDURE

      00013  05600005 05 1  00005 2  INPOUT   ASG       5               TEST TO SEE IF FUNCTION CODE IS
      00014  05600001 05 1  00001 2           ASG       1               LEGAL.
      00015  00000015 00 0 P00015 0           HLT       *               BLIND HALT ON ILLEGAL CODE

      00016  12000005 12 0  00005 0           SHA       5               POSITION  FC AND FWA IN A
      00017  13000022 13 0  00022 0           SHAQ      18              A 14-00 = FWA OF USER#S BUFFER
                                                                        A 23 = 1 IF BCD REQUEST ,0 IF BINARY

      00020  14700002 14 1  00002 3           ENQ       2               BCD SELECT CODE TO Q  +
      00021  03300023 03 0 P00023 3           AZJ,LT    *+2             IS REQUEST BCD
      00022  14700001 14 1  00001 3           ENQ       1                 NO  - THEN BINARY CODE TO Q
      00023  43000247 43 0 P00051 3           SQCH      SELECT+3        PLACE SELECTED CODE IN SEL INSTRUCTION

      00024  44000066 44 0 P00066 0           SWA       INPUT+1         SET FWA IN INPUT/OUTPUT
      00025  44000062 44 0 P00062 0           SWA       OUTPUT+1        INSTRUCTIONS
      00026  15600036 15 1  00036 2           INA       30              FORM BCD LWA+1
      00027  03300031 03 0 P00031 3           AZJ,LT    *+2             IS REQUESTBCD
      00030  15600012 15 1  00012 2           INA       10                NO - THEN FORM BINARY LWA+1
      00031  44000065 44 0 P00065 0           SWA       INPUT           SET LWA+1 IN INPUT/OUTPUT
      00032  44000061 44 0 P00061 0           SWA       OUTPUT          INSTRUCTIONS
```

```
COMPASS-32     (2.1)              EXAMPLE   25 (MTDRIVER)                         11/21/66  PAGE    4
                                  ******* CONNECT PROCEDURE ********

      00033  77001000 77 0  01000 0  CONNECT  CON       CONCODE,CH      CONNECT TO SPECIFIED MAG TAPE
      00034  01000033 01 0 P00033 0           UJP       *-1

                                  ******* TEST FOR READY ********

      00035  77200001 77 0  00001 2           EXS       0001,CH         IS THE CONNECTED UNIT READY
      00036  01000051 01 0 P00051 0           UJP       SELECT            YES - THEN GO TO SELECT PROCEDURE

      00037  77600400 77 1  00400 2           PAUS      400B              NO - THEN TYPE DIAGNOSTIC
      00040  01000037 01 0 P00037 0           UJP       *-1             WAIT FOR TY NOT BUSY

      00041  11000360 11 0 P00074 0           ECHA      RDYMSG          -
      00042  53420023 53 1  20023 0           TAM       23B              -
      00043  15600013 15 1  00013 2           INA       11               - INITIATE TY OUTPUT
      00044  53420033 53 1  20033 0           TAM       33B              -
      00045  77760000 77 1  60000 3           CTO

      00046  77200001 77 0  00001 2           EXS       0001,CH         -
      00047  01000051 01 0 P00051 0           UJP       *+2             - LOOP UNTIL READY
      00050  01000046 01 0 P00046 0           UJP       *-2             -

                                  ******* SELECT PROCEDURE *********

      00051  77100000 77 0  00000 1  SELECT   SEL       0000,CH         INITIATE NON-I/O OPERATION OR
      00052  01000051 01 0 P00051 0           UJP       *-1             SELECT MODE FOR I/O OPERATION

      00053  22000400 22 0 P00100 0           LACH      FC              FUNCTION CODE TO A
      00054  05600006 05 1  00006 2           ASG       6               IS THIS AN I/O REQUEST
      00055  01000055 01 0 P00055 0           UJP       *                 NO - THEN GO TO READ/WRITE PROCEDURE
      00056  01000072 01 0 P00072 0           UJP       EXIT              YES - THEN  GO TO EXIT

                                  ******* READ/WRITE PROCEDURE ********

      00057  05600003 05 1  00003 2           ASG       3               IS THIS A READ REQUEST
      00060  01000065 01 0 P00065 0           UJP       INPUT             YES - GO TO INPUT INSTRUCTION

      00061  76077777 76 0  77777 0  OUTPUT   OUT*      CH,**,**          NO -  THEN  INITIATE OUTPUT
      00062  00077777 00 0  77777 0
      00063  01000061 01 0 P00061 0           UJP       *-2             LOOP ON REJECT
      00064  01000070 01 0 P00070 0           UJP       WAIT            GO TO WAIT BEFORE EXIT

      00065  74077777 74 0  77777 0  INPUT    INP*      CH,**,**        INITIATE INPUT
      00066  00077777 00 0  77777 0
      00067  01000065 01 0 P00065 0           UJP       *-2             LOOP ON REJECT
```

```
                                        ******* WAIT FOR END OF OPERATION ********

    00070  77200002 77 0  00002 2  WAIT     EXS      0002,CH              IS UNIT STILL BUSY
    00071  01000070 01 0 P00070 0           UJP      *-1                    YES - THEN LOOP

                                        ******* EXIT PROCEDURE ********

    00072  77200000 77 0  00000 2  EXIT     COPY     CH
    00073  01000000 01 0 P00000 0           UJP      MTDRIVER             RETURN TO USER

                                        ******* MISCELLANEOUS ********

    00074           51252124       RDYMSG   BCD,C    10,READY MT X
    00075           70604463
    00076           6067
    00077           77000000                VFD      06/77
    00100                          FC       BSS,C    1

                                        ******* SYMBOL EQUATIONS ********

                          00000    CH       EQU      0                    THIS DRIVER MAY BE ALTERED TO FIT ANY
                          01000    CONCODE  EQU      1000B                EQUIPMENT CONFIGURATION BY ONLY THESE
                                            END

                                             NUMBER OF LINES WITH DIAGNOSTICS        0
```



```
    CH          00000                      P00033      P00035      P00046      P00051
                                           P00061      P00065      P00070      P00072
    CONCODE     01000                      P00033
    CONNECT     P00033                     P00001      P00012
    EXIT        P00072                     P00056
    FC          P00100                     P00005      P00053
    INPOUT      P00013                     P00010
    INPUT       P00065                     P00024      P00031      P00060
    MTDRIVER    P00000                     P00073
    OUTPUT      P00061                     P00025      P00032
    RDYMSG      P00074                     P00002      P00041
    SELECT      P00051                     P00011      P00023      P00036
    WAIT        P00070                     P00064
```

```
COMPASS-32    (2.1)              MAC                                    11/21/66  PAGE     1

   EXTERNAL SYMBOLS
       CIO


   LENGTH OF SUBPROGRAM        00076
   LENGTH OF COMMON            00000
   LENGTH OF DATA              00000
```

```
COMPASS-32    (2.1)              MAC                                    11/21/66  PAGE     2
                                           LIBM       READS,REWIND,STATUS,FORMAT
                                  ***************************************************************************
                                           MACRO EXAMPLES


                                  READS    MACRO      (L,R,FWA,N,X,IA,M,C)
                                           EXT        CIO
                                           RTJ        CIO
                                           01         L,X
                                           IFT        /*/,R,1
                                           UJP        *-2
                                           IFF        /*/,R,1
                                           UJP        R
                                           M          FWA
                                           C          N
                                           IFF        /0/,X,1
                                           00         IA
                                           ENDM
                                  REWIND   MACRO      (L,R,X,IA)
                                           EXT        CIO
                                           RTJ        CIO
                                           04         L,X
                                           IFT        /*/,R,1
                                           UJP        *-2
                                           IFF        /*/,R,1
                                           UJP        R
                                           IFF        /0/,X,1
                                           00         IA
                                           ENDM
                                  STATUS   MACRO      (L,X)
                                           EXT        CIO
                                           RTJ        CIO
                                           13         L,X
                                           ENDM
                                  FORMAT   MACRO      (L,R,X)
                                           EXT        CIO
                                           RTJ        CIO
                                           14         L,X
                                           IFT        /*/,R,1
                                           UJP        *-2
                                           IFF        /*/,R,1
                                           UJP        R
                                           ENDM
                                           READS      (14,*,INBUFF,40,,,40)
                                           EXT CIO                                                  READS
     00000  00777777 00 1 X77777 3         RTJ CIO                                                  READS
     00001  01000016 01 0  00016 0         01 14,0                                                  READS
                                           IFT *,*,1                                                READS
     00002  01000000 01 0 P00000 0         UJP *-2                                                  READS
                                           IFF *,*,1                                                READS
     00003  40000026 40 0 P00026 0         40 INBUFF                                                READS
     00004  00000050 00 0  00050 0         0 40                                                     READS
```

```
COMPASS-32    (2.1)           MAC                                          11/21/66  PAGE     3
                                              IFF 0,0,1                                         READS

                                              READS     (14,REJX,INBUFF,40,2,INTADD,40,40)
                                              EXT CIO                                           READS
      00005  00700000 00 1 X00000 3           RTJ CIO                                           READS
      00006  01200016 01 0  00016 2           01 14,2                                           READS
                                              IFT *,REJX,1                                      READS
                                              IFF *,REJX,1                                      READS
      00007  01000024 01 0 P00024 0           UJP REJX                                          READS
      00010  40000026 40 0 P00026 0           40 INBUFF                                         READS
      00011  40000050 40 0  00050 0           40 40                                             READS
                                              IFF 0,2,1                                         READS
      00012  00000022 00 0 P00022 0           00 INTADD                                         READS

                                              REWIND    (14,*)
                                              EXT CIO                                           REWIND
      00013  00700005 00 1 X00005 3           RTJ CIO                                           REWIND
      00014  04000016 04 0  00016 0           04 14,0                                           REWIND
                                              IFT *,*,1                                         REWIND
      00015  01000013 01 0 P00013 0           UJP *-2                                           REWIND
                                              IFF *,*,1                                         REWIND
                                              IFF 0,0,1                                         REWIND

                                              FORMAT    (14,14,2)
                                              EXT CIO                                           FORMAT
      00016  00700013 00 1 X00013 3           RTJ CIO                                           FORMAT
      00017  14200016 14 0  00016 2           14 14,2                                           FORMAT
                                              IFT *,14,1                                        FORMAT
                                              IFF *,14,1                                        FORMAT
      00020  01000016 01 0  00016 0           UJP 14                                            FORMAT

      00021  77770000 77 1  70000 3           UCS
      00022  01077777 01 0  77777 0  INTADD   UJP       **
      00023  01400022 01 1 P00022 0           UJP,I     INTADD
      00024  01077777 01 0  77777 0  REJX     UJP       **
      00025  01400024 01 1 P00024 0           UJP,I     REJX
      00026                          INBUFF   BSS       40
                                              END
                                             NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)           MAC                                          11/21/66  PAGE     1

    CIO                          EXTERNAL     P00000      P00005      P00013      P00016
    INBUFF      P00026                        P00003      P00010
    INTADD      P00022                        P00012      P00023
    REJX        P00024                        P00007      P00025
```

```
EXTERNAL SYMBOLS
    PRDRIVER
    CRDRIVER
    MTDRIVER



ENTRY-POINT SYMBOLS
    COPY           00000



LENGTH OF SUBPROGRAM       00112
LENGTH OF COMMON           00000
LENGTH OF DATA             00000
```



```
                                               ENTRY     COPY
                                               EXT       MTDRIVER,CRDRIVER,PRDRIVER
                                           THIS SUBPROGRAM IS DESIGNED TO TEST THE DRIVERS THAT WERE WRITTEN
                                           PREVIOUSLY (EXAMPLE   25 AND WORKSHEET   8). IT COPIES A DECK OF HOLLERITH
                                           CARDS TO MAG TAPE, REWINDS THE TAPE AND COPIES THE TAPE ON THE PRINTER.

                                           PROGRAM REPEATS ON RESTART UNLESS JUMP KEY 1 IS SET IN WHICH CASE
                                           IT WILL EXIT BACK TO SCOPE.
00000  01077777 01 0  77777 0  COPY       UJP       **                    LINKAGE BACK TO SCOPE

                                          --------- REWIND TAPE 1 ---------

00001  14600010 14 1  00010 2             ENA       10B                   PLACE FUNCTION CODE
00002  13077771 13 0  77771 0             SHAQ      -6                       IN Q 23-18 (REWIND)
00003  14600001 14 1  00001 2             ENA       1                     PLACE TAPE NUMBER IN A 5-1
00004  00777777 00 1 X77777 3             RTJ       MTDRIVER

                                          --------- READ NEXT CARD --------

00005  14600054 14 1 P00054 2  NEXTCARD   ENA       BUF
00006  13077755 13 0  77755 0             SHAQ      -18
00007  14600001 14 1  00001 2             ENA       1
00010  13077771 13 0  77771 0             SHAQ      -6
00011  00777777 00 1 X77777 3             RTJ       CRDRIVER

                                          --------  TEST FOR END OF FILE CARD --------

00012  17600010 17 1  00010 2             ANA       10B
00013  03100023 03 0 P00023 1             AZJ,NE    FILEMARK

                                          --------- OUTPUT CARD IMAGE TO MAG TAPE 1 ---------

00014  14600054 14 1 P00054 2             ENA       BUF
00015  13077755 13 0  77755 0             SHAQ      -18
00016  14600003 14 1  00003 2             ENA       3
00017  13077771 13 0  77771 0             SHAQ      -6
00020  14600001 14 1  00001 2             ENA       1
00021  00700004 00 1 X00004 3             RTJ       MTDRIVER

00022  01000005 01 0 P00005 0             UJP       NEXTCARD
```

```
                                                  --------- CLOSE OUT MAG TAPE 1 WITH A FM ---------

00023 14600015 14 1  00015 2 FILEMARK ENA      15B
00024 13077771 13 0  77771 0          SHAQ     -6
00025 14600001 14 1  00001 2          ENA      1
00026 00700021 00 1 X00021 3          RTJ      MTDRIVER
                                      --------- REWIND MAG TAPE 1 ----------

00027 14600010 14 1  00010 2          ENA      10B
00030 13077771 13 0  77771 0          SHAQ     -6
00031 14600001 14 1  00001 2          ENA      1
00032 00700026 00 1 X00026 3          RTJ      MTDRIVER
                                      --------- READ NEXT RECORD FROM MAG TAPE 1 ---------

00033 14600054 14 1 P00054 2 NEXTREC  ENA      BUF
00034 13077755 13 0  77755 0          SHAQ     -18
00035 14600001 14 1  00001 2          ENA      1
00036 13077771 13 0  77771 0          SHAQ     -6
00037 14600001 14 1  00001 2          ENA      1
00040 00700032 00 1 X00032 3          RTJ      MTDRIVER
                                      --------- TEST FOR END OF FILE ---------

00041 17600010 17 1  00010 2          ANA      10B
00042 03100051 03 0 P00051 1          AZJ,NE   EXIT
                                      --------- OUTPUT RECORD TO PRINTER --------

00043 14600054 14 1 P00054 2          ENA      BUF
00044 13077755 13 0  77755 0          SHAQ     -18
00045 14600003 14 1  00003 2          ENA      3
00046 13077771 13 0  77771 0          SHAQ     -6
00047 00777777 00 1 X77777 3          RTJ      PRDRIVER

00050 01000033 01 0 P00033 0          UJP      NEXTREC
                                      --------- EXIT PROCEDURE ---------

00051 77770000 77 1  70000 3 EXIT     UCS
00052 00100000 00 0 P00000 1          SJ1      COPY
00053 01000001 01 0 P00001 0          UJP      COPY+1
```



```
                                      --------- BUFFER AREA --------

00054                        BUF      BSS      30

                                      END      COPY

                                      NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)              EXAMPLE   26  (COPY)                              11/21/66  PAGE     1

       BUF         P00054                            P00005         P00014        P00033         P00043
       COPY        P00000                            P00052         P00053
       CHDRIVER                   EXTERNAL           P00011
       EXIT        P00051                            P00042
       FILEMARK    P00023                            P00013
       MTDRIVER                   EXTERNAL           P00004         P00021        P00026         P00032
                                                     P00040
       NEXTCARD    P00005                            P00022
       NEXTREC     P00033                            P00050
       PRDRIVER                   EXTERNAL           P00047
```

```
COMPASS-32    (2.1)              CIC          VERSION  SI 0.0       12/07/64              11/21/66  PAGE     1


   EXTERNAL SYMBOLS
       CDI
       ABNORMAL


   ENTRY-POINT SYMBOLS
       CIC             00000
       CIT             00044


   LENGTH OF SUBPROGRAM        00072
   LENGTH OF COMMON            00000
   LENGTH OF DATA              00000
```

```
                                            * * * CENTRAL INTERRUPT CONTROL PROCEDURE   REVISED 12-04-64

                                                  WHENEVER AN INTERRUPT OCCURS, THE HARDWARE
                                                  1.  DISABLES THE INTERRUPT SYSTEM
                                                  2.  REPLACES (00004, BITS 14-00) WITH THE LOCATION OF THE
                                                      INTERRUPTED INSTRUCTION
                                                  3.  REPLACES (00005, BITS 11-00) WITH AN IDETIFYING CODE
                                                  4.  TRANSFERS CPU CONTROL TO LOCATION 00005.

                                                  SCOPE-32 LOADS THE FOLLOWING LINKAGE TO CIC
                                                  (00004)   UJP     0
                                                  (00005)   NOP     0
                                                  (00006)   UJP     CIC

                                                  CIC PERFORMS THE FOLLOWING TASKS
                                                  1.  LOGICALLY IGNORES AN INTERRUPT ON A DINT INSTRUCTION
                                                  2.  SAVES THE (A), (Q), (B1), (B2) AND (B3)
                                                  3.  SETS LOCKOUT FLAG TO IDENTIFY INTERRUPT PROCESSING
                                                  4.  TRANSFORMS INTERRUPT CODE INTO RELATIVE CIT ENTRY
                                                  5.  SETS ENTRY LOCATION (FROM CIT) TO LINK TO USER
                                                  6.  SETS INCL INSTRUCTION FOR EXECUTION ON USER RETURN
                                                  7.  RESTORES ABNORMAL ADDRESS TO CIT ENTRY
                                                  8.  ENTERS USER INTERRUPT PROCEDURE
                                                  9.  CLEARS NON-I/O INTERRUPTS
                                                  10. RESTORES LOCK-OUT FLAG
                                                  11. RESTORES SAVED REGISTERS
                                                  12. ENABLES INTERRUPT SYSTEM
                                                  13. EXITS TO INTERRUPTED PROGRAM
                                            * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```



```
                                          ENTRY    CIC,CIT
                                          EXT      ABNORMAL,CDI

00000  45000045 45 0 P00045 0  CIC        STAQ     CIT+1               SAVE (A) AND (Q)
                                - - - - - - - - -  LOGICALLY IGNORE INTERRUPT ON DINT - - - - - - - - -
00001  24400004 24 1  00004 0             LCA,I    4                   ((4))= INTERRUPTED INSTRUCTION
00002  37000043 37 0 P00043 0             LPA      DINT                MASK DINT INST (ZERO BITS 11-0)
00003  03100006 03 0 P00006 1             AZJ,NE   CIC2.1              JUMP IF ((4)) NOT DINT
00004  20000045 20 0 P00045 0             LDA      CIT+1               ELSE RESTORE (A)
00005  01400004 01 1  00004 0             UJP,I    4                   AND EXIT, INTERRUPT DISABLED
                                - - - - - - - - -  SAVE REGISTERS IN CIT - - - - - - - - - - - - - - -
00006  47100047 47 0 P00047 1  CIC2.1     STI      CIT+3,1             SAVE (B1)
00007  47200050 47 0 P00050 2             STI      CIT+4,2                  (B2)
00010  47300051 47 0 P00051 3             STI      CIT+5,3                  (B3)
                                - - - - - - - - -  SET LOCK-OUT FLAG   - - - - - - - - - - - - - - - -
00011  14477777 14 1  77777 0             ENA,S    -0
00012  40000044 40 0 P00044 0             STA      CIT
                                - - - - - - - - -  TRANSFORM INTERRUPT CODE TO RELATIVE CIT ENTRY - - -
00013  54100005 54 0  00005 1             LDI      5,1                 LOAD AND
00014  17107777 17 0  07777 1             ANI      7777B,1             MASK INTERRUPT CODE
00015  05100110 05 0  00110 1             ISG      110B,1              SKIP IF NON-I/O INTERRUPT
00016  01000040 01 0 P00040 0             UJP      CIC4.1              ELSE GO PROCESS THEM
00017  15177675 15 0  77675 1             INI      -102B,1             COMPUTE INDEX RELATIVE TO CIT,
                                - - - - - - - - -  SET USER ENTRY (FROM CIT) INTO RTJ - - - - - - - - -
00020  20100044 20 0 P00044 1  CIC5.0     LDA      CIT,1               USER ENTRY LOCATION GOES
00021  44000026 44 0 P00026 0             SWA      CIC8.0              TO RTJ INSTRUCTION
                                - - - - - - - - -  SET INCL MASK FOR CLEARING INTERRUPT - - - - - - - -
00022  12000006 12 0  00006 0             SHA      6                   CHARACTER 0 CARRIES MASK
00023  42000136 42 0 P00027 2             SACH     CIC9.0+2
                                - - - - - - - - -  RESTORE ABNORMAL ADDRESS TO CIT ENTRY  - - - - - - -
00024  14677777 14 1 X77777 2             ENA      ABNORMAL
00025  44100044 44 0 P00044 1             SWA      CIT,1
                                - - - - - - - - -  ENTER USER INTERRUPT PROCEDURE - - - - - - - - - - -
00026  00700026 00 1 P00026 3  CIC8.0     RTJ      *
                                - - - - - - - - -  CLEAR INTERRUPT IF NON-I/O - - - - - - - - - - - - -
00027  77500000 77 1  00000 1  CIC9.0     INCL     0                   MASK WILL BE ZERO ON I/O
                                          REM      INTERRUPTS , CLEARED WITHIN CIO
                                - - - - - - - - -  RESTORE LOCK-OUT FLAG - - - - - - - - - - - - - - -
00030  14400000 14 1  00000 0             ENA,S    0
00031  40000044 40 0 P00044 0             STA      CIT
                                - - - - - - - - -  RESTORE SAVED REGISTERS  - - - - - - - - - - - - - -
00032  54100047 54 0 P00047 1             LDI      CIT+3,1
00033  54200050 54 0 P00050 2             LDI      CIT+4,2
00034  54300051 54 0 P00051 3             LDI      CIT+5,3
00035  25000045 25 0 P00045 0             LDAQ     CIT+1
                                - - - - - - - - -  ENABLE INTERRUPT AND EXIT TO INTERRUPTED PROGRAM - -
00036  77740000 77 1  40000 3             EINT
00037  01400004 01 1  00004 0             UJP,I    4
                                - - - - - - - - -  TRANSFORM I/O INTERRUPT CODE - - - - - - - - - - - -
00040  17100007 17 0  00007 1  CIC4.1     ANI      7,1                 MASK CHANNEL BITS
00041  15100016 15 0  00016 1             INI      CITCH0-CIT,1        INCREASE (B1) TO RELATIVE
00042  01000020 01 0 P00020 0             UJP      CIC5.0              CHANNEL ENTRY AND CONTINUE
                                - - - - - - - - -  CONSTANTS AND CENTRAL INTERRUPT TABLE  - - - - - - -
00043  77730000 77 1  30000 3  DINT       DINT
```

```
COMPASS-32    (2.1)              CIC        VERSION  SI 0.0         12/07/64                11/21/66  PAGE      4
                                                                                                            00089
                                                     C    I    T                                            00090
                                                                                                            00091
      00044          77777777        CIT      OCT         77777777            INTERRUPT LOCK-OUT FLAG.       00092
                                              REM         VALUE IS -0 WHEN  INTERRUPT PROCESSING IN PROGRESS,  00093
                                              REM         INTERRUPT DISABLED, AND IS +0 OTHERWISE           00094

                                              CONTENTS OF REGISTERS ON ENTRY TO CIC SAVED IN CIT AND         00096
                                              RESTORED FROM THESE LOCATIONS                                 00097
      00045          00000000                 OCT         0                   (A)                           00098
      00046          00000000                 OCT         0                   (Q)                           00099
      00047          00000000                 OCT         0                   (B1)                          00100
      00050          00000000                 OCT         0                   (B2)                          00101
      00051          00000000                 OCT         0                   (B3)                          00102

                                              NON-I/O USER INTERRUPT LINKAGE CELLS.  INCL MASK IS IN         00104
                                              CHARACTER 0 AND GOES INTO BIS 11-06 OF INCL INSTRUCTION.       00105
                                              ADDRESS IS INITIALIZED TO ABNORMAL AND RESTORED PRIOR TO       00106
                                              ENTRY TO A USER ROUTINE.                                      00107
      00052  04000024 04 0 X00024 0           04          ABNORMAL    CODE=0110 REAL TIME CLOCK             00108
      00053  20000052 20 0 X00052 0           20          ABNORMAL         0111 ARITHMETIC OVERFLOW         00109
      00054  20000053 20 0 X00053 0           20          ABNORMAL         0112 DIVIDE FAULT                00110
      00055  10000054 10 0 X00054 0           10          ABNORMAL         0113 EXPONENT OVERFLOW           00111
      00056  10000055 10 0 X00055 0           10          ABNORMAL         0114 BCD FAULT                   00112
      00057  40000056 40 0 X00056 0           40          ABNORMAL         0115 SEARCH/MOVE                 00113
      00060  00000057 00 0 X00057 0           00          ABNORMAL         0116 MANUAL FROM CONSOLE         00114
      00061  00000060 00 0 X00060 0           00          ABNORMAL         0117 ADJACENT PROCESSOR          00115
                                              I/O INTERRUPT LINKAGE CELLS.  INCL MASK ACTS AS NOP - A CLEAR  00116
                                              MUST BE GIVEN IN THE I/O INTERRUPT PROCEDURE.  ADDRESS         00117
                                              INITIALIZATION IS PERFORMED BY CIO.                           00118
      00062  00077777 00 0 X77777 0  CITCH0   00          CDI                 CHANNEL 0                     00119
      00063  00000062 00 0 X00062 0           00          CDI                 CHANNEL 1                     00120
      00064  00000063 00 0 X00063 0           00          CDI                 CHANNEL 2                     00121
      00065  00000064 00 0 X00064 0           00          CDI                 CHANNEL 3                     00122
      00066  00000065 00 0 X00065 0           00          CDI                 CHANNEL 4                     00123
      00067  00000066 00 0 X00066 0           00          CDI                 CHANNEL 5                     00124
      00070  00000067 00 0 X00067 0           00          CDI                 CHANNEL 6                     00125
      00071  00000070 00 0 X00070 0           00          CDI                 CHANNEL 7                     00126
                                              END                                                           00127

                                             NUMBER OF LINES WITH DIAGNOSTICS         0
```

```
COMPASS-32    (2.1)              CIC        VERSION  SI 0.0         12/07/64                11/21/66  PAGE      1

    ABNORMAL                EXTERNAL          P00024 00064    P00052 00108    P00053 00109    P00054 00110
                                              P00055 00111    P00056 00112    P00057 00113    P00060 00114
                                              P00061 00115
    CDI                     EXTERNAL          P00062 00119    P00063 00120    P00064 00121    P00065 00122
                                              P00066 00123    P00067 00124    P00070 00125    P00071 00126
    CIC2.1        P00006                      P00003 00041
    CIC4.1        P00040                      P00016 00055
    CIC5.0        P00020                      P00042 00085
    CIC8.0        P00026                      P00021 00059
    CIC9.0        P00027                      P00023 00062
    CIT           P00044                      P00000 00037    P00004 00042    P00006 00045    P00007 00046
                                              P00010 00047    P00012 00050    P00020 00058    P00025 00065
                                              P00031 00073    P00032 00075    P00033 00074    P00034 00077
                                              P00035 00078    P00041 00084
    CITCH0        P00062                      P00041 00084
    DINT          P00043                      P00002 00040

  SYMBOLS NOT REFERENCED

        *CIC      P00000
```

```
EXTERNAL SYMBOLS
    CIO


ENTRY-POINT SYMBOLS
    MTMTCIO          00000


LENGTH OF SUBPROGRAM        00274
LENGTH OF COMMON            00000
LENGTH OF DATA              00000
```



```
                                                THIS SUBPROGRAM COPIES A VARIABLE SIZE RECORD INPUT TAPE (LOGI-
                                                CAL UNIT 14) TO ANOTHER TAPE (LOGICAL UNIT 15) THE DENSITY OF
                                                THE OUTPUT TAPE WILL BE THE DENSITY SET BY THE OPERATOR.
                                                THIS SUBPROGRAM DOES NOT CHECK FOR TAPE ERRORS. PARITY IS
                                                CHECKED ONLY TO INSURE THAT THE MODE OF THE INPUT TAPE IS THE
                                                SAME AS THE MODE SELECTED.

                                        ENTRY    MTMTCIO
                                        EXT      CIO
00000  01077777 01 0  77777 0  MTMTCIO  UJP      **
00001  00777777 00 1 X77777 3           RTJ      CIO              REWIND INPUT TAPE
00002  04000016 04 0  00016 0           04       14
00003  01000001 01 0 P00001 0           UJP      *-2
00004  00700001 00 1 X00001 3           RTJ      CIO              REWIND OUTPUT TAPE
00005  04000017 04 0  00017 0           04       15
00006  01000004 01 0 P00004 0           UJP      *-2
00007  00700004 00 1 X00004 3           RTJ      CIO              ASSUME AND SET INPUT TAPE TO
00010  14200016 14 0  00016 2  MODE     14       14,2             BINARY MODE (MODE MAY BE CHANGED
00011  01000007 01 0 P00007 0           UJP      *-2              LATER)
00012  00700007 00 1 X00007 3           RTJ      CIO              INITIATE READING INPUT RECORD
00013  01000016 01 0  00016 0           01       14               FROM LOGICAL UNIT 14 (MAX RECORD
00014  01000012 01 0 P00012 0           UJP      *-2              SIZE IS 500 CHARACTERS)
00015  00000374 00 0 P00077 0  FCA      00,C     INBUFF
00016  40000764 40 0  00764 0           40       500
00017  00700012 00 1 X00012 3           RTJ      CIO              WAIT UNTIL THE INPUT IS COMPLETE
00020  13100016 13 0  00016 1           13       14,1
00021  03200017 03 0 P00017 2           AZJ,GE   *-2
00022  17702010 17 1  02010 3           ANQ      2010B            MASK OUT EVERY SATAUS BIT EXCEPT
                                                                  EOF AND PARITY
00023  04700000 04 1  00000 3           QSF      0                WAS THERE AN EOF OR PARITY ERROR
00024  01000046 01 0 P00046 0           UJP      TEST             YES JUMP TO TEST.
00025  37000076 37 0 P00076 0           LPA      MASK             AFTER STATUS REQUEST (A) = LCA+1
00026  31000015 31 0 P00015 0           SBA      FCA              CALCULATE NUMBER OF INPUT CHAR-
00027  44000041 44 0 P00041 0           SWA      NOC              ACTERS AND STORE IN OUTPUT
00030  22000041 22 0 P00010 1           LACH     MODE+1           FETCH MODE OF INPUT RECORD AND
00031  42000155 42 0 P00033 1           SACH     OUTMODE+1        STORE TO SET OUTPUT MODE THE
00032  00700017 00 1 X00017 3           RTJ      CIO              SAME AS INPUT.
00033  14000017 14 0  00017 0  OUTMODE  14       15,0
00034  01000032 01 0 P00032 0           UJP      *-2
00035  00700032 00 1 X00032 3           RTJ      CIO              INITIATE WRITING OUTPUT BUFFER
00036  02000017 02 0  00017 0           02       15
00037  01000035 01 0 P00035 0           UJP      *-2
00040  00000374 00 0 P00077 0           00,C     INBUFF
00041  40000000 40 0  00000 0  NOC      40       0
00042  00700035 00 1 X00035 3           RTJ      CIO              WAIT UNTIL OUTPUT IS COMPLETE
00043  13100017 13 0  00017 1           13       15,1
00044  03200042 03 0 P00042 2           AZJ,GE   *-2
00045  01000007 01 0 P00007 0           UJP      MODE-1           LOOP TO READ NEW INPUT RECORD


00046  17700010 17 1  00010 3  TEST     ANQ      10B
00047  04700000 04 1  00000 3           QSF      0                WAS AN EOF READ
00050  01000061 01 0 P00061 0           UJP      EOF              YES JUMP TO EOF
```

```
COMPASS-32    (2.1)              MTMTCIO                                               11/21/66  PAGE     3
      00051  77770000 77 1  70000 3          UCS                               IF PARITY ERROR STOP SO THE
                                                                               OPERATOR MAY DECIDE IF IT IS A
                                                                               LEGAL PARITY ERROR OR WRONG MODE
      00052  00700042 00 1 X00042 3          RTJ        CIO
      00053  06000016 06 0  00016 0          06         14                     BACKSPACE INPUT TAPE A RECORD
      00054  01000052 01 0 P00052 0          UJP        *-2
      00055  22000041 22 0 P00010 1          LACH       MODE+1                 FETCH ASSUMED MODE AND
      00056  16600030 16 1  00030 2          XOA        30B                    CHANGE IT.
      00057  42000041 42 0 P00010 1          SACH       MODE+1                 SET NEW MODE IN SEL CALL AND
      00060  01000007 01 0 P00007 0          UJP        MODE-1                 TRY AGAIN.

      00061  00700052 00 1 X00052 3  EOF     RTJ        CIO                    WRITE EOF ON OUTPUT TAPE
      00062  11000017 11 0  00017 0          11         15
      00063  01000061 01 0 P00061 0          UJP        *-2
      00064  77700000 77 1  00000 3          SLS                               STOP IF SELECTIVE STOP SWITCH
                                                                               SET ON CONSOLE.
      00065  00100067 00 0 P00067 1          SJ1        EXIT                   EXIT AND UNLOAD TAPES IF JUMP
                                                                               KEY 1 IS SET ON CONSOLE.
      00066  01000007 01 0 P00007 0          UJP        MODE-1                 IF NOT JUMP TO READ INPUT RECORD

      00067  00700061 00 1 X00061 3  EXIT    RTJ        CIO                    UNLOAD INPUT TAPE
      00070  05000016 05 0  00016 0          05         14
      00071  01000067 01 0 P00067 0          UJP        *-2
      00072  00700067 00 1 X00067 3          RTJ        CIO                    UNLOAD OUTPUT TAPE
      00073  05000017 05 0  00017 0          05         15
      00074  01000072 01 0 P00072 0          UJP        *-2
      00075  01400000 01 1 P00000 0          UJP,I      MTMTCIO                EXIT TO SCOPE
      00076        00377777          MASK    OCT        377777
      00077                          INBUFF  BSS,C      500
                                             END        MTMTCIO
                                           NUMBER OF LINES WITH DIAGNOSTICS         0
```

```
COMPASS-32    (2.1)              MTMTCIO                                               11/21/66  PAGE     1

      CIO                       EXTERNAL      P00001        P00004        P00007        P00012
                                              P00017        P00032        P00035        P00042
                                              P00052        P00061        P00067        P00072
      EOF        P00061                       P00050
      EXIT       P00067                       P00065
      FCA        P00015                       P00026
      INBUFF     P00077                       P00015        P00040
      MASK       P00076                       P00025
      MODE       P00010                       P00030        P00045        P00055        P00057
                                              P00060        P00066
      MTMTCIO    P00000                       P00075
      NOC        P00041                       P00027
      OUTMODE    P00033                       P00031
      TEST       P00046                       P00024
```

```
COMPASS-32    (2.1)              TYPEIN                                      11/21/66  PAGE     1


  ENTRY-POINT SYMBOLS
      TYPEIN          00000



  LENGTH OF SUBPROGRAM        00027
  LENGTH OF COMMON            00000
  LENGTH OF DATA              00000
```

```
COMPASS-32    (2.1)              TYPEIN                                      11/21/66  PAGE     2
                                                     THIS SUBROUTINE ALLOWS FOR TYPING IN A VARIABLE QUANTITY OF
                                                     FOUR DECIMAL DIGIT NUMBERS.THE INPUT IS TERMINATED WHEN A
                                                     PERIOD IS TYPED IN.THE CALLING SEQUENCE IS.
                                                     CALL (P)   = RTJ       TYPEIN
                                                          (P+1)= RETURN
                                                          (A)   =FIRST CHARACTER ADDRESS OF INPUT BUFFER

                                                     OUTPUT  (B1)= NUMBER OF NUMBERS

                                                     ENTRY     TYPEIN
      00000  01077777 01 0  77777 0  TYPEIN   UJP       **
      00001  14100000 14 0  00000 1           ENI       0,1                CLEAR B1
      00002  46000020 46 0 P00020 0           SCHA      CKPERIOD
      00003  46000010 46 0 P00010 0           SCHA      SET23              SAVE INPUT  PAR.
      00004  15400004 15 1  00004 0           INA,S     4
      00005  77600400 77 1  00400 2           PAUS      400B               IS THE TYPEWRITER BUSY
      00006  01000005 01 0 P00005 0           UJP       *-1                YES LOOP
      00007  53420033 53 1  20033 0           TAM       33B                SET LAST CHARACTER ADDRESS+1 OF
                                                                           INPUT BUFFER INTO REGISTER FILE
                                                                           LOCATION 33B.
      00010  11377777 11 0  77777 3  SET23    ECHA      **
      00011  53420023 53 1  20023 0           TAM       23B                SET FIRST CHARACTER ADDRESS INTO
                                                                           REGISTER FILE LOCATION 23B.
      00012  77750000 77 1  50000 3           CTI                          SET TYPE IN
      00013  77602000 77 1  02000 2  LOOP     PAUS      2000B              HAS THE REPEAT SWITCH ON TYPE-
      00014  01000016 01 0 P00016 0           UJP       FINISH             WRITER BEEN PUSHED-YES JUMP TO
      00015  01000010 01 0 P00010 0           UJP       SET23              ADDRESS SET23 AND START OVER-
                                                                           NO JUMP TO FINISH.
      00016  77601000 77 1  01000 2  FINISH   PAUS      1000B              HAS THE FINISH SWITCH BEEN
      00017  01000013 01 0 P00013 0           UJP       LOOP               PUSHED-NO JUMP TO LOOP.
      00020  22377777 22 0  77777 3  CKPERIOD LACH      **
      00021  04600033 04 1  00033 2           ASE       33B                IS THE FIRST CHARACTER A PERIOD-
      00022  01000024 01 0 P00024 0           UJP       BYPASS             YES EXIT-NO JUMP TO BYPASS
      00023  01400000 01 1 P00000 0           UJP,I     TYPEIN
      00024  15100001 15 0  00001 1  BYPASS   INI       1,1                INCREASE B1 BY 1
      00025  53020033 53 0  20033 0           TMA       33B                SET NEW INPUT BUFFER AND LOOP
      00026  01000002 01 0 F00002 0           UJP       TYPEIN+2           TO TYPEIN+2
                                                     END

                                                   NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
BYPASS      P00024                  P00022
CKPERIOD    P00020                  P00002
FINISH      P00016                  P00014
LOOP        P00013                  P00017
SET23       P00010                  P00003       P00015
TYPEIN      P00000                  P00023       P00026
```



```
ENTRY-POINT SYMBOLS
    SORT          00000


LENGTH OF SUBPROGRAM      00030
LENGTH OF COMMON          00000
LENGTH OF DATA            00000
```

```
COMPASS-32    (2.1)              SORT                                                  11/21/66  PAGE    2
                                                       THIS SUBPROGRAM SORTS A BLOCK OF NUMBERS INTO ASCENDING ORDER.
                                                       UPON ENTRY THE ADDRESS OF THE FIRST NUMBER IS LOCATED IN THE
                                                       LOWER 15 BITS OF THE A REGISTER AND THE NUMBER OF NUMBERS IS IN
                                                       B2.

                                                       CALL   (P)  =RTJ        SORT
                                                              (P+1)=RETURN
                                                              (A)  =ADDRESS OF THE FIRST NUMBER
                                                              (B1) =NUMBER OF NUMBERS

                                                       ENTRY      SORT
  00000  01077777 01 0  77777 0  SORT                  UJP        **
  00001  44000010 44 0 P00010 0                        SWA        INIT-1              SAVE FIRST WORD ADDRESS OF DATA
                                                                                      BLOCK.
  00002  53640000 53 1  40000 2                        IAI        2                   ADD FIRST WORD ADDRESS TO NUMBER
                                                                                      OF ENTRIES TO CALCULATE LAST
                                                                                      WORD ADDRESS+1 OF INPUT BLOCK.
  00003  15277776 15 0  77776 2                        INI        -1,2
  00004  47200022 47 0 P00022 2                        STI        INLOOP,2            SET LIMIT OF INLOOP PASSES
  00005  15277776 15 0  77776 2                        INI        -1,2
  00006  47200024 47 0 P00024 2                        STI        OUTLOOP,2           SET LIMIT OF OUTLOOP PASSES
  00007  47100026 47 0 P00026 1                        STI        BSAVE,1             SAVE (B1)
  00010  14177777 14 0  77777 1                        ENI        **,1                ENTER B1 WITH FIRST WORD ADDRESS
                                                                                      OF INPUT BLOCK
  00011  53100000 53 0  00000 1  INIT                  TIA        1
  00012  15600001 15 1  00001 2                        INA        1                   SET B2 EQUAL TO (B1)+1
  00013  53600000 53 1  00000 2                        TAI        2
  00014  21100000 21 0  00000 1                        LDQ        0,1                 LOAD Q WITH FIRST NUMBER FOR
                                                                                      THIS PASS.
  00015  20200000 20 0  00000 2  LOOP                  LDA        0,2                 LOAD A WITH NEXT NUMBER
  00016  03600022 03 1 P00022 2                        AQJ,GE     INLOOP              IS A GE Q YES JUMP TO INLOOP
  00017  41200000 41 0  00000 2                        STQ        0,2                 IF (A) WAS LESS THAN (Q) SWAP
  00020  40100000 40 0  00000 1                        STA        0,1                 THE REGISTER AND ALSO SWAP THEM
  00021  13000030 13 0  00030 0                        SHAQ       24                  IN CORE.
  00022  10277777 10 0  77777 2  INLOOP                ISI        **,2
  00023  01000015 01 0 P00015 0                        UJP        LOOP
  00024  10177777 10 0  77777 1  OUTLOOP               ISI        **,1
  00025  01000011 01 0 P00011 0                        UJP        INIT
  00026  14177777 14 0  77777 1  BSAVE                 ENI        **,1
  00027  01400000 01 1 P00000 0                        UJP,I      SORT
                                                       END

                                                      NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)              SORT                                                  11/21/66  PAGE    1

        BSAVE      P00026                                P00007
        INIT       P00011                                P00001        P00025
        INLOOP     P00022                                P00004        P00016
        LOOP       P00015                                P00023
        OUTLOOP    P00024                                P00006
        SORT       P00000                                P00027
```

```
ENTRY-POINT SYMBOLS
    TYPEOUT          00000


LENGTH OF SUBPROGRAM        00010
LENGTH OF COMMON            00000
LENGTH OF DATA              00000
```



```
                                                  THIS SUBROUTINE ALLOWS FOR TYPING OUT A VARIBLE NUMBER OF
                                                  CHARACTERS.THE CALLING SEQUENCE IS.

                                                  CALL     (A)  =FIRST CHARACTER ADDRESS OF OUTPUT BUFFER
                                                           (B1) =NUMBER OF CHARACTERS IN OUTPUT BUFFER
                                                           (P)  =RTJ     TYPEOUT
                                                           (P+1)=RETURN

                                                  ENTRY     TYPEOUT
    00000  01077777 01 0  77777 0  TYPEOUT  UJP       **
    00001  77600400 77 1  00400 2           PAUS      400B              IS THE TYPEWRITER BUSY
    00002  01000001 01 0 P00001 0           UJP       *-1               YES LOOP AND WAIT UNTIL NOT BUSY
    00003  53420023 53 1  20023 0           TAM       23B               TRANSFER FIRST CHARACTER ADDRESS
                                                                        INTO REGISTER FILE LOCATION 23B.
    00004  53140000 53 0  40000 1           AIA       1                 CALCULATE LAST CHARACTER ADDRESS
                                                                        +1 BY ADDING (A) AND (B1).
    00005  53420033 53 1  20033 0           TAM       33B               TRANSFER LCA+1 INTO RF 33B
    00006  77760000 77 1  60000 3           CTO                         SET TYPE OUT
    00007  01400000 01 1 P00000 0           UJP,I     TYPEOUT
                                            END

                                        NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32    (2.1)               TYPEOUT                                          11/21/66  PAGE     1
     TYPEOUT    P00000                          P00007
```

```
COMPASS-32    (2.1)               FLOATF                                           11/21/66  PAGE     1


  ENTRY-POINT SYMBOLS
      FLOATF          00000
      FLOAT           00000


  LENGTH OF SUBPROGRAM        00025
  LENGTH OF COMMON            00000
  LENGTH OF DATA              00000
```

```
                                          THIS SUBPROGRAM CONVERTS AN INTEGER NUMBER INTO FLOATING POINT
                                          FORMAT.UPON ENTRY THE ADDRESS OF THE INTEGER NUMBER IS LOCATED
                                          IN THE LOWER 15 BITS OF P+1.

                                          CALL  (P)   = RTJ    FLOATF
                                                (P+1)= ADDRESS OF THE INTEGER NUMBER
                                                (P+2)= RETURN

                                          OUTPUT (AQ)= FLOATING POINT EQUIVALENT OF THE INTEGER NUMBER


                                          ENTRY    FLOAT,FLOATF
00000  01077777 01 0  77777 0   FLOATF   UJP      **
                     00000      FLOAT    EQU      FLOATF          EQUATE FLOAT TO FLOATF
00001  47100021 47 0 P00021 1            STI      FOUT,1          SAVE  B1
00002  54100000 54 0 P00000 1            LDI      FLOATF,1        LOAD B1 WITH ADDRESS OF INTEGER
00003  20500000 20 1  00000 1            LDA,I    0,1             LOAD A WITH INTEGER NUMBER
00004  15100001 15 0  00001 1            INI      1,1             INCREASE AND SET RETURN ADDRESS
00005  47000022 47 0 P00022 0            STI      EXIT            TO P+2 OF CALLING ROUTINE
00006  13077747 13 0  77747 0            SHAQ     -24
00007  03400021 03 1 P00021 0            AQJ,EQ   FOUT            DID THE INPUT NUMBER=0 YES EXIT
00010  40000023 40 0 P00023 0            STA      MASKO           SAVE SIGN OF INPUT NUMBER
00011  13502057 13 1  02057 1            SCAQ     20578,1         NORMALIZE THE INTEGER BY USING
                                                                  THE SCALE INSTRUCTION
00012  13077764 13 0  77764 0            SHAQ     -11             MERGE THE EXPONENT AND BIAS
                                                                  (CONTENTS OF B1) WITH THE
00013  41000024 41 0 P00024 0            STQ      TEMP            MANTISSA
00014  13077763 13 0  77763 0            SHAQ     -12
00015  53100000 53 0  00000 1            TIA      1
00016  36000023 36 0 P00023 0            SCA      MASKO           COMPLEMENT EXPONENT AND BIAS IF
                                                                  THE INPUT NUMBER WAS NEGATIVE.
00017  13000014 13 0  00014 0            SHAQ     12
00020  21000024 21 0 P00024 0            LDQ      TEMP
00021  14177777 14 0  77777 1   FOUT     ENI      **,1
00022  01077777 01 0  77777 0   EXIT     UJP      **
00023           00000000        MASKO    OCT      0
00024                           TEMP     BSS      1
                                         END
                                         NUMBER OF LINES WITH DIAGNOSTICS        0
```



```
      EXIT       P00022                      P00005
      FLOATF     P00000                      P00000        P00002
      FOUT       P00021                      P00001        P00007
      MASKO      P00023                      P00010        P00016
      TEMP       P00024                      P00013        P00020

   SYMBOLS NOT REFERENCED

          *FLOAT     P00000
```

```
ENTRY-POINT SYMBOLS
    CRDTP           00000



LENGTH OF SUBPROGRAM        00121
LENGTH OF COMMON            00000
LENGTH OF DATA              00000
```



```
                                                  THIS SUBPROGRAM COPIES A FILE OF CARDS FROM A CARD READER(UNIT
                                                  0,CONTROLLER 3,ON CHANNEL 0) TO A TAPE UNIT (UNIT 1,CONTROLLER
                                                  0 ON CHANNEL 1).THIS SUBPROGRAM DOES NOT CHECK FOR CARD OR
                                                  TAPE ERRORS,THE MODE OF EACH TAPE RECORD IS DETERMINED BY THE
                                                  MODE OF THE CARD RECORD. THE DENSITY OF THE OUTPUT TAPE WILL
                                                  BE THE DENSITY SET BY THE OPERATOR.


                                                  ENTRY    CRDTP
00000  01077777 01 0  77777 0  CRDTP     UJP      **
00001  77003000 77 0  03000 0            CON      3000B,0              CONNECT CARD READER ON CHANNEL 0
00002  01000001 01 0 P00001 0            UJP      *-1
00003  77010001 77 0  10001 0            CON      1B,1                 CONNECT OUTPUT TAPE ON CHANNEL
00004  01000003 01 0 P00003 0            UJP      *-1
00005  77110010 77 0  10010 1            SEL      10B,1                REWIND OUTPUT TAPE
00006  01000005 01 0 P00005 0            UJP      *-1
00007  77200000 77 0  00000 2  INPUT     COPY     0                    IS THE CARD READER READY AND
00010  17600003 17 1  00003 2            ANA      3B                   NOT BUSY-YES INITIATE INPUT-
00011  04600001 04 1  00001 2            ASE      1B                   NO LOOP UNTIL IT BECOMES READY
00012  01000007 01 0 P00007 0            UJP      INPUT                AND NOT BUSY.
00013  74000121 74 0 P00121 0            INPW     0,BUFF,BUFF+40       INITIATE READING A BINARY OR
00014  00000051 00 0 P00051 0
00015  01000013 01 0 P00013 0            UJP      *-2                  BCD CARD.
00016  77200002 77 0  00002 2            EXS      2B,0                 WAIT UNTIL THE CARD READER
00017  01000016 01 0 P00016 0            UJP      *-1                  BECOMES NOT BUSY.
00020  77200004 77 0  00004 2            EXS      4B,0                 WAS THE CARD JUST READ A BINARY
00021  01000041 01 0 P00041 0            UJP      BINARY               CARD YES JUMP TO BINARY.
00022  77200010 77 0  00010 2            EXS      10B,0                WAS A FILE CARD READ (ROW 7 AND
00023  01000044 01 0 P00044 0            UJP      EOF                  8 PUNCHED) YES JUMP TO EOF
00024  14600002 14 1  00002 2            ENA      2B
00025  42000133 42 0 P00026 3            SACH     SELMODE+3            SET BCD MODE FOR OUTPUT TAPE.
00026  77110000 77 0  10000 1  SELMODE   SEL      0,1
00027  01000026 01 0 P00026 0            UJP      *-1
00030  53020000 53 0  20000 0            IMA      0                    FETCH LAST CHARACTER ADDRESS+1
00031  12077775 12 0  77775 0            SHA      -2                   AND CHANGE IT TO LAST WORD
                                                                       ADDRESS+1
00032  44000033 44 0 P00033 0            SWA      OUTPUT               STORE ADDR IN OUTPUT INSTRUCTION
00033  76077777 76 0  77777 0  OUTPUT    OUTW     1,BUFF,**            INITIATE WRITING OUTPUT BUFFER
00034  10000051 10 0 P00051 0
00035  01000033 01 0 P00033 0            UJP      *-2
00036  77210002 77 0  10002 2            EXS      2B,1                 WAIT UNTIL THE OUTPUT TAPE
00037  01000036 01 0 P00036 0            UJP      *-1                  BECOMES NOT BUSY
00040  01000007 01 0 P00007 0            UJP      INPUT
                               *****************************************************************
                               *****************************************************************
00041  14600001 14 1  00001 2  BINARY    ENA      1                    SET BINARY MODE FOR OUTPUT TAPE.
00042  42000133 42 0 P00026 3            SACH     SELMODE+3
00043  01000026 01 0 P00026 0            UJP      SELMODE
                               *****************************************************************
                               *****************************************************************
00044  77110015 77 0  10015 1  EOF       SEL      15B,1                WRITE EOF ON OUTPUT TAPE
00045  01000044 01 0 P00044 0            UJP      *-1
00046  77110011 77 0  10011 1            SEL      11B,1                UNLOAD OUTPUT TAPE (UNIT 1)
```

```
       00047  01000046 01 0 P00046 0          UJP      *-1
       00050  01400000 01 1 P00000 0          UJP,I    CRDTP              EXIT TO SCOPE
       00051                          BUFF    BSS      40
                                              END      CRDTP
                                             NUMBER OF LINES WITH DIAGNOSTICS          0
```



```
    BINARY     P00041                   P00021
    BUFF       P00051                   P00013          P00013          P00033
    CRDTP      P00000                   P00050
    EOF        P00044                   P00023
    INPUT      P00007                   P00012          P00040
    OUTPUT     P00033                   P00032
    SELMODE    P00026                   P00025          P00042          P00043
```

```
ENTRY-POINT SYMBOLS
    MTMT            00000


LENGTH OF SUBPROGRAM        00256
LENGTH OF COMMON            00000
LENGTH OF DATA              00000
```



```
                                                   THIS SUBPROGRAM COPIES A VARIABLE SIZE RECORD INPUT TAPE (UNIT
                                                   1,CONTROLLER 0, ON CHANNEL 0) TO ANOTHER TAPE (UNIT 2,CONTROL
                                                   LER 0,ON CHANNEL 1). THE DENSITY OF THE OUTPUT TAPE WILL BE THE
                                                   DENSITY SET BY THE OPERATOR.
                                                   THIS SUBPROGRAM DOES NOT CHECK FOR TAPE ERRORS.PARITY IS
                                                   CHECKED ONLY TO INSURE THAT THE MODE OF THE INPUT TAPE IS THE
                                                   SAME AS THE MODE SELECTED.


                                                   ENTRY    MTMT
00000  01077777 01 0  77777 0  MTMT                UJP      **
00001  77000001 77 0  00001 0                      CON      1B,0                   CONNECT INPUT TAPE(UNIT 1)
00002  01000001 01 0 P00001 0                      UJP      *-1                    ON CHANNEL 0
00003  77010002 77 0  10002 0                      CON      2B,1                   CONNECT OUTPUT TAPE (UNIT 2)
00004  01000003 01 0 P00003 0                      UJP      *-1                    ON CHANNEL 1
00005  77100010 77 0  00010 1                      SEL      10B,0                  REWIND INPUT TAPE
00006  01000005 01 0 P00005 0                      UJP      *-1
00007  77110010 77 0  10010 1                      SEL      10B,1                  REWIND  OUTPUT TAPE
00010  01000007 01 0 P00007 0                      UJP      *-1
00011  77100001 77 0  00001 1  MODE                SEL      1B,0                   ASSUME AND SET INPUT TAPE TO
00012  01000011 01 0 P00011 0                      UJP      *-1                    BINARY MODE (MODE MAY BE CHANGED
                                                                                   LATER).
00013  73001270 73 0 P00256 0                      INPC     0,INBUFF,INBUFF+500 READ INPUT RECORD FROM TAPE UNIT
00014  00000304 00 0 P00061 0
00015  01000013 01 0 P00013 0                      UJP      *-2                    1 (MAX RECORD SIZE IS 500
                                                                                   CHARACTERS)
00016  77200002 77 0  00002 2                      EXS      2B,0                   WAIT UNTIL INPUT IS COMPLETE
00017  01000016 01 0 P00016 0                      UJP      *-1
00020  77200010 77 0  00010 2                      EXS      10B,0                  WAS AN EOF READ
00021  01000047 01 0 P00047 0                      UJP      EOF                    YES JUMP TO EOF
00022  77202000 77 0  02000 2                      EXS      2000B,0                WAS THERE A PARITY ERROR
00023  01000040 01 0 P00040 0                      UJP      SETMODE                YES JUMP TO CHANGE MODES
00024  53020000 53 0  20000 0                      TMA      0                      FETCH LAST CHARACTER ADDRESS OF
                                                                                   INPUT RECORD+1
00025  46000032 46 0 P00032 0                      SCHA     OUTPUT                 STORE CHARACTER ADDRESS IN OUT-
                                                                                   PUT INSTRUCTION.
00026  22000047 22 0 P00011 3                      LACH     MODE+3                 FETCH MODE OF INPUT RECORD AND
00027  42000143 42 0 P00030 3                      SACH     OUTMODE+3              STORE TO SET OUTPUT MODE THE
00030  77110000 77 0  10000 1  OUTMODE             SEL      0,1                    SAME AS INPUT
00031  01000030 01 0 P00030 0                      UJP      *-1
00032  75377777 75 0  77777 3  OUTPUT              OUTC     1,INBUFF,**            INITIATE WRITING OUTPUT RECORD
00033  10000304 10 0 P00061 0
00034  01000032 01 0 P00032 0                      UJP      *-2
00035  77210002 77 0  10002 2                      EXS      2B,1                   WAIT UNTIL OUTPUT IS COMPLETE
00036  01000035 01 0 P00035 0                      UJP      *-1
00037  01000011 01 0 P00011 0                      UJP      MODE                   LOOP TO READ NEW INPUT RECORD
                               ***********************************************************************
                               ***********************************************************************

                               ***********************************************************************
00040  77770000 77 1  70000 3  SETMODE             UCS                             IF PARITY ERROR STOP SO THE
                                                                                   OPERATOR MAY DECIDE IF IT IS A
                                                                                   LEGAL PARITY ERROR OR WRONG MODE
00041  77100012 77 0  00012 1                      SEL      12B,0                  BACKSPACE INPUT TAPE A RECORD
```

```
COMPASS-32     (2.1)               MTMT                                                          11/21/66  PAGE    3
       00042  01000041 01 0 P00041 0            UJP      *-1
       00043  22000047 22 0 P00011 3            LACH     MODE+3          FETCH ASSUMED MODE AND
       00044  16600003 16 1  00003 2            XOA      3               CHANGE IT
       00045  42000047 42 0 P00011 3            SACH     MODE+3          SET NEW MODE IN SEL INSTRUCTION
                                                                         AND TRY AGAIN.
       00046  01000011 01 0 P00011 0            UJP      MODE
                                         ***************************************************************************
                                         ***************************************************************************
                                         ***************************************************************************
       00047  77110015 77 0  10015 1  EOF       SEL      15B,1           WRITE EOF ON OUTPUT TAPE
       00050  01000047 01 0 P00047 0            UJP      *-1
       00051  77700000 77 1  00000 3            SLS                      STOP IF SELECTIVE STOP SWITCH
                                                                         SET ON CONSOLE.
       00052  00100054 00 0 P00054 1            SJ1      EXIT            EXIT AND UNLOAD TAPES IF JUMP
                                                                         KEY 1 IS SET ON CONSOLE.
       00053  01000011 01 0 P00011 0            UJP      MODE            IF NOT JUMP TO READ INPUT RECORD
                                         ***************************************************************************
                                         ***************************************************************************
                                         ***************************************************************************
       00054  77100011 77 0  00011 1  EXIT      SEL      11B,0           UNLOAD INPUT TAPE
       00055  01000054 01 0 P00054 0            UJP      *-1
       00056  77110011 77 0  10011 1            SEL      11B,1           UNLOAD OUTPUT TAPE
       00057  01000056 01 0 P00056 0            UJP      *-1
       00060  01400000 01 1 P00000 0            UJP,I    MTMT            EXIT TO SCOPE
       00061                          INBUFF    BSS,C    500
                                                END      MTMT
                                            NUMBER OF LINES WITH DIAGNOSTICS        0
```

```
COMPASS-32     (2.1)               MTMT                                                          11/21/66  PAGE    1

      EOF        P00047                      P00021
      EXIT       P00054                      P00052
      INBUFF     P00061                      P00013         P00013         P00032
      MODE       P00011                      P00026         P00037         P00043         P00045
                                             P00046         P00053
      MTMT       P00000                      P00060
      OUTMODE    P00030                      P00027
      OUTPUT     P00032                      P00025
      SETMODE    P00040                      P00023
```

```
COMPASS-32    (2.1)              CVTBCDB                                              11/21/66  PAGE     1


  ENTRY-POINT SYMBOLS
      CVTBCDB          00000


  LENGTH OF SUBPROGRAM         00017
  LENGTH OF COMMON             00000
  LENGTH OF DATA               00000
```

```
COMPASS-32    (2.1)              CVTBCDB                                              11/21/66  PAGE     2
                                                     THIS SUBPROGRAM CONVERTS A POSITIVE FOUR CHARACTER BCD NUMBER
                                                     TO A 24 BIT BINARY NUMBER.

                                                     CALL (P)  =RTJ     CVTBCCB
                                                          (P+U)=RETURN
                                                          (A)  =THE FOUR CHARACTER BCD NUMBER

                                                     OUTPUT (A)=24 BIT BINARY NUMBER

                                                     ENTRY     CVTBCDB
      00000  01077777 01 0  77777 0  CVTBCDB  UJP       **
      00001  40000015 40 0 P00015 0           STA       TEMP                SAVE INPUT PAR.
      00002  47200013 47 0 P00013 2           STI       B2SAVE,2            SAVE (B2)
      00003  14200000 14 0  00000 2           ENI       0,2
      00004  22000064 22 0 P00015 0           LACH      TEMP                LOAD A WITH MOST SIGNIFICANT
                                                                            CHARACTER.
      00005  50000016 50 0 P00016 0  LOOP     MUA       =012                MULTIPLY (A) BY AN OCTAL 12
      00006  15200001 15 0  00001 2           INI       1,2
      00007  23400064 23 1 P00015 0           LQCH      TEMP,2              LOAD Q WITH NEXT SIGNIFICANT
                                                                            CHARACTER.
      00010  53040000 53 0  40000 0           AQA
      00011  04200003 04 0  00003 2           ISE       3,2                 IS B2 EQUAL TO 3 YES EXIT
      00012  01000005 01 0 P00005 0           UJP       LOOP                NO JUMP TO LOOP
      00013  14277777 14 0  77777 2  B2SAVE   ENI       **,2                RESTORE B2
      00014  01400000 01 1 P00000 0           UJP,I     CVTBCDB
      00015                          TEMP     BSS       1
                                              END

  LITERALS
 00016            00000012

                                                  NUMBER OF LINES WITH DIAGNOSTICS        0
```

B2SAVE	P00013		P00002		
CVTBCDB	P00000		P00014		
LOOP	P00005		P00012		
TEMP	P00015		P00001	P00004	P00007
LITERAL	P00016	00000012	P00005		

ENTRY-POINT SYMBOLS

CVTBBCD	00000

LENGTH OF SUBPROGRAM	00033
LENGTH OF COMMON	00000
LENGTH OF DATA	00000

```
COMPASS-32    (2.1)              CVTBBCD                                      11/21/66  PAGE     2
                                                THIS SUBPROGRAM CONVERTS A 24 BIT BINARY NUMBER TO A EIGHT
                                                CHARACTER BCD NUMBER WITH BLANKS INSERTED TO THE LEFT OF THE
                                                MOST SIGNIFICANT DIGIT.

                                                CALL (P)  =RTJ      CVTBBCD
                                                     (P+1)=RETURN
                                                     (A)  = 24 BIT BINARY NUMBER

                                                OUTPUT     (AQ) = EIGHT CHARACTER BCD NUMBER

                                                ENTRY      CVTBBCD
      00000  01077777 01 0  77777 0  CVTBBCD  UJP        **
      00001  47100025 47 0 P00025 1           STI        B1SAVE,1           SAVE (B1)
      00002  21000027 21 0 P00027 0           LDQ        BLANKS
      00003  41000030 41 0 P00030 0           STQ        BCDANS             SET OUTPUT AREA TO BLANKS
      00004  41000031 41 0 P00031 0           STQ        BCDANS+1
      00005  43000113 43 0 P00022 3           SQCH       SETSIGN+3          SET ASSUMED SIGN TO POSITIVE
      00006  03200012 03 0 P00012 2           AZJ,GE     BYPASS             IS INPUT NUMBER POSITIVE YES JUMP
      00007  14100040 14 0  00040 1           ENI        40B,1              NO SET SIGN
      00010  47100022 47 0 P00022 1           STI        SETSIGN,1
      00011  16477777 16 1  77777 0           XOA,S      -0                 COMPLEMENT THE 24 BIT NUMBER
      00012  14100007 14 0  00007 1  BYPASS   ENI        7,1                SET MAX TIMES THROUGH LOOP
      00013  13077747 13 0  77747 0  LOOP     SHAQ       -24                SHIFT FOR 48 BIT DIVIDEND
      00014  51000032 51 0 P00032 0           DVA        =012               DIVIDE BY OCTAL 12
      00015  43400140 43 1 P00030 0           SQCH       BCDANS,1           STORE NEXT SIGNIFICANT DIGIT
      00016  02500020 02 1 P00020 1           IJD        *+2,1
      00017  01000022 01 0 P00022 0           UJP        SETSIGN
      00020  04400000 04 1  00000 0           ASE,S      0                  IS THE QUOTIENT ZERO-YES SKIP
      00021  01000013 01 0 P00013 0           UJP        LOOP
      00022  14700060 14 1  00060 3  SETSIGN  ENQ        60B                PLACE SIGN JUST TO THE LEFT OF
      00023  43400140 43 1 P00030 0           SQCH       BCDANS,1           MOST SIGNIFICANT DIGIT.
      00024  25000030 25 0 P00030 0           LDAQ       BCDANS
      00025  14177777 14 0  77777 1  B1SAVE   ENI        **,1               RESTORE (B1)
      00026  01400000 01 1 P00000 0           UJP,I      CVTBBCD            EXIT
      00027            60606060      BLANKS   BCD        1,
      00030                          BCDANS   BSS        2
                                              END

 LITERALS
 00032           00000012
                                              NUMBER OF LINES WITH DIAGNOSTICS       0
```

```
COMPASS-32    (2.1)              CVTBBCD                                      11/21/66  PAGE     1

      B1SAVE      P00025                        P00001
      BCDANS      P00030                        P00003       P00004       P00015       P00023
                                                P00024
      BLANKS      P00027                        P00002
      BYPASS      P00012                        P00006
      CVTBBCD     P00000                        P00026
      LOOP        P00013                        P00021
      SETSIGN     P00022                        P00005       P00010       P00017
      LITERAL     P00032       00000012         P00014
```

```
SEQUENCE,002
JOB,,,,
COMPASS,L,X
```

```
COMPASS-32     (2.1)                IDC                                          11/21/66  PAGE      1


  EXTERNAL SYMBOLS
       CIO


  ENTRY-POINT SYMBOLS
       IDC             00000


  LENGTH OF SUBPROGRAM        00032
  LENGTH OF COMMON            00050
  LENGTH OF DATA              00000
```

```
COMPASS-32    (2.1)             IDC                                                    11/21/66  PAGE    2
                                                  ENTRY    IDC
                                                  EXT      CIO
        00000  01077777 01 0  77777 0  IDC        UJP      **
        00001  00777777 00 1 X77777 3  READ       RTJ      CIO
        00002  01000074 01 0  00074 0             01       60
        00003  01000001 01 0 P00001 0             UJP      *-2
        00004  00000000 00 0 C00000 0                      INBUFF
        00005  00000050 00 0  00050 0                      40
        00006  00700001 00 1 X00001 3             RTJ      CIO
        00007  13000074 13 0  00074 0             13       60
        00010  03200006 03 0 P00006 2             AZJ,GE   *-2
        00011  17700010 17 1  00010 3             ANQ      10B
        00012  04700000 04 1  00000 3             QSE      0
        00013  01000031 01 0 P00031 0             UJP      EOF
        00014  22000000 22 0 C00000 0             LACH     INBUFF
        00015  04600041 04 1  00041 2             ASE      41B
        00016  01000001 01 0 P00001 0             UJP      READ
        00017  00700006 00 1 X00006 3             RTJ      CIO
        00020  02000073 02 0  00073 0             02       59
        00021  01000017 01 0 P00017 0             UJP      *-2
        00022  00000002 00 0 C00002 0                      INBUFF+2
        00023  00000002 00 0  00002 0                      2
        00024  00700017 00 1 X00017 3             RTJ      CIO
        00025  13000073 13 0  00073 0             13       59
        00026  03200024 03 0 P00024 2             AZJ,GE   *-2
        00027  77700000 77 1  00000 3             SLS
        00030  01000001 01 0 P00001 0             UJP      READ
        00031  01400000 01 1 P00000 0  EOF        UJP,I    IDC
                                                  COMMON
        00000                          INBUFF     BSS      40
                                                  END      IDC

                                                NUMBER OF LINES WITH DIAGNOSTICS         0
```

```
LOAD,56
SNAP,(IDC)15,C0,C47,0,0P
RUN,10
```

```
SUBP
 15547  IODRAIN      15611  IOPACK       16245  SNAPSHOT     17705  IDC

ENTR
 15557  IODRAIN      16134  READINP      16012  READLUN      15611  WRITECTO     16200  WRITEACC     16172  WRITEPUN
 15621  WRITELUN     16163  WRITEOUT     16307  PROGDUMP     16266  FORTDUMP     16245  SNAPSHOT     17705  IDC
 00745  SEL          02130  UST          02170  CST          00060  CIT          02241  RHT          02201  AET
 02402  RDCKSUM      02305  RDCKF1       02015  BCDBOXS      02015  FDPBOXS      00107  CIO          02453  START2
 02737  LOADER       02261  ACCOUNTS     02303  MEMORY       02015  ABNORMAL

COMM
 03206   03255

DATA
     NONE

EXTA
     NONE
```

```
DP   LOC     17722          A  00000060     Q  00000000     B1    00000      B2    17705      B3    00000     IMR 0003
OCTAL MEMORY
03206  00000    60606060    60605125    21436044    64734564    73432144    22242179    31475131    44257331
03216  00010    45657360    31626321    51734547    65734473    44222151    73443021    63734447    73442221
03226  00020    51477344    30216347    60606060    60606060    00702015    00702015    00702015    00702015
     GAP
                                             * END *
```

```
DP   LOC     17722          A  00000060     Q  00000000     B1    00000      B2    17705      B3    00000     IMR 0003
OCTAL MEMORY
03206  00000    60606060    60017345    64212273    60606060    60606060    60606060    60606060    60606060
     GAP
03226  00020    60606060    60606060    60606060    60606060    00702015    00702015    00702015    00702015
     GAP
                                             * END *
```

```
SEQUENCE,003
JOB,JC,482,15
OCC,X16
OCC,(IDC)27,01000000X
OCC,X,20000024(IDC),44000003X,44000010X,00777777
OCC,+,02000073,01000003X,00000015X,00000001
OCC,+,00777777,13000073,03200010X,77700000
OCC,+,01000030(IDC),77606060
RUN,10
```

```
SUBP
 17635  IDC

ENTR
 17635  IDC         00745  SEL         02130  UST         02170  CST         00060  CIT         02241  RHT
 02201  AET         02402  RDCKSUM     02305  RDCKEI      02015  RCDBOXS     02015  FDPBOXS     00107  CIO
 02453  START2      02737  LOADER      02261  ACCOUNTS    02303  MEMORY      02015  ABNORMAL

COMM
     NONE

DATA
     NONE

EXTA
 17617
```

```
LOC 00043   A 00002015   Q 40004003   B1 00014   B2 17635   B3 00000   IC 0116   IA 17645   TC 00   TA 02015   IMR 0003

REGISTER FILE
   00   00077460  20413534  00770077  00770077  00770077  00770077  00770077  00770077
   10   04077574  26013534  00770077  00770077  00770077  00770077  00770077  00770077
   20   60445400  00045254  26571102  00007725  67030634  00002015  40004003  00000014
   30   71045400  72045404  23575770  00007725  00770077  00017635  00000000  00030007
   40   00006243  00002403  00077776  00003320  00000247  00000000  00017302  00000000
   50   01007331  00003274  00000000  00000000  00000067  00000605  00000000  00002037
   60   00000006  00000070  00000000  60606060  00000006  00003271  00006171  00000013
   70   00000002  04077776  00000003  00000050  00000144  00000013  60606060  00000000

MEMORY
GAP
03200   60606060  60606060  60606060  60606060  60606060  60606060  00702015  00702015
GAP
17610   00702015  00702015  00702015  00702015  00702015  00702015  00702015  20017661
17620   44017622  44017627  00777777  02000073  01017622  00017634  00000001  00777777
17630   13000073  03217627  77700000  01017665  77606060  01002037  00700107  01000074

17640   01017636  00017667  00000050  00700107  13000074  03217643  17700010  04700000
17650   01017666  22077334  04600041  01017636  00700107  02000073  01017654  00017671
17660   00000002  00700107  13000073  03217661  01017617  01017636  01417635  00054010
17670   20102001  11002001  44002020  11022100  11021004  00000000  00000000  00000000

GAP
17730   00000000  00000000  00000000  00000000  00000000  00000000  00000000  00702015

                                    *END*

SEQ ERR
SEQ ERR

SEQUENCE,004
```

ADDITIONAL EXERCISES (Assignment Sheets)

Appendix B

3200 COMPUTER CHARACTERISTICS

1. For each of the following word addresses and character positions, provide the equivalent character address and the storage module in which it is contained.

Word Address	Character Position	Character Address	Storage Module
a) 00027	#0		
b) 06313	#1		
c) 15346	#2		
d) 20476	#3		

2. For each of the following character addresses provide the equivalent word address, character position and storage module.

Character Address	Word Address	Character Position	Storage Module
a) 300630			
b) 152063			
c) 325076			
d) 150762			

3. If Character Address 340556 were specified, what character address would actually be referenced in an 8K system?

4. If Character Address 160560 were specified, what character address would actually be referenced in a 16K system?

5. The 3200 system can consist of a maximum of ____________ 12-bit data channels.

6. A 24-bit data channel may be used in place of ___________ 12-bit data channel(s). It will be programmed as channel number ___________.

7. A 3200 data channel may control a maximum of ___________ peripheral equipment controllers.

8. Give a brief description of the four (4) types of Processors.

9. What memory locations are always permanently protected and why?

10. What address or block of addresses are protected by the Storage Protect Switches below?

    111 111 110 NNN NNN = ______________________

11. Describe what happens when an instruction attempts to write into a Protected address?

12. Give the function of each location within the register file.

LOAD INSTRUCTIONS

GIVEN: (A) =	00000000	(B^1) =	2
(Q) =	00007777	(B^2) =	2
		(B^3) =	0

TEMP = Memory Location 13314

TEMP	27	31	33	17
+1	40	51	33	15
+2	20	41	33	14
+3	23	14	26	15
+4	00	71	33	16

What are the contents of the indicated registers after the execution of each instruction? Assume initial condition above for each problem.

1.	LDA	TEMP	(A) =
2.	LDQ	TEMP+1	(Q) =
3.	LACH	TEMP,1	(A) =
4.	LDA,I	TEMP,2	(A) =
5.	LDL	TEMP,2	(A) =
6.	LCAQ	TEMP+1	(A) = (Q) =
7.	20113315		(A) =
8.	22055462		(A) =
9.	54113316		(B^1) =
10.	LDI,I	TEMP+4,1	(B^1) =
11.	LQCH	TEMP+7	(Q) =
12.	LACH	TEMP+2,1	(A) =

STORE INSTRUCTIONS

GIVEN: (A) = 24130120 (B^1) = -1

(Q) = 13000003 (B^2) = 10

(B^3) = 1

TEMP = Memory Location 33444

TEMP1 = Memory Location 33446

TEMP	01	33	34	43
	77	53	34	44
TEMP1	66	73	34	45
	65	03	34	46
	44	55	66	77

What are the contents of the indicated registers or memory locations after the execution of each instruction? (Assume original settings at beginning of each instruction set.)

1.	STA	TEMP+4	(A) =
2.	STQ,I	TEMP	(TEMP) =
3.	SACH	TEMP,2	(TEMP+2) =
4.	SWA	TEMP+3	(TEMP+3) =
5.	STAQ,I	TEMP	Where are A & Q stored =
6.	SCHA	TEMP+1	(TEMP+1) =
7.	STI	TEMP+4	(TEMP+4) =
8.	SQCH	TEMP1,1	(Modified location) =
9.	STI	TEMP1,3	(TEMP1) =
10.	SWA,I	TEMP1+1	(TEMP1) =

ARITHMETIC, FIXED POINT

The following problem set is to familiarize the student with the arithmetic instructions.

1. MC, set P to "GO" and start.

```
GO          ENA,S     604B
            ENQ       77777B
            MUA       INTEGER
            HLT       GO
INTEGER     HLT       4
```

$(A)_f$ =

$(Q)_f$ =

2. MC, set P to "GO" and start.

```
GO          ENA,S     0
            ENQ,S     600B
            DVA       DIVISOR
            HLT       GO
DIVISOR     OCT       -7
```

$(A)_f$ =

$(Q)_f$ =

3. MC, set P to "GO" and start.

```
GO          LDA       NUMB
            ADA       NUMB+1
            ANA       77777B
            RAD       NUMB+2
            HLT
NUMB        OCT       -10,-2000,1
```

$(A)_f$ =

4. MC, set P to "GO" and start.

```
GO          ENI       7,1
            ENA,S     6
            INA,S     1
            SBA       MINUS
            HLT
MINUS       OCT       10
```

$(A)_f$ =

5. What are the contents of A register when program halts?

```
            ENI     -6,1
            LDA     TEMP
            SHA     5,1
            HLT
TEMP        OCT     40123400

            (A)  =
```

REGISTER OPERATIONS WITHOUT STORAGE REFERENCE

For each of the following short routines, indicate the final contents of designated register. Assume that a M.C. was performed prior to starting each program.

1.

M.L.	CONTENTS	
00000	ENI	40000B,1
00001	INI	100B,1
00002	XOI	7677B,1
00003	ANI	7777B,1
00004	HLT	

$(B^1)_f$ =

2.

00000	ENA,S	40000B
00001	XOA,S	40000B
00002	INA,S	50000B
00003	ANA,S	40000B
00004	HLT	

$(A)_f$ =

3.

00000	ENQ	60000B
00001	XOQ	70000B
00002	INQ	77777B
00003	ANQ	77777B
00004	HLT	

$(Q)_f$ =

4.

00000	ECHA	2003B
00001	ENQ	0
00002	SHA	-2
00003	SHAQ	24
00004	SHQ	1
00005	SHAQ	35430B
00006	HLT	

$(A)_f$ =

$(Q)_f$ =

GIVEN: (A) = 40372156 (B^1) = 77777

(Q) = 35642761 (B^2) = 41745

(B^3) = 72156

Regarding each of the following instructions as separate problems, indicate which will RNI at P + 1 by placing a check (✓) in the space provided.

1. _____ISE 0,1
2. _____ISE 41745B,3
3. _____ISE 43745B,2
4. _____ASE,S 27614B
5. _____ASE 72156B
6. _____QSE 47321B
7. _____QSE,S 34763B
8. _____ISE 72156B,3
9. _____ISE 0,0
10. _____ASE,S 72156B
11. _____ISG 77777B,1
12. _____ISG 27317B,2
13. _____ISG 77345B,3
14. _____ASG,S 73452B
15. _____QSG,S 04210B
16. _____ASG 72156B
17. _____QSG 35016B
18. _____ISG 72156B,3
19. _____ISG 17774B,0
20. _____ISG 37432B,2

STOP AND JUMP INSTRUCTIONS

GIVEN:	(A) = 40372156		(B^1)	= 77777
	(Q) = 35642761		(B^2)	= 41745
			(B^3)	= 72156

Regarding each of the following instructions as separate problems, indicate which will RNI at P + 1 by placing a check (✓) in the space provided.

1. _____ISI 0,1
2. _____ISI 30632B,2
3. _____ISI 72156B,3
4. _____ISD 0,0
5. _____ISD 77777B,1
6. _____ISD 47445B,2
7. _____ISD 05621B,3
8. _____ISD 41745B,2
9. _____ISI 37621B,1
10. _____IJI 0,0
11. _____IJD 62156B,3
12. _____IJI 44444B,3
13. _____IJI 77777B,3
14. _____IJD 67565B,0
15. _____AZJ,EQ 73125B
16. _____AZJ,NE 33127B
17. _____AZJ,GE 27215B
18. _____AZJ,LT 77777B
19. _____AQJ,EQ 41425B
20. _____AQJ,GE 42761B

1. MC, set P to 06000 and start.

M.L.	CONTENTS	
06000	LDA	6004B
06001	INA,S	-1
06002	AZJ,NE	6005B
06003	HLT	
06004	00	0
06005	INA,S	2
06006	UJP	6001B

$(A)_f$ =

2. MC, set P to 05120 and start.

M.L.	CONTENTS	
05120	ENI	77B,1
05121	INA,S	10000B
05122	IJD	5121B,1
05123	INQ,S	10000B
05124	ISI	77B,1
05125	UJP	5123B
05126	ANA	0
05127	HLT	

$(A)_f$ =

$(Q)_f$ =

$(B^1)_f$ =

3. MC, set P to 07000 and start.

M.L.	CONTENTS	
07000	IJI	7007B,1
07001	UJP	7006B,3
07002	UJP	7004B
07003	IJI	7002B,2
07004	UJP	7005B,1
07005	UJP	7002B
07006	RTJ	7002B
07007	HLT	

$(P)_f$ =

(07002) =

4. What does this program do?

```
            ENI      4,1
AGAIN       LDA      TEMP,1
            RTJ      ROUTINE
            UJP      *+4
           *RAD      TALLY
            IJD      AGAIN,1
            HLT      **
            RAD      COUNT
            UJP      *-3
ROUTINE     UJP      **,2
            ENI      0,2
            ASG      100B
            INI      1,2
            ENA      1
            UJP,I    ROUTINE
TEMP        OCT      100
            OCT      21
            OCT      77
            OCT      101
            OCT      10
TALLY       OCT      0
COUNT       OCT      0
```

*The RAD instruction must have been discussed before the above problem can be done.

5. MC, set P to "C.0" and start. The selective stop switch and jump switches 1 and 6 are set.

M.L.	CONTENTS	
C.0	UJP	C.6
C.1	HLT	C.0
C.2	SJ1	C.1
	SLS	
C.4	SJ3	C.10
	SJ6	C.2
C.6	SJ2	C.10
	UJP	C.4
C.10	SLS	

$(P)_f =$

If the machine were restarted from where it stopped, what memory location would it go to?

INTER-REGISTER TRANSFER

1. What are the contents of the A register and Q register when program is executed?

M.L.			
00000		LDQ	TEMP
00001		ENA	GET
00002		SWA	*+1
00003		LDA	**
00004		AQA	
00005		STA	*+2
00006		ENQ	-6
00007		HLT	**
00010		HLT	**
00011	GET	ENI	0,0
00012	TEMP	OCT	02677771

(A) =

(Q) =

2. MC, set P to GO and start.

```
GO    ENA    10
      TAI    3
      ENQ    10
      INI    -1,3
      HLT
```

$(A)_f$ =

$(Q)_f$ =

$(B^3)_f$ =

3. Write the octal coding that will be generated by the following COMPASS coding.

	COMPASS			OCTAL
1)	AQA		=	
2)	INA	3	=	
3)	TIA	2	=	
4)	TQM	22B	=	
5)	AIA	1	=	
6)	TIM	20B,2	=	
7)	TAM	77B	=	
8)	TMI	60B,3	=	
9)	TMA	27B	=	
10)	TMQ	55B	=	
11)	TAI	1	=	

4. MC, set P to BEGIN and start.

```
BEGIN      ENI      -100B,1
           ENI      -200B,2
           ENI      300B,3
           ENQ,S    -0
           TQM      24B
           TIA      1
           SHAQ     -24
           TIA      3
           AQA
           TAM      25B
AIA        AIA      2
           TAM      26B
           ENA,S    -1
           IAI      1
           TIM      27B,2
           TMQ      24B
           ENA      0
           AQA
           HLT
```

$(A)_f$ =

$(Q)_f$ =

$(B^1)_f$ =

(V24) =

(V25) =

(V26) =

(V27) =

5. MC, set P to BEGIN and start.

```
BEGIN      LDAQ     NUMB
           MUAQ     INTEGER
           DVAQ     DIVISOR
           STAQ     ANSWER
           ELQ
           EUA
           STAQ     ANSWER+2
           HLT
NUMB       OCT      -0,-100
INTEGER    OCT      0,4
DIVISOR    OCT      0,2
ANSWER     OCT      0,0,0,0
```

(ANSWER) =

(ANSWER+1) =

(ANSWER+2) =

(ANSWER+3) =

SEARCH AND MOVE OPERATIONS

1.

```
                IDENT       MAIN
                ENTRY       START
                EXT         DELBLANK
START           .
                .
                .
                ENA         DATACARD
                RTJ         DELBLANK
                .
                .
                .
DATACARD        BSS         20
                END         START
                IDENT       DELETE
                ENTRY       DELBLANK
BELBLANK        UJP         **
                STI         SAVEB2,2
                ENI         0,2
                SHA         2
                SCHA        FCA
                SCHA        SRC+1
                INA,S       80
                SCHA        SRC
SRC             SRCN        60B,**,**
                UJP         *-2
                PAUS        4000B
                UJP         *-1
                TMA         30B
                LPA         MASK
                SHAQ        24
                TMA         20B
                LPA         MASK
                AQJ,EQ      EXIT
                SCHA        *+3
INCRE           INA,S       1
                SCHA        SCR+1
                LACH        **
FCA             SACH        **,2
                INI         1,2
                UJP         SRC
EXIT            LDA         *-3
                LPA         MASK
                AIA         2
SAVEB2          ENI         **,2
                UJP,I       DELBLANK
MASK            OCT         00377777
                END
                FINIS
```

Assume program MAIN had previously read in one card image into the area labeled DATACARD before it transfers control to a commonly used subprogram called DELETE.

A. Why is Index Register No. 2 saved upon entrance to the DELETE subroutine?

B. Why does the program MAIN execute an ENA instruction before it does a return jump to the DELETE subroutine?

C. What is the significance of the double asterisk (**) in the coding of the SRCN instruction in the DELETE subroutine?

D. What is the function of the unconditional jump instruction which follows the SRCN instruction in the DELETE subroutine?

E. What two conditions will cause the PAUS instruction within the DELETE ROUTINE to do a SKIP EXIT (P + 2)?

F. Why at location INCRE is the character address in A updated by 1?

G. What does the A register contain when control is transferred back to program MAIN?

2.

```
PROG1    ENTRY    PROG1
         ENI      0,1
         ENI      0,2
MOVE     LACH     FILE1,1
         SACH     FILE2,2
         INI      1,2
         ISI      7,1
         UJP      MOVE
         HLT
         END      PROG1

         ENTRY    PROG2
PROG2    MOVE     10B,FILE1,FILE2
         UJP      +-2
         PAUS     4000B
         UJP      *-1
         HLT
         END      PROG2
```

Given the above routines, which one will accomplish the move faster? Assume both routines do a character by character move.

Does the MOVE instruction buy the programmer much time if he has to wait until the MOVE is completed?

3. Write a short program which will search a character block (character addresses CARD to CARD+80) for the first COMMA(,). Loop until the search is complete and determine if a COMMA(,) was found; if one were found, load the ADDRESS into the A register; if not, set A = 0.

STORAGE TESTS

1.

```
          ENTRY     SEARCH
SEARCH    ENI       0,2
          ENI       7,1
          ENA       200
          ENQ       100
          CPR       LIST,1
          UJP       *+3
          UJP       *+2
          RTJ       FIND
          IJD       *-4,1
          HLT
FIND      UJP       **
          ENA       LIST
          AIA       1
          STA       ADDRESS,2
          INI       1,2
          UJP,I     FIND
LIST      DEC       1,150,20,300,5,200,100,77
ADDRESS   OCT       0,0,0,0,0,0,0,0
          END
```

What does the above program do?

When the program comes to a HALT, what do the following locations contain?

ADDRESS =

ADDRESS+1 =

ADDRESS+2 =

ADDRESS+3 =

2. The number in the A register after executing a SSH instruction is?

a) Zero

b) The original number from memory, unshifted.

c) The original number from memory, shifted.

d) The same number that was in A.

3.

```
            ENTRY       SCAN
SCAN        ENI         0,3
            ENI         0,2
            ENI         3,1
            LDQ         MASK
CONTINUE    LDA         DATA
            MEQ         LIST,1
            UJP         CHECK
            ENA         LIST
            AIA         1
            SHA         2
CHARADDR    AIA         2
            STA         LIST1,3
            INI         1,3
            UJP         CONTINUE
CHECK       SSH         CONTROL
            HLT
            SHQ         18
            SHA         18
            STAQ        MASK
            INI         1,2
            UJP         SCAN+2
CONTROL     OCT         73567356
MASK        OCT         77000000
DATA        OCT         45000000
LIST        BSS         3
LIST1       OCT         0,0,0,0,0,0,0,0,0,0,0,0
            END
```

What does the above program do?

4. Write a program which will search a table called INFO, looking for the value 62_8 in bit positions 11 - 06. Search every other location in INFO, which is a total of 16_{10} locations long, starting with the last location within the INFO table. The program must keep track of all addresses, where a find had occurred.

BCD OPERATIONS

1. The decimal quantity +32,768,987 is contained in a field beginning at character address 010000. Indicate the octal contents of the appropriate memory locations.

MEMORY LOCATIONS	CONTENTS

2. After executing a SET 12 and a LDE AA+2 instruction, indicate the sign and contents of the E register. AA - 65136

		CONTENTS
	AA	11071002
		02050711
$(E)_f$ =		06010210
		11117102

3. After executing a SET 10 and a ADE BB+2 instruction, indicate the final sign and contents of the E register. BB = 13417

		CONTENTS
$(E)_i$ = -0,000,987,654,321	BB	04060701
		10010010
$(E)_f$ =		11100000

4. After executing a SET 4 and a SBE CC+2 instruction, indicate the final sign and contents of the E register. CC = 40000

		CONTENTS
$(E)_i$ = +0,000,000,000,989	CC	01141011
		02650411
$(E)_f$ =		

5. After executing a SET 13 and a ADE DD+1,3 instruction, indicate the final sign and contents of the E register. (B3) = 77765 DD = 04002

		CONTENTS
$(E)_i$ = +1,000,000,000,000.		01100611
		11070302
$(E)_f$ =		10100301
	DD	00111151

6. After executing a SET 9 and a STE 10B instruction, indicate the final sign and contents of the E register as well as the contents of the storage locations affected.

$(E)_i$ = -9,568,765,867,898. M.L. CONTENTS

$(E)_f$ =

7. Fill in the six (6) locations starting with "CHARS" with their octal contents, after the following has been executed. Place X's where contents not known.

(E_D) = +0000045468799

```
          EZJ,EQ    OUT
          EZJ,LT    OUT
          SET       10
          SFE       2
          STE       ANSWER
          NOP
OUT       HLT
CHARS     BCD,C     12,TOTAL EQUAL
ANSWER    BCD,C     10,
```

CHARS

$(E)_f$ =

(D) =

8. Fill in the octal contents of the four (4) locations starting at "DATA", after the following program has been executed. Place X's where the contents are not known.

E_D = -0405060708090

```
              SET        1
              ENI        0,2
LOOP          EZJ,EQ     DONE
              SFE        -1
              STE        DATA,2
              INI        1,2
              UJP        LOOP
DONE          HLT
DATA          BCD,C      12,
```

DATA

$(E)_f$ =

ANSWER SHEETS

Appendix C

3200 COMPUTER CHARACTERISTICS - ANSWERS

1.

Character Address	Storage Module
a) 000134_8	0
b) 031455_8	0
c) 065632_8	0
d) 102373_8	1

2.

Word Address	Character Position	Storage Module
a) 60146_8	0	3
b) 32414_8	3	1
c) 65217_8	2	3
d) 32174_8	2	1

3.

Character Address	Word Address	Character Position
040556_8	10133_8	2

4.

Character Address	Word Address	Character Position
160560_8	34134_8	0

5. 4

6. a) 2

   b) #2

7. 8

8. a) 3204 (Basic Processor) contains the logic to perform 24-bit fixed point arithmetic, 48-bit fixed point addition and subtraction, Boolean, character and word handling and decision making operations.

   b) 3205 (Scientific Processor) contains the capability of the 3204, plus floating point and 48-bit precision fixed point multiplication and division.

c) 3210 (Data Processor) contains the capability of the 3204, plus the ability to handle BCD characters.

d) 3215 (General Processor) contains the capability of the 3204, 3205 and 3210.

9.

Memory Size	Locations Protected
4K	07640 - 07677
8K	17640 - 17677
16K	37640 - 37677
32K	77640 - 77677

The auto-load program resides here, and consists of the necessary instructions to bring in a program from magnetic tape unit. If these locations were not protected, this program could be destroyed and no more auto-load capability, which is a necessary item for the 3200 Scope operating system.

10. LOCATIONS 77600_8 thru 77677_8

11. No writing takes place and the write instruction acts like a NOP instruction. The computer does not HALT and does not generate an interrupt. The illegal write can be only sensed by the INS instruction.

12.

Register Numbers	Reserved for:
00 - 07	Modified I/O instruction word containing the current character or word address (channel 0-7 control)
10 - 17	Modified I/O instruction word containing the last character or word address $\pm$ 1, depending on the instruction (channel 0-7 control)
20	Search instruction word containing the current character address (search control)
21	Move instruction word containing the source address (move control)

12. (cont.)

Register Numbers	Reserved for:
22	Real-time clock, current time
23	Current character address (typewriter control)
24 - 27	Temporary storage
30	Instruction word containing the last character address +1 (search control)
31	Instruction word containing the destination address (move control)
32	Real-time clock, interrupt mask
33	Last character address + 1 (typewriter control)
34 - 77	Temporary storage

LOAD INSTRUCTIONS - ANSWERS

1. 27313317

2. 40513315

3. 00000033

4. 23142615

5. 00003314

6. 37264462
   57364463

7. 23142615

8. 00000033

9. 13314

10. 42615

11. 00000015

12. 00000040

STORE INSTRUCTIONS - ANSWERS

1. 24130120

2. 01333443

3. 20733445

4. 65030120

5. (TEMP) = A

   (TEMP+1) = Q

6. 77530120

7. 44500000

8. (TEMP+1) = 77533403

9. 66700001

10. 66730120

ARITHMETIC, FIXED POINT - ANSWERS

1. $(A)_f$ = 00003020

   $(Q)_f$ = 00000000 (can't be a negative zero)

2. $(A)_f$ = 77777711 (-66_8)

   $(Q)_f$ = 00000006 Same Sign as Dividend

3. $(A)_f$ = 00075767

4. $(A)_f$ = 77777776

5. $(A)_f$ = 60051600

REGISTER OPERATIONS WITHOUT STORAGE REFERENCE - ANSWERS

1. $(B^1)_f = 07777$

2. $(A)_f = 77740000$

3. $(Q)_f = 00007777$

4. $(A)_f = 00001000$

   $(Q)_f = 00000000$

1. ✓
2. ✓
3. ✓
4. ✓
5.
6. ✓
7. ✓
8.
9.
10. ✓
11.
12.
13. ✓
14. ✓
15.
16.
17.
18.
19. ✓
20.

STOP AND JUMP INSTRUCTIONS - ANSWERS

1. ✓
2. ✓
3.
4.
5.
6. ✓
7. ✓
8.
9. ✓
10. ✓
11.
12.
13.
14. ✓
15. ✓
16.
17. ✓
18.
19. ✓
20. ✓

1. $(A)_f$ = 00000000

2. $(A)_f$ = 00000000

   $(Q)_f$ = 01000000

   $(B^1)_f$ = 00000

3. $(P)_f$ = 07007

   (07002) = UJP 07007B

4. Looks at all values of TEMP   TEMP+4, for values greater or equal to 100 octal. A count of all values equal to or greater than 100 octal are kept in COUNT. A count of all values less than a 100 octal are kept in TALLY.

5. $(P)_f$ = C.1
   C.0

INTER-REGISTER TRANSFERS - ANSWERS

1. $(A) = 16600000$

   $(Q) = 00077771$

2. $(A) = 00000012$

   $(Q) = 00000012$

   $(B^3)_f = 00011$

3. 1) 53040000

   2) 53740000

   3) 53200000

   4) 53410022

   5) 53140000

   6) 53630020

   7) 53420077

   8) 53330060

   9) 53020027

   10) 53010055

   11) 53500000

4. $(A)_f = 00000000$

   $(Q)_f = 77777777$

   $(B^1)_f = 77676$

   $(V24) = 77777777$

   $(V25) = 00100177$

   $(V26) = 00177776$

   $(V27) = 00077577$

5. 77777777

   77777577

   00000000

   00000000

SEARCH AND MOVE OPERATIONS - ANSWERS

1. A) All subroutines which are used by other programs, should save any register that is uses in performing its task. Index Register #2 may contain valuable data to program MAIN, at the time it transfers control to the DELETE subroutine; so if (B^2) was not saved upon entrance and restored before exiting from the DELETE subroutine, it would contain invalid data upon return to program MAIN.

   B) The DELETE subroutine must have the first word address of the card image area in the A Register upon entrance to its routine. So program MAIN must obtain the first word address of the card image area into A, before it transfers control to the DELETE subroutine. It does this by an ENA DATACARD.

   C) Normally a field represented by a double asterisk(**) will be modified during the execution of a program and the double asterisk (**) provides a convenient way to see if the modification took place. (**) presets the field to all 1_2's.

   D) Control is transferred to this instruction if a SRCE, SRCN, or MOVE instruction is already in progress and the search instruction preceding this jump instruction will not be initiated until any previous search or move is completed.

   E) 1. When a comparison occurs between the search character (non-blank) and a non-blank character in storage.

      2. When register file 20 is equal to register file 30 (no non-blank character found).

   F) The search is to continue until all blank characters are deleted. Upon a find, the search is terminated and register file location #20 contains the address of the find. So to continue the search this address must be updated by 1 or the program will be hung in a loop.

G) Upon exiting from the DELETE subroutine, A will contain the last character address + 1 of the DATACARD area with all blank characters deleted.

2. A)

PROG1		PROG2
1.8		90.2
1.8		1.8
3.5		92.0 usec.
3.5	Repeated 8 times	
1.8		
2.6		
1.8		
1.8		
109.2 usec.		

B) On the above move he saves only 17.2 usec. (approximately 2 usec. per character). On a maximum move of 128 characters, the MOVE instruction would be approximately 256 usec.

```
        IDENT     PROGRAM
        ENTRY     START
START   SRCE      73B,CARD,CARD+80
        UJP       *-2
        PAUS      4000B
        UJP       *-1
        TMA       30B
        LPA       MASK
        SHAQ      24
        TMA       20B
        LPA       MASK
        AQJ,EQ    EXIT
        HLT
EXIT    ENA,S     +0
        UJP       *-2
MASK    ØCT       377777
        END
```

STORAGE TESTS - ANSWERS

1. A) The program searches a list of operands from LIST thru LIST+7 (10 locations) looking for values that are within or equal to the upper limit in A (200_{10}) and the lower limit in Q (100_{10}). On a find, the addresses of the operands are stored in a table called ADDRESS.

   B)

M.L.	Contents of
ADDRESS	LIST+6
ADDRESS+1	LIST+5
ADDRESS+2	LIST+1
ADDRESS+3	0

2. Answer is d; contents of A is not altered.

3. The program searches a list of 6 bit characters, from LIST thru LIST+2 (3 locations) for a 45 code in any character position (0 thru 3) of each location. Upon a find, the character address is generated and stored into a table called LIST1.

4.

```
          IDENT   PRØGRAM
          ENTRY   START
START     ENI     17,1        B1 = SIZE ØF TABLE (16) + INTERVAL-1
          ENI     0,2         B2 = ADDRESS CØUNTER
          ENQ     7700B       Q = 00007700 (MASK)
SEARCH    ENA     6200B
          MEQ     INFØ,2      INFØ = START ØF TABLE, 2 = INTERVAL
          UJP     THRU        SEARCH CØMPLETE
          ENA     INFØ        (A) = 000INFØ
          AIA     1           (A) = 000INFØ+B1
          STA     LIST,2      SAVE FIND ADDRESS
          INI     1,2         PREPARE FØR NEXT FIND
          UJP     SEARCH
THRU      HLT
INFØ      BSS     16
LIST      ØCT     0,0,0,0,0,0,0,0
```

Index register 1 must start with 17_{10}, because it will be decremented by the interval (2) before the search begins. This will start the search at INFØ+15, which is the last location of the table.

BCD OPERATIONS - ANSWERS

1. 02000 03020706

   02001 10111007

2. $(E)_f$ = +0822579612899

3. $(E)_f$ = +0006193435479

4. $(E)_f$ = +0000000009914

5. $(E)_f$ = +0026711689001

6. 00010 = 07060510

   00011 = 06071011

   00012 = 50XXXXXX

   $(E)_f$ = -0000000009568

7. CHARS

T	O	T	A
L		E	Q
U	A	L	
	04	05	04
06	10	07	11
11	00	00	XX

   $(E)_f$ = +0000000000000

   (D) = 10_{10} or 12_B

8. DATA

51	50	47	46
45	44	XX	XX
XX	XX	XX	XX
XX	XX	XX	XX

   $(E)_f$= +0000000000000

   automatically changes to a +0

SUMMARY OF INSTRUCTION EXECUTION TIMES, μsec.

2.5	ADA
3.8	ADAQ
11.5*	ADE
1.3*	AEU
1.3	AIA
1.3	ANA
1.3	ANI
1.3	ANQ
1.3	AQA
1.3*	AQE
1.9	AQJ
1.9	ASE
1.9	ASG
1.9	AZJ
1.3-1.7	CINS
***	CON
1.3-1.7	COPY
2.5-3.4	CPR
1.3	CTI
1.3	CTO
1.3	DINT
11.25	DVA
22.5*	DVAQ
1.3*	EAQ
1.3	ECHA
1.3	EINT
1.3*	ELQ
1.3	ENA
1.3	ENI
1.3	ENQ
1.3*	EOJ
1.3*	EUA
1.3-1.7	EXS
1.3*	EZJ
10.0-12.0*	FAD
20.0*	FDV
14.0-18.0*	FMU
10.0-12.0*	FSB
—	HLT
1.3	IAI
**	IAPR
1.9	IJD
1.9	IJI
1.3	INA
***	INAC
***	INAW
1.3	INCL
1.3	INI
3.3	INPC
3.3	INPW
1.3	INQ
1.3-1.7	INS
1.3-1.7	INTS
1.3	IOCL
1.9	ISD
1.9	ISE
1.9	ISG
1.9	ISI
2.5	LACH
2.5	LCA
3.8	LCAQ
2.5	LDA
3.8	LDAQ
8.0*	LDE

2.5	LDI
2.5	LDL
2.5	LDQ
2.5	LPA
2.5	LQCH
4.2 + 4.2n	MEQ
3.3	MOVE
4.2 + 4.2n	MTH
7.8-11.0	MUA
16.0-21.0*	MUAQ
3.3	OTAC
3.3	OTAW
3.3	OUTC
3.3	OUTW
2.0 us-40 ms	PAUS
1.3*	QEL
1.9	QSE
1.9	QSG
3.8	RAD
2.5	RTJ
2.5	SACH
2.5	SBA
3.8	SBAQ
1.3	SBCD
11.5*	SBE
2.5	SCA
1.9-3.9	SCAQ
2.5	SCHA
1.3	SCIM
***	SEL
1.3*	SET
1.3-4.3*	SFE
1.3	SFPF
1.3-2.7	SHA
1.3-2.7	SHAQ
1.3-2.7	SHQ
1.3	SJ1-6
1.3	SLS
2.5	SQCH
3.3	SRCE
3.3	SRCN
2.5	SSA
3.8	SSH
1.3	SSIM
2.5	STA
3.8	STAQ
8.0*	STE
2.5	STI
2.5	STQ
2.5	SWA
1.3	TAI
1.8	TAM
1.3	TIA
1.8	TIM
1.8	TMA
1.8	TMI
1.8	TMQ
1.8	TQM
—	UCS
1.3	UJP
1.3	XOA
1.3	XOI
1.3	XOQ

n = number of words searched.

* = Trapped instruction in computers without the appropriate optional hardware package.

** = Dependent upon interrupt response.

*** = Dependent upon a variable signal response time from an external source of equipment.

INSTRUCTION INDEX

CONTROL DATA

►►CUT OUT FOR USE AS LOOSE-LEAF BINDER TITLE TAB

31/32/33/3500 COMPASS PROGRAMMING TRAINING MANUAL

CONTROL DATA
CORPORATION

CORPORATE HEADQUARTERS, 8100 34th AVE. SO., MINNEAPOLIS, MINN, 55440
SALES OFFICES AND SERVICE CENTERS IN MAJOR CITIES THROUGHOUT THE WORLD

Pub. No. 60184200

Litho in U.S.A.