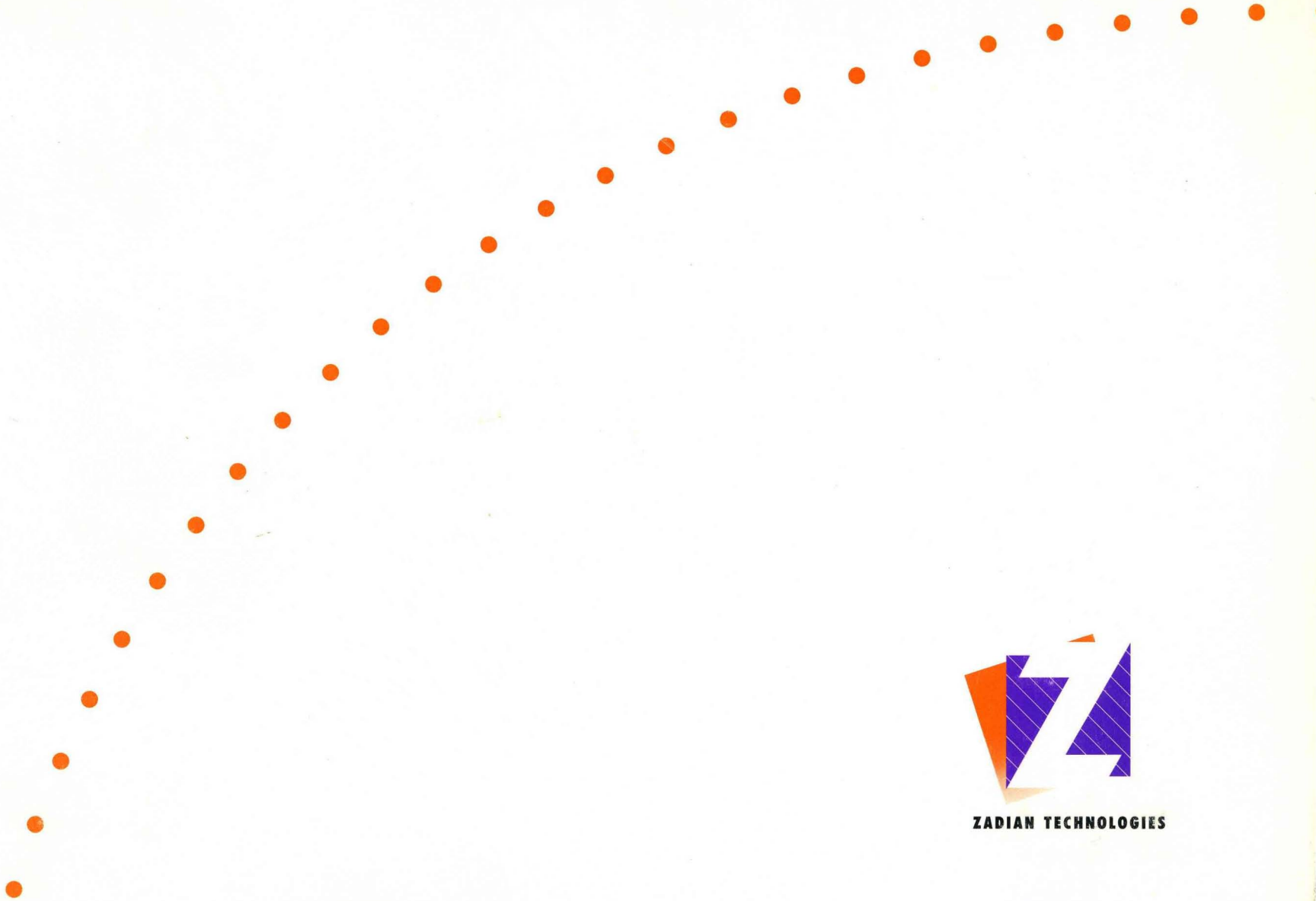
# SCSI, the Nuts and Bolts





ZADIAN TECHNOLOGIES

# Welcome Notes

Welcome to the Zadian seminar.

Please locate in the following pages of this book:

1. Copyright Notice
2. Disclaimer Notice
3. Information about Zadian products and services
4. Table of Contents

In the back of the book, you will find an index with subjects and page numbers.

We hope that you will find the course informative, helpful, and enjoyable.

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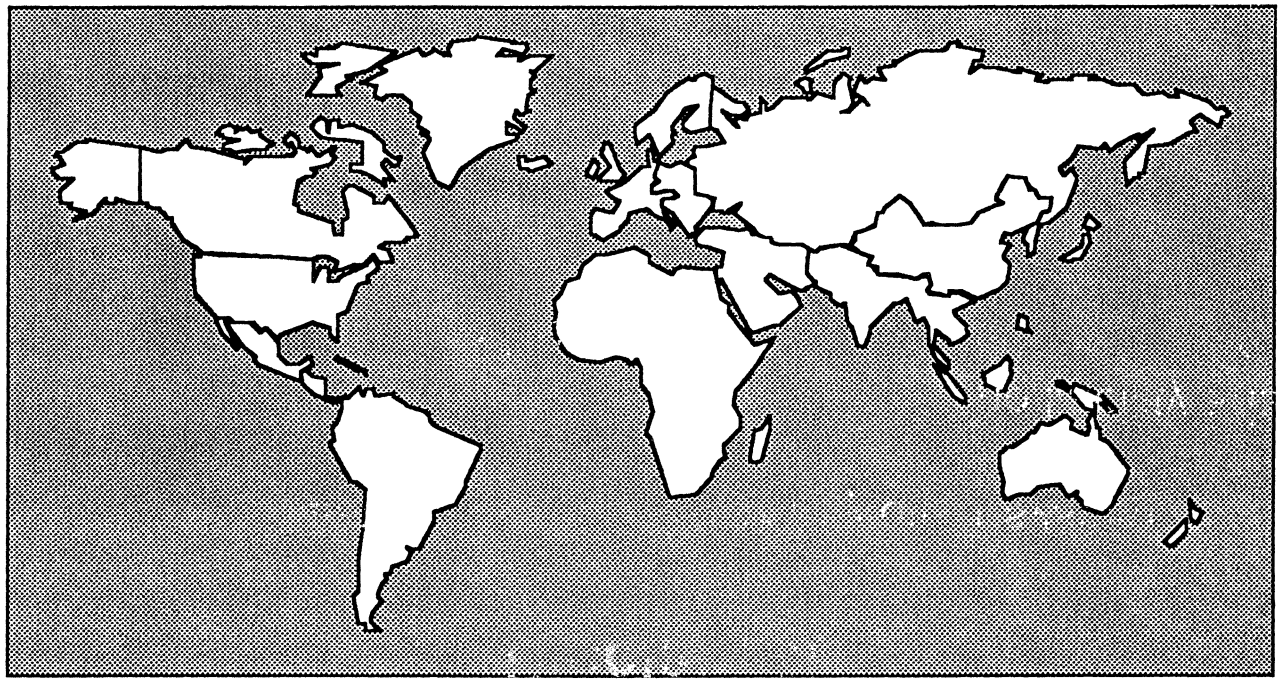
# A B O U T Z A D I A N

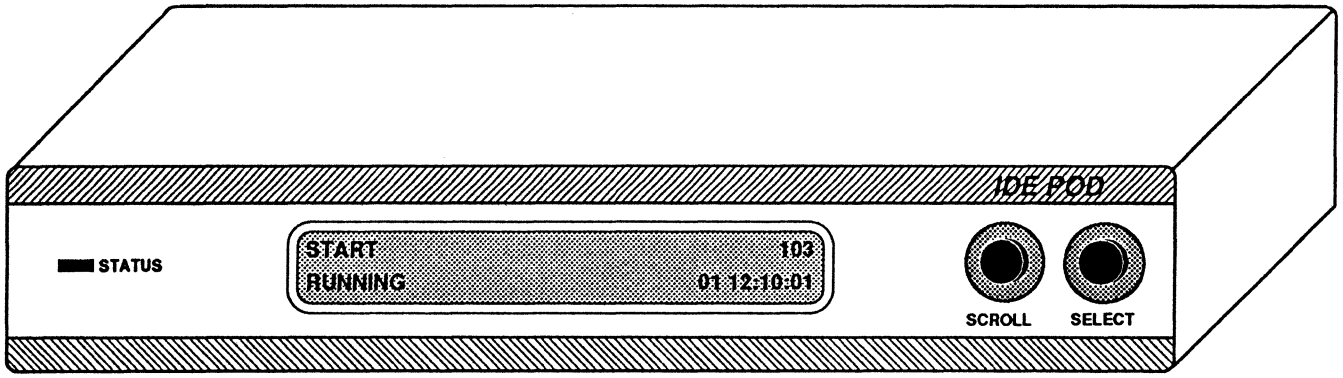
Zadian Technologies is a leading supplier of test, evaluation, and production systems and software for SCSI and IDE (ATA) disk, tape, optical and other peripheral devices. We also provide training seminars, custom software and consulting services in the area of SCSI, IDE, and disk drive technology.



Established in 1983, we have over 150 prestigious clients, have given hundreds of seminars, and trained thousands of students worldwide.

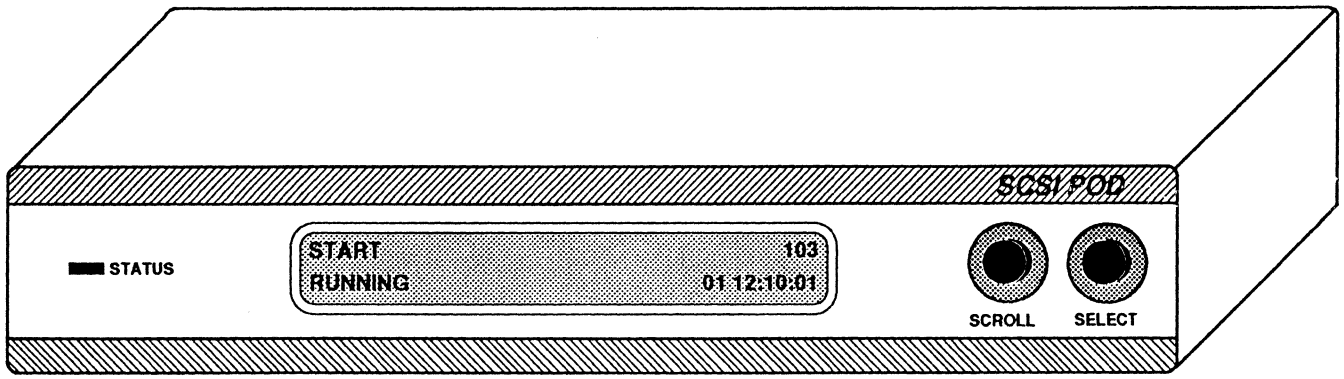
# IDE Pod

This is a multi-featured, powerful, flexible, and affordable IDE disk drive test system with turnkey and programmable software for stand-alone and multi-port production applications.

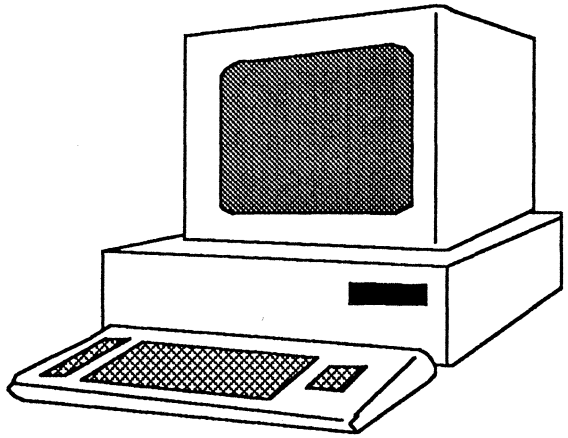


# SCSI Pod

This is a multi-featured, powerful, flexible, and affordable SCSI disk, optical, and tape drive test system with turnkey and programmable software for stand-alone and multi-port production applications.



# T E S T  S O F T W A R E



Our turnkey software packages are powerful, extensive, flexible, and user-friendly. They feature unsurpassed testing power offering the highest test coverage. They are also configurable with easy-to-use ASCII text parameter files that are editable by the user.

Also provided are detailed error reporting, debug and single-step modes, logic analyzer interface, and comprehensive documentation. Hardware platforms are the industry-standard Adaptec test adapters.

# SOFTWARE PACKAGES

**SCSI Host Basher**
This software is a complete SCSI disk and optical device target emulator with programmable error injection capabilities. It verifies host adapters' and device drivers' SCSI compliance and error condition handling, such as time-outs, status, sense, parity, media defects, and protocol violations.

**SCSI Disk/Optical Investigator/SCSI Tape Investigator**
This is SCSI target firmware evaluation and verification software. It thoroughly tests the SCSI protocol under legal and illegal conditions, including commands, messages, Attention, Unit Attention, Contingent Allegiance, Mode Select, reset, ECC, parity errors, linking, and synchronous negotiation.

**SCSI Tape Basher**
This software is a SCSI tape drive reliability, production, and functional test. It sequentially and randomly verifies read/write/space, rewind, erase, load/unload, filemarks, fixed/variable, buffered/unbuffered, write protect, data integrity, and performance.

**SCSI Queue Basher**
This is a SCSI-2 tagged queueing data integrity and throughput test. One or more targets are stressed using sequential and random commands and tagged messages.

**SCSI Tagged Queueing Drive Simulator**
This is a SCSI-2 disk or optical target simulator, supporting tagged queueing, to be used as a gold drive for testing host systems.

**SCSI Logic Analyzer Tool Kit**
This is user-friendly software to enhance the Adaptec SDS-210, 310, 310A, or 310S SCSI Logic Analyzer, with many features such as timing/state toggle, search, pop-up windows, and translated SCSI commands, status and messages.

**SCSI Bus Sampler**
This is an on-screen SCSI bus monitor, displaying signals and phases at real-time. It provides the capabilities of a hardware bus analyzer without the expense.

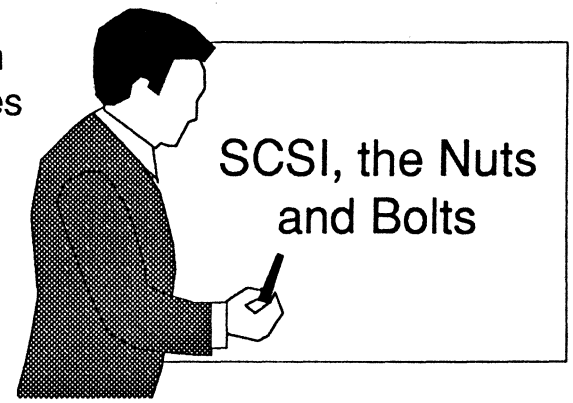
**SCSI Disk/Optical Basher**
This software is for reliability, production, and functional testing of SCSI disk and optical drives. It provides sequential and random read/write/seek testing, format, media scan, defect handling, data integrity checking, and industry-standard performance analysis.

**ATA/IDE Disk Basher**
This is an IDE disk drive reliability production, and functional test.

# TRAINING COURSES

Our seminars are designed to provide extensive technical training, with special emphasis on practical applications. They are based on decades of experience in I/O engineering, integration, and testing, and are presented by expert instructors.

The courses are offered publicly and on-site worldwide.




**SCSI, the Nuts and Bolts**
This is a comprehensive and up-to-date seminar covering hardware, software, firmware and all other SCSI aspects.

**Introduction to SCSI**
This course provides an overview of SCSI fundamentals and concepts.

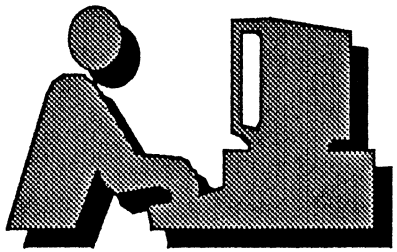
**Disk Drive Technology**
This seminar offers extensive training on essentials of disk drives including heads and media, read/write, servo, and interfaces.

**IDE (ATA)**
This is a thorough examination of IDE covering hardware, software, and firmware.

# C O N S U L T I N G

Our expert team of professional software engineers has produced millions of lines of very high quality 'C' and assembly code for SCSI, IDE, and other peripheral device software and firmware, for a large variety of systems and applications.

Areas of expertise include:



**Host Device Drivers**

We have a library of device drivers for numerous protocol chips and hardware platforms, which can be customized for your specific application.

**Device Firmware**

We have firmware for various target device types which can be ported to your own device.

**Test Software**

You can choose from tens of test applications which can be modified to suit your needs.

# Table of Contents
# Introduction

# Table of Contents
# Commands

# Table of Contents
# Commands
(Continued)

# Table of Contents
# Commands
(Continued)

# Table of Contents
# Electrical Characteristics

# Table of Contents
# Advanced Features

# Table of Contents
# SCSI-2

# Table of Contents
# Practical Aspects

# INTRODUCTION

# History of SCSI

1979: Shugart Associates develops SASI (Shugart Associates System Interface) for intelligent disk drives.

1982: ANSI (American National Standards Institute) X3T9.2 committee names SCSI (Small Computer System Interface) and begins work on SCSI-1 standard.

1984: SCSI-1 standard semi-finalized.

1986: Industry group completes CCS (Common Command Set) standard mainly to supplement SCSI-1 for disk drives.

1986: SCSI-1 standard released.

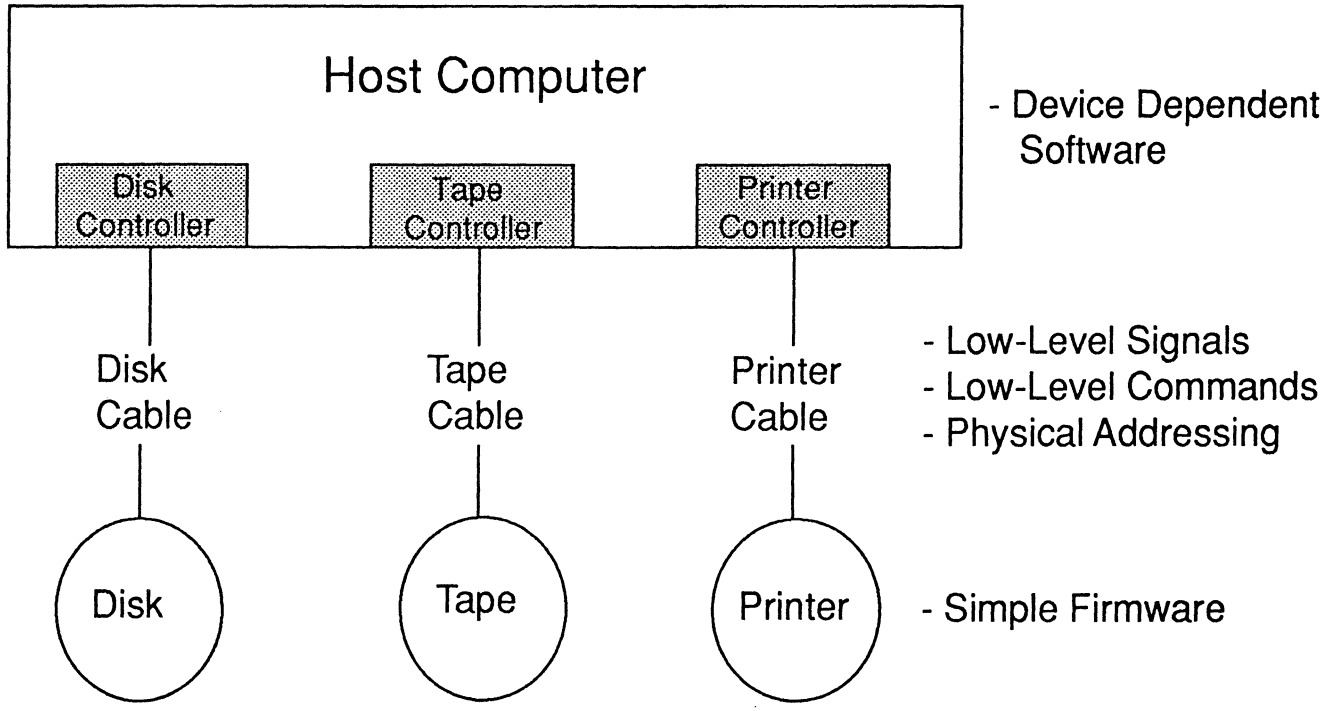
1986: ANSI begins work on SCSI-2 standard.

1989: SCSI-2 standard semi-finalized.

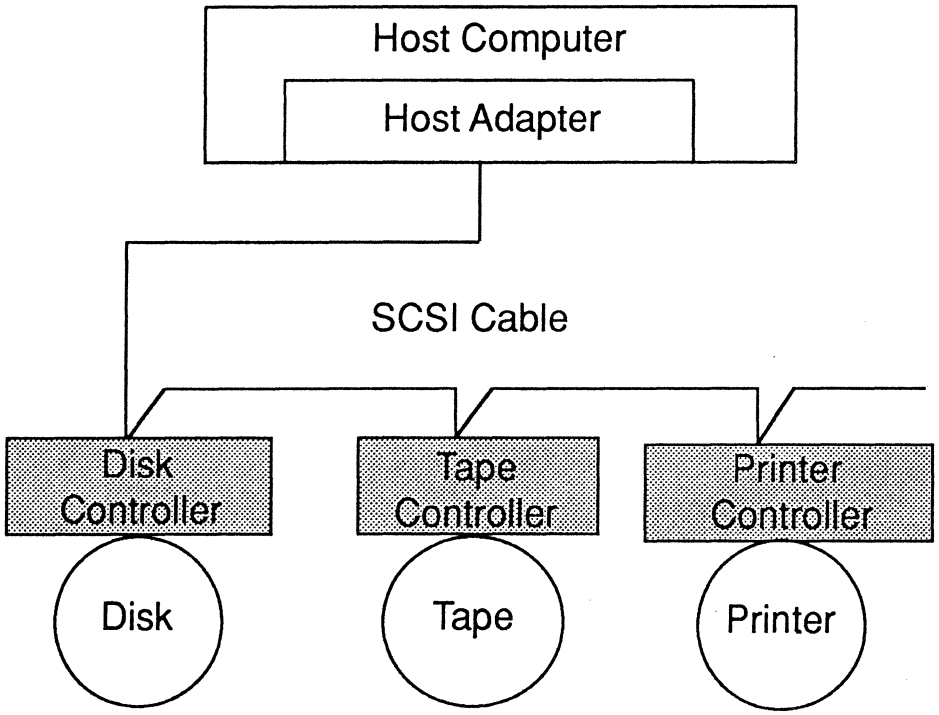
1991: ANSI begins work on SCSI-3 standard.

1992: SCSI-2 standard completed.

# Overview of Non-SCSI System



# Overview of SCSI System




- generic software

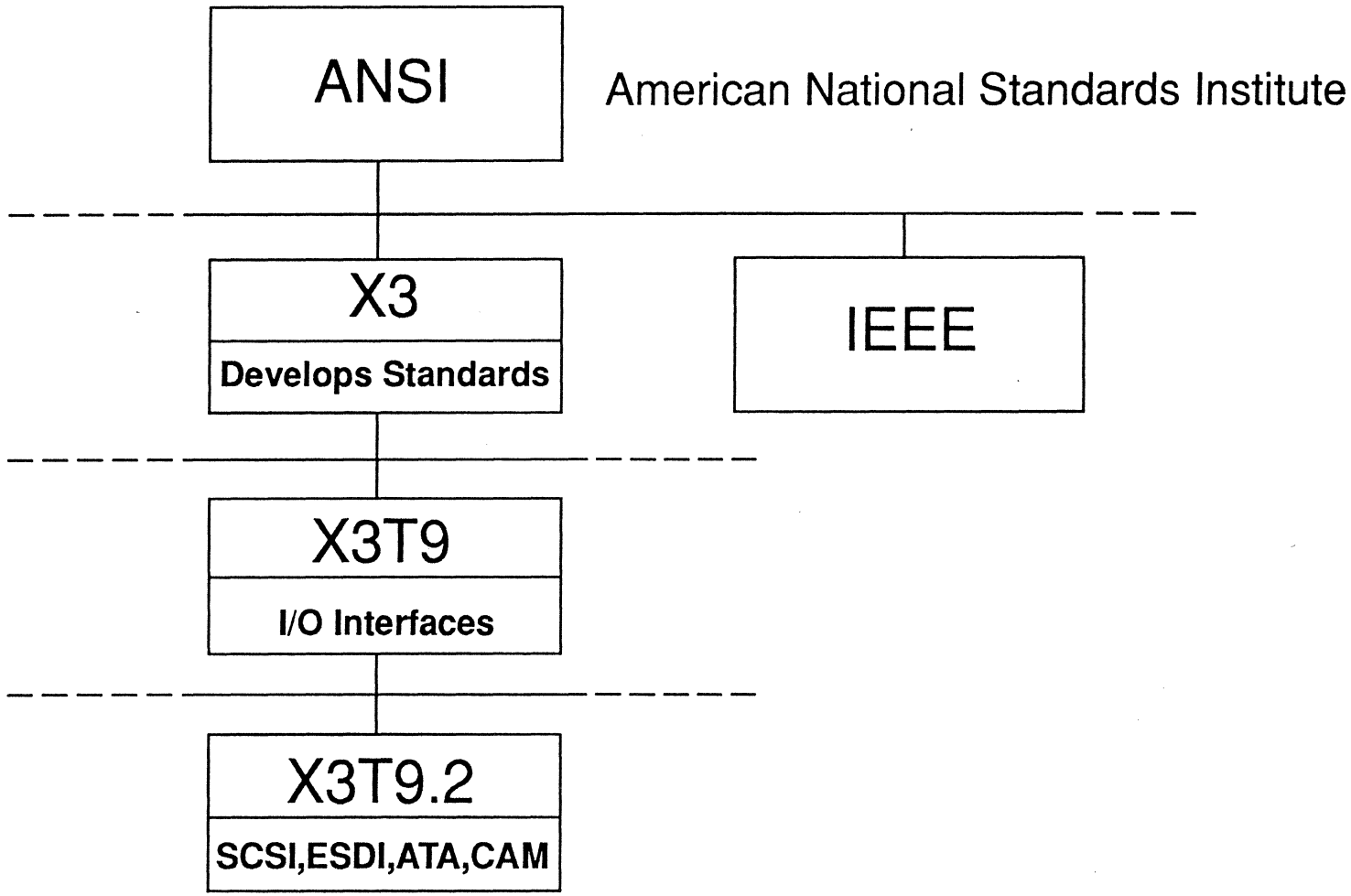
- high-level signals
- high-level commands
- logical addressing

- intelligent firmware

# Overview

- SCSI = Small Computer System Interface
- I/O Bus Interface between Computers and Peripheral Devices
- Allows Communication With All Device Types Using The Same Host Adapter
- Provides Mechanical, Electrical, and Functional Definitions
- Uses Logical Rather than Physical Addressing of Data Blocks
- For Personal Computers and Minicomputers

# Standards


ANSI
American National Standards Institute
X3
Develops Standards
IEEE
X3T9
I/O Interfaces
X3T9.2
SCSI,ESDI,ATA,CAM

# Standards
(Continued)

| | |
|---|---|
| SCSI-1: | ANSI X3.131-1986 |
| CCS: | X3T9.2/85-52, 1986 (Revision 4.B) |
| SCSI-2: | ANSI X3.131-1992 (Revision 10h) |
| SCSI-3: | ANSI X3.131-199x |

## Where to Get Documents

SCSI Bulletin Board System: (719)574-0424 or (316)636-8700

SCSI-1 and CCS:

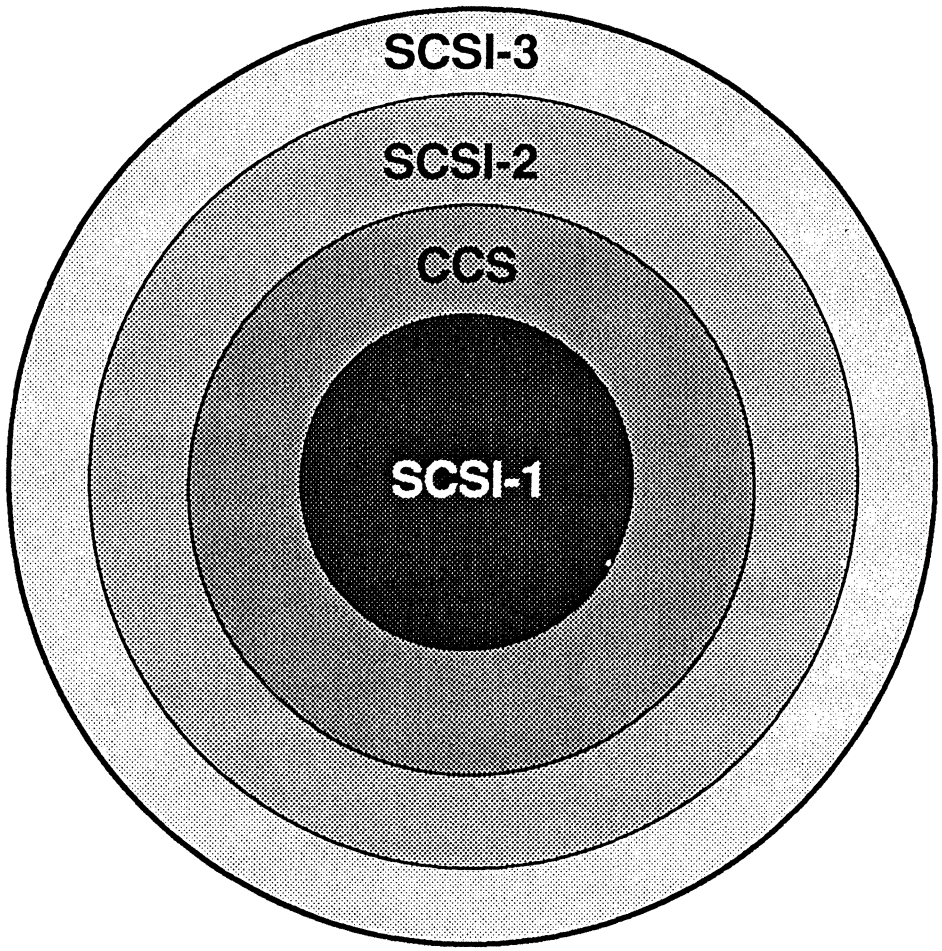
American National Standards Institute
1430 Broadway
New York, NY 10018

SCSI-2 and most others:

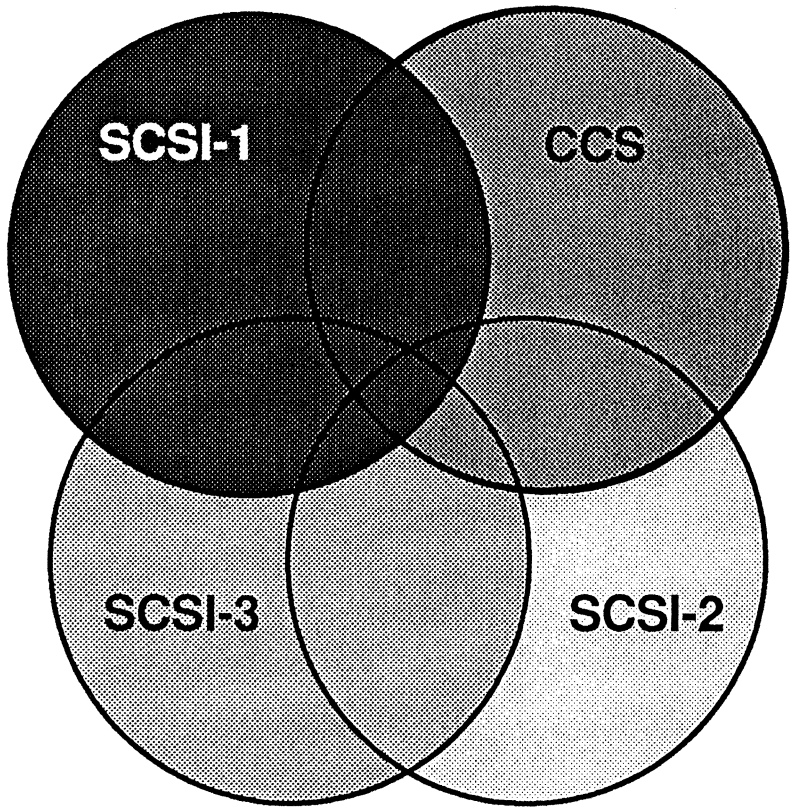
Global Engineering Documents
2805 McGaw
Irvine, CA 92714
Tel: (800) 854-7179 or (714) 261-1455

# Relationship Between Standards

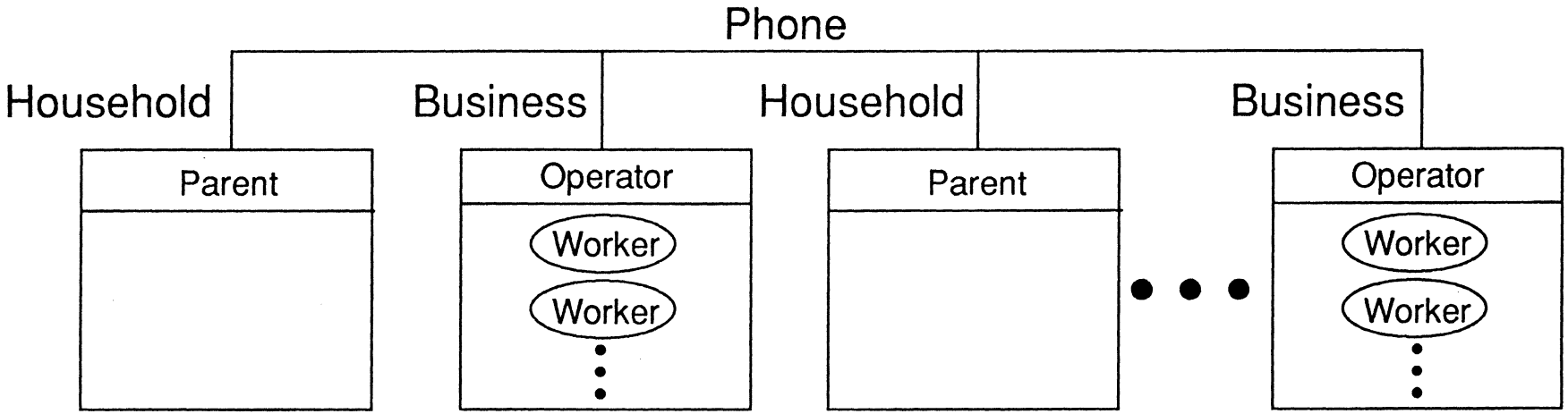
Roughly:




Accurately:

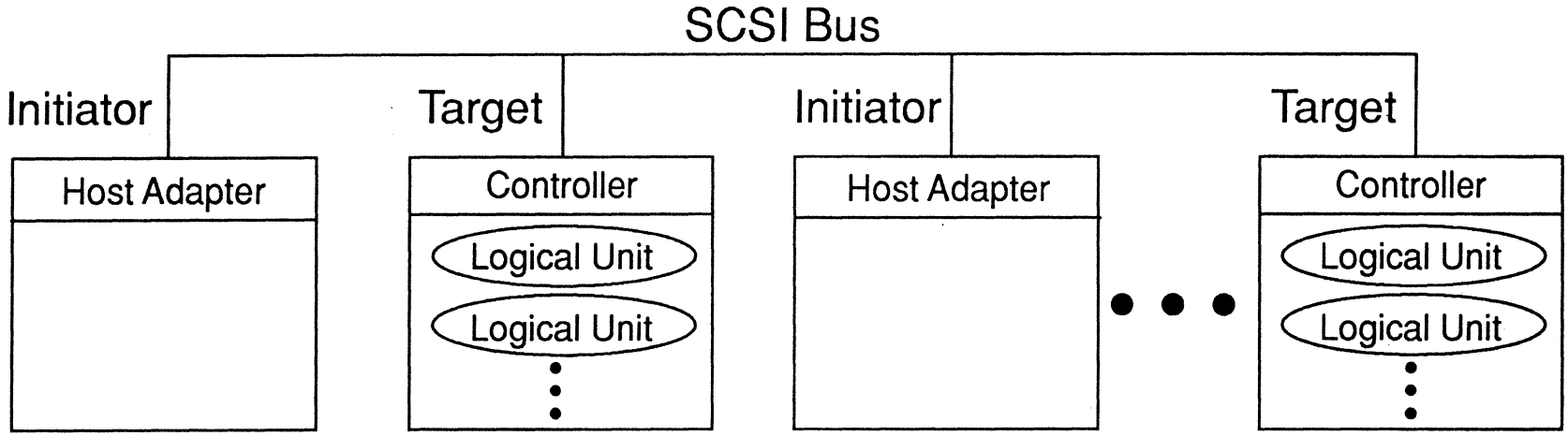


# Analogy With Phone System




| | |
|---|---|
| Phone System | SCSI Bus |
| Phone Subscriber | SCSI Device |
| 1-8 Subscribers | 1-8 Devices |
| Household | Initiator |
| Parent | Host Adapter |
| Business | Target |
| Operator | Controller |
| Worker | Logical Unit |
| 1-8 Workers per Store | 1-8 Logical Units per Target |
| Phone Number | SCSI Address |
| Worker's Extension | Logical Unit Number |

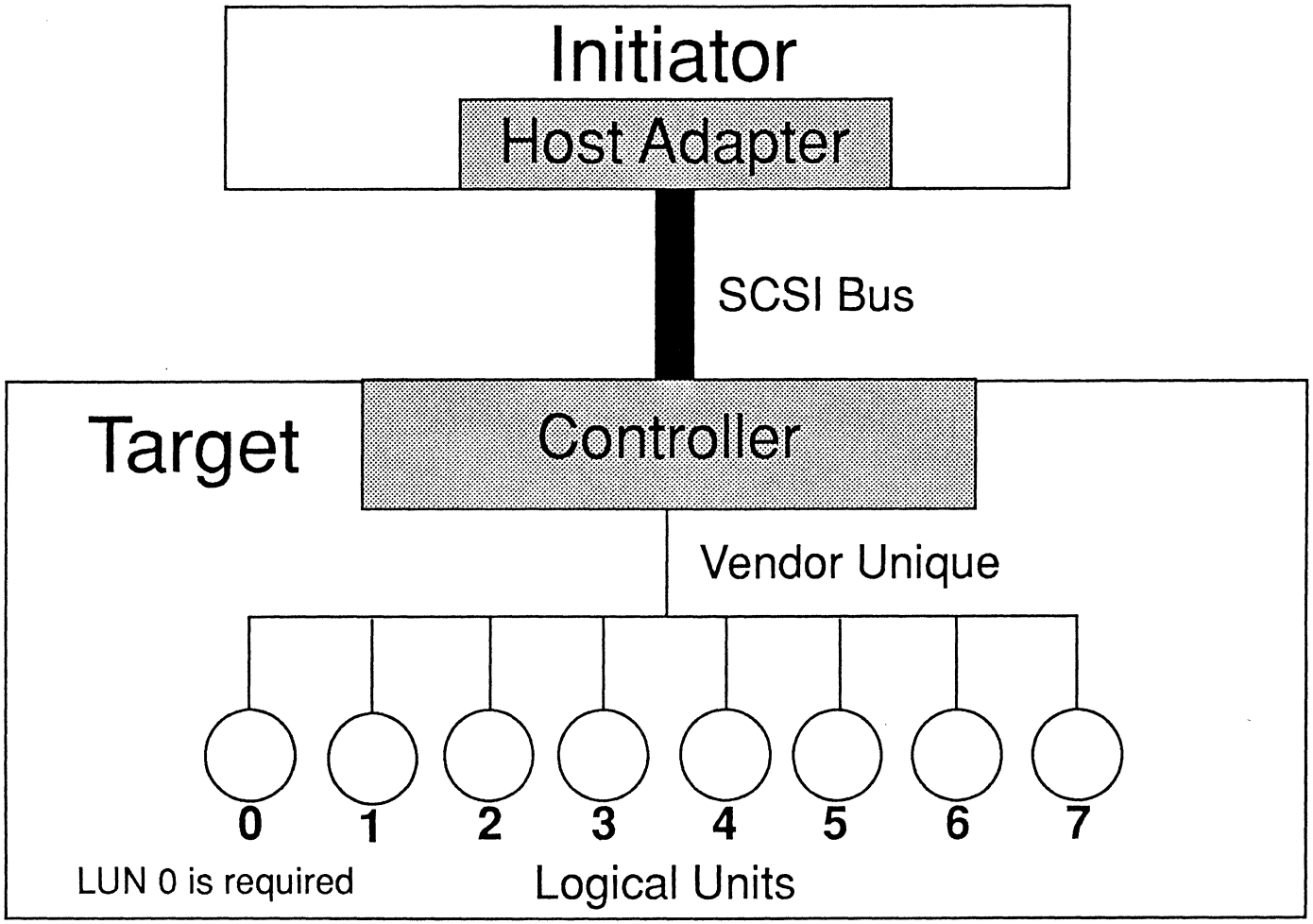
# SCSI Devices




- SCSI Device — Initiator or Target
- Initiator — Originates Operation (Usually Host Computer)
- Target — Performs the Operation (Usually Peripheral Device)
- Each Device has unique SCSI Address (ID), 0-7

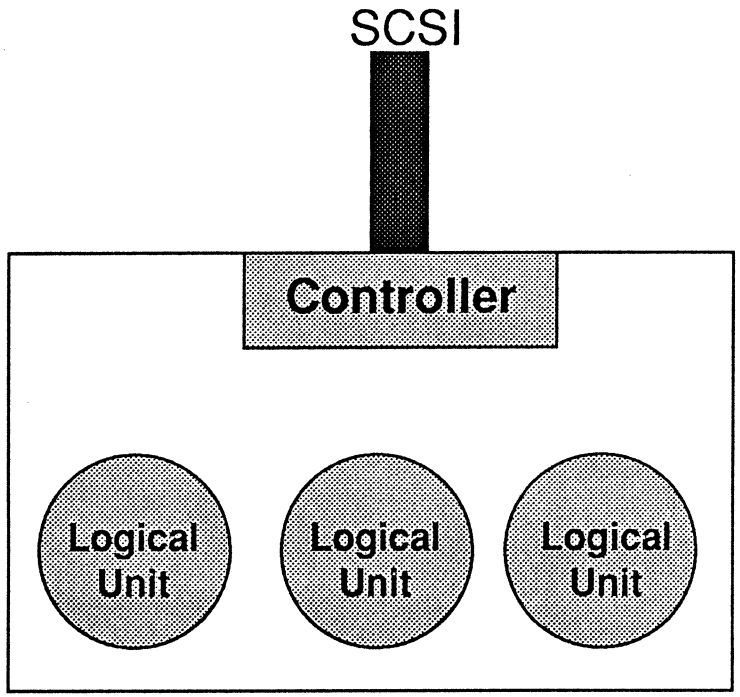
- Two Devices Communicating at a Time
- Max 8 SCSI Devices
- Logical Units
  - Peripheral Devices on the Controller
  - Max 8 Logical Units Per Controller
  - Each has Logical Unit Number (LUN)

# SCSI Devices
(Continued)



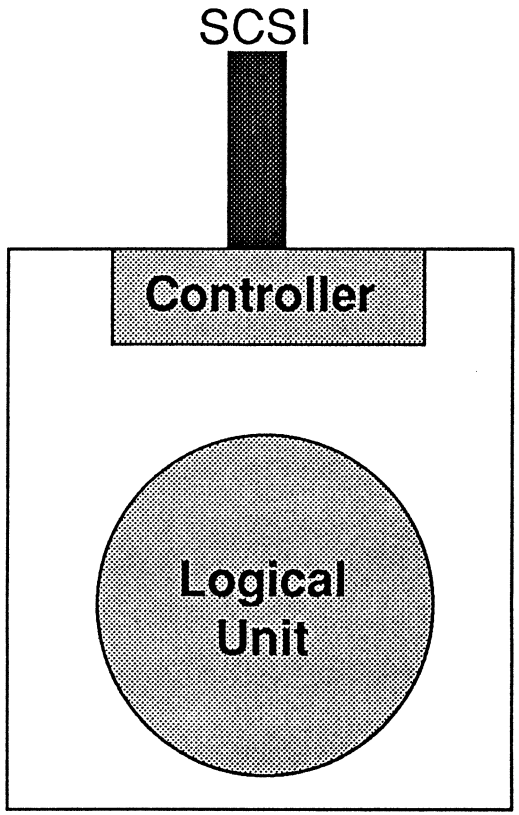
# Logical Units

Typical Floppy Drive



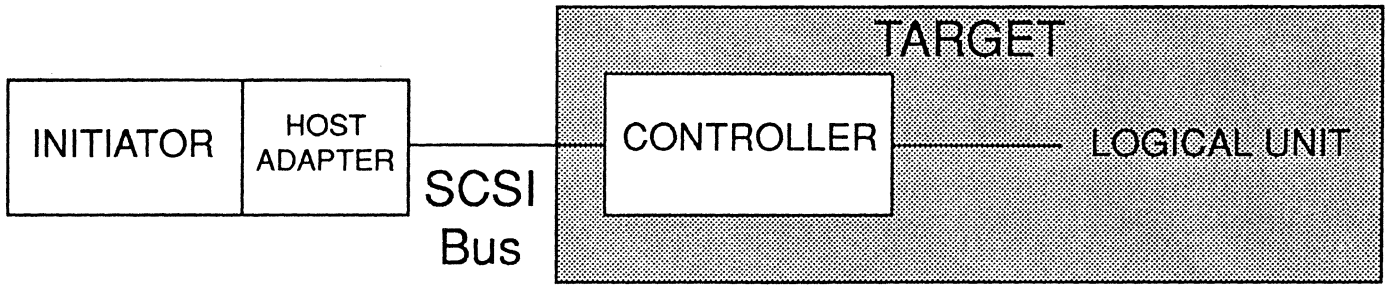

One or More Logical Units
(Logical Unit is the physical drive)

Typical Disk Drive

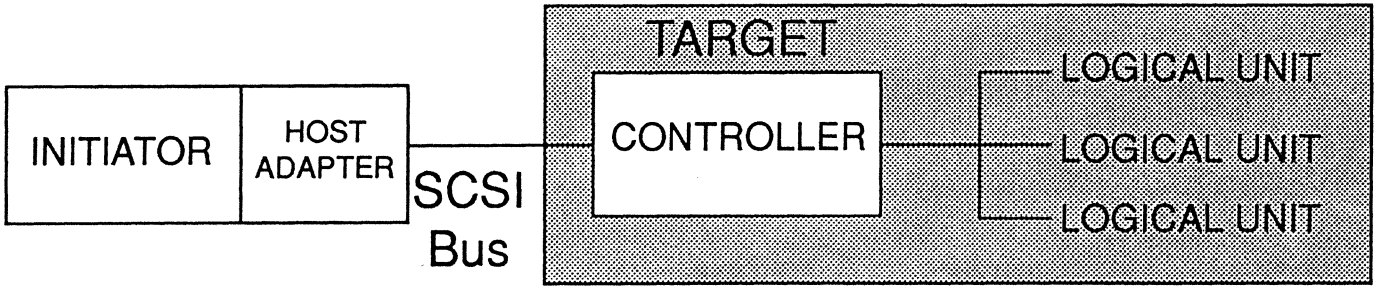



One Logical Unit Only
(Logical Unit is the HDA)

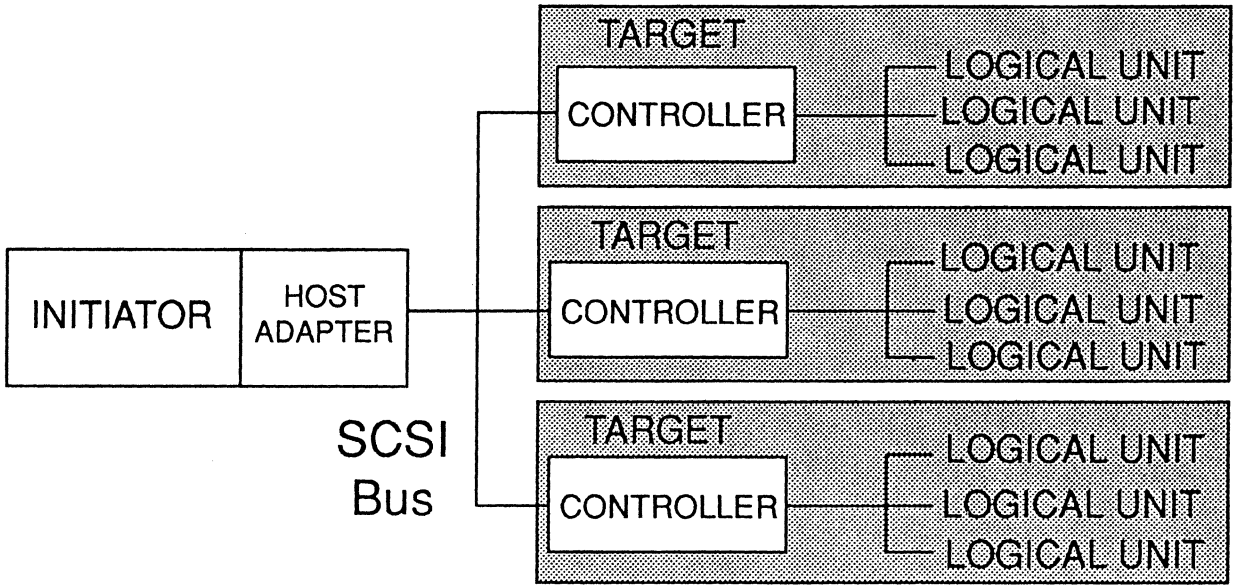
# System Configurations
## Single Initiator, Single Target



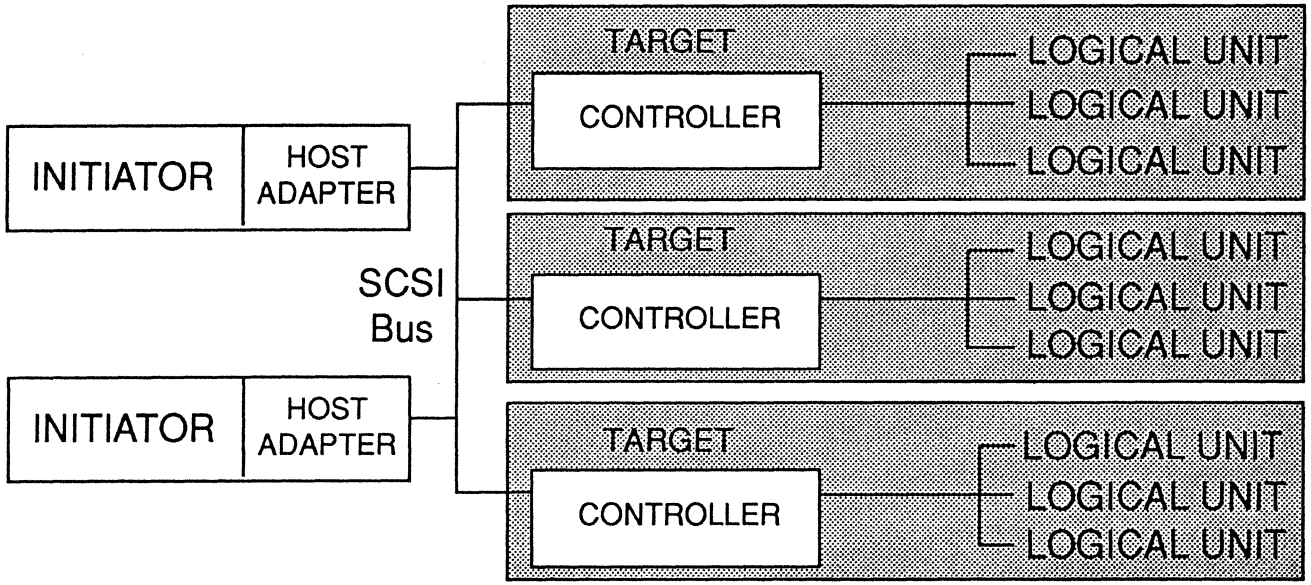
# System Configurations
## (Continued)
## Single Initiator, Single Target, Multiple Logical Units



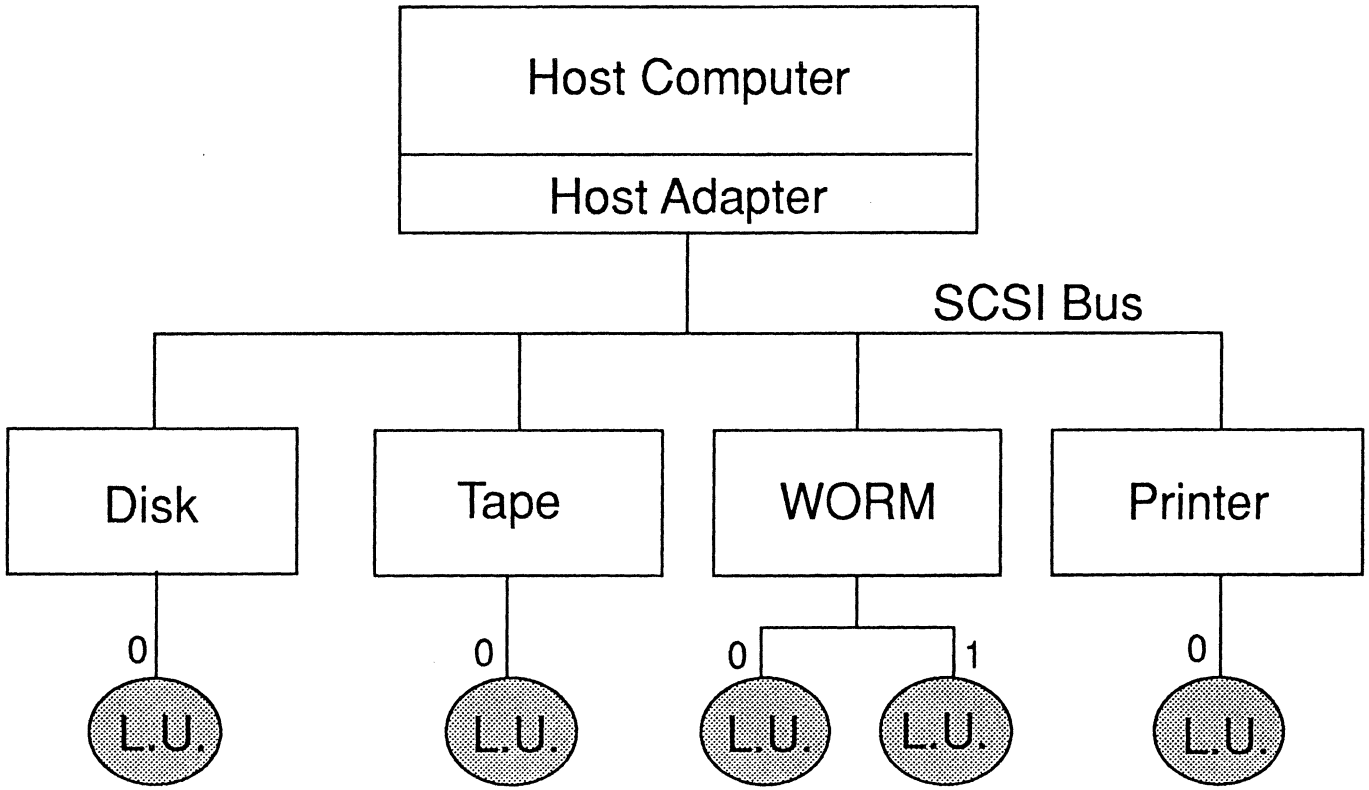
# System Configurations
## (Continued)
## Single Initiator, Multiple Targets



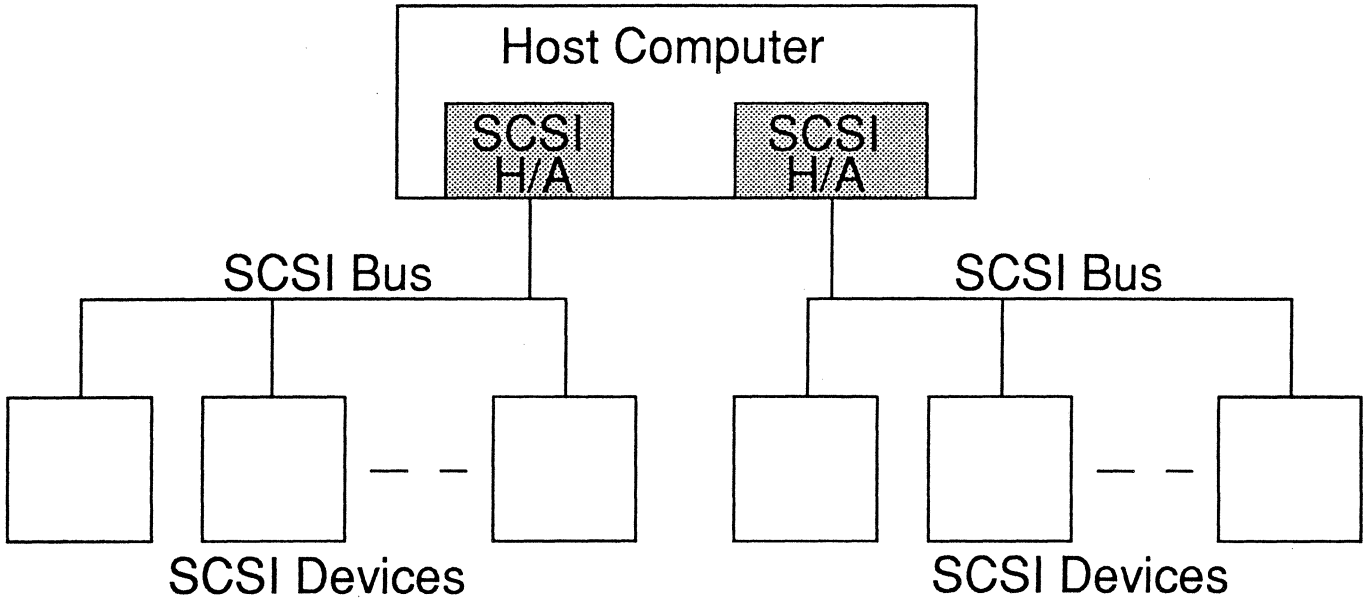
# System Configurations
## (Continued)
## Multiple Initiators, Multiple Targets



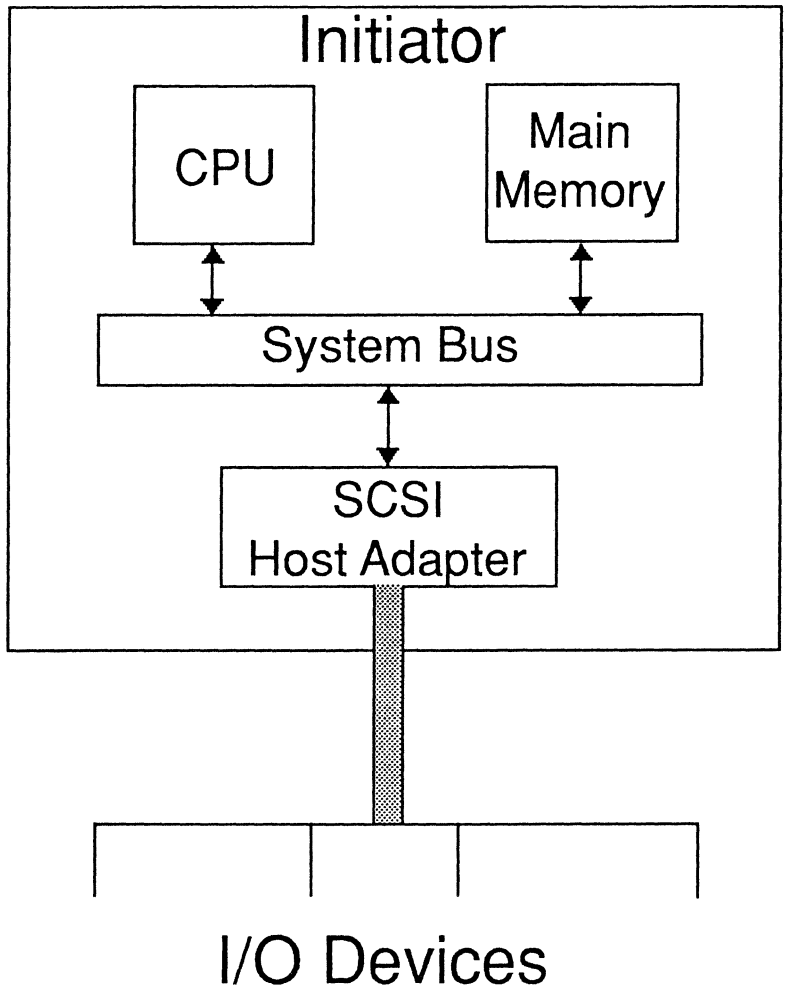
# System Configurations
## (Continued)
## Typical System



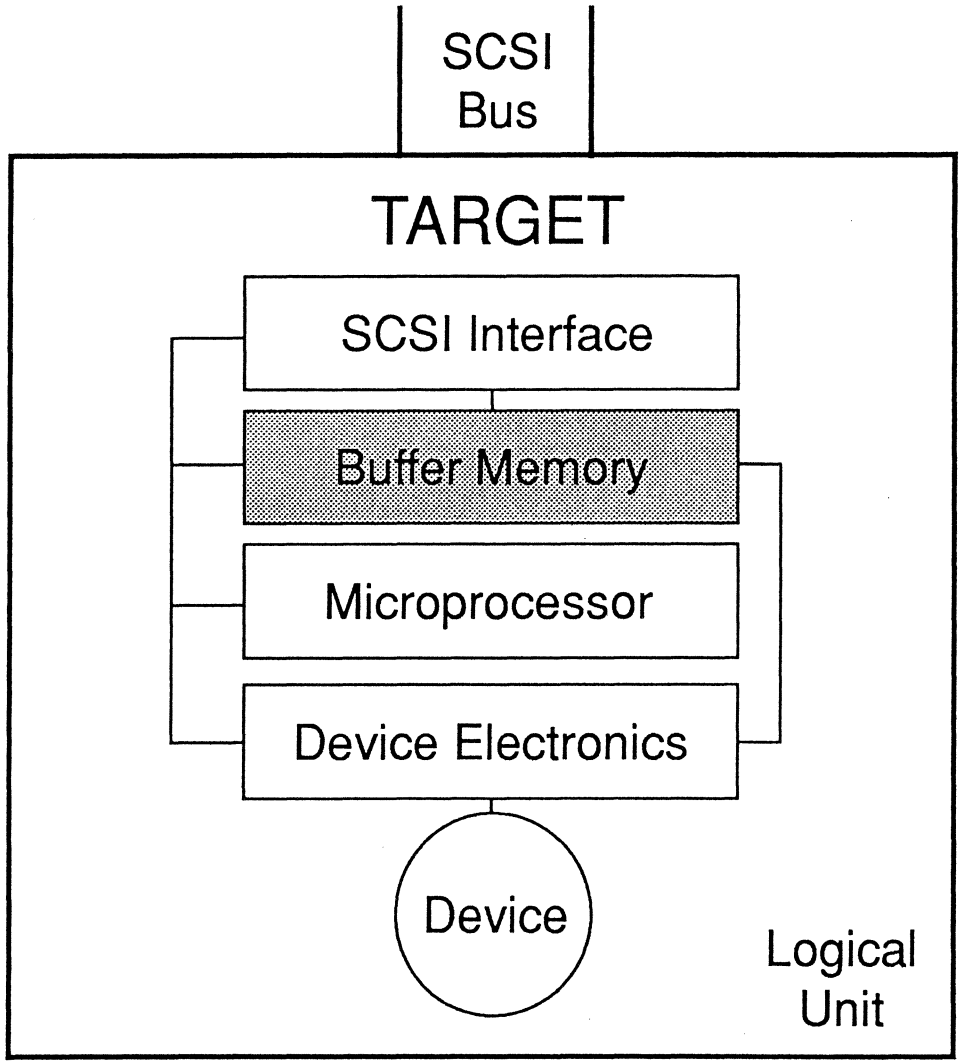
# System Configurations
## (Continued)
## Multiple Buses



# Initiator Block Diagram



# Target Block Diagram



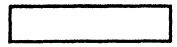
# Configuration Jumpers

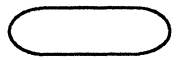
(Not required by SCSI Standard)

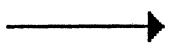
- SCSI Target Device Jumpers (or Dip Switches):
  - SCSI Address
  - Parity Enable (SCSI-1)
  - Disk Wait Spin (no spin on power-up)
  - Self-Test (Action is Vendor-Unique)
  - Terminator Power
  - Unit Attention Disable

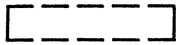
- SCSI Host Adapter Jumpers (or Dip Switches):
  - SCSI Address
  - Parity Enable (SCSI-1)
  - I/O Port Address Base
  - Interrupt Address
  - Self-Test (Action is Vendor-Unique)

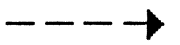
# Conventions Used in Handout


Process


Decision


Flow


Optional Process


Optional Flow

| | |
|---|---|
| V.U. | Vendor Unique |
| xxh | Hexadecimal Value |
| xb | Binary Value |
| M | Mandatory |
| O | Optional |
| iid | Initiator SCSI ID |
| tid | Target SCSI ID |

| | |
|---|---|
| MSB | Most Significant Bit |
| LSB | Least Significant Bit |
| H/A | Host Adapter |
| LU | Logical Unit |
| LUN | Logical Unit Number |
| ? | Don't Care |
| ms | Millisecond |
| us | Microsecond |
| ns | Nanosecond |

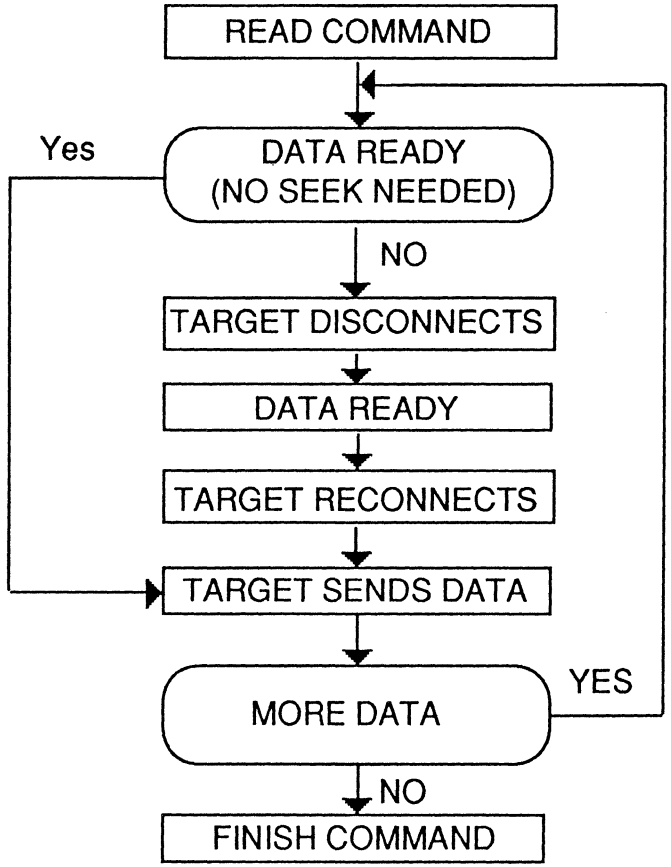
# Disconnect/Reconnect Procedures

| | |
|---|---|
| Connect | Initiator Selects (Dials a Target) |
| Disconnect | Target Releases Control of the Bus<br>(Will call back) |
| Reconnect | Target Reselects (Redials) an Initiator to Resume Command Execution<br>After Reconnection,<br>Target Resumes its Target Role<br>Initiator Resumes its Initiator Role |

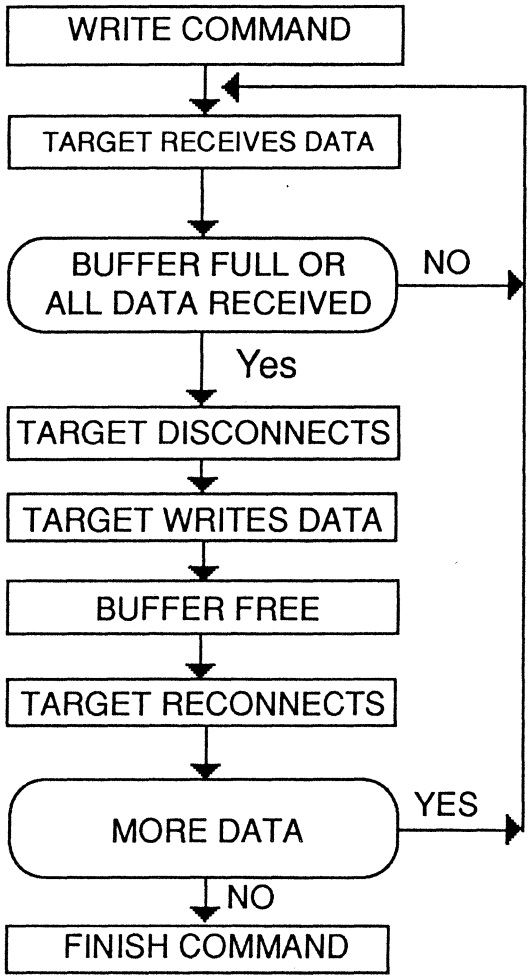
# Disconnect/Reconnect Procedures
(Continued)

- What
  - Free Bus in the Middle of the command Execution
- Why
  - Improves Bus Utilization
- How
  - Disconnect When Target is Not Ready
  - Reconnect When Target is Ready

# Disconnect/Reconnect Procedures
(Continued)



# Disconnect/Reconnect Procedures
(Continued)



# Bus Phases

- Bus Free
  - Bus is Idle
  - Data Bus = 0
  - Terminators in Control
- Arbitration
  - Resolve Contention Over Bus
  - Arbitrating Devices Put their ID's on Data Bus
  - Highest ID Wins and Gains Control Over Bus
  - Losers Back Off
- Selection
  - Initiator Selects (Dials) a Target
  - Initiator Puts Initiator and Target ID's on Data Bus
- Reselection
  - Target Reselects (Redials) an Initiator
  - Target Puts Initiator and Target ID's on Data Bus

# **Bus Phases**
(Continued)

## Connect and Reconnect Procedures Revisited

- Connect
  - Wait for Bus Free, Arbitrate, and Select
  - A Sequence of Phases
- Reconnect
  - Wait for Bus Free, Arbitrate, and Reselect
  - A Sequence of Phases

# Bus Phases
(Continued)

CDB

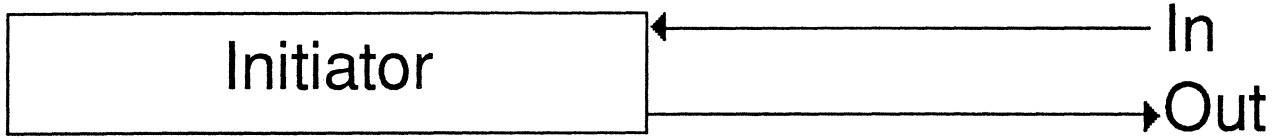
Command Descriptor Block
Bytes describing the command to execute
Prepared by the initiator and sent to the target
Transferred during command phase

# Bus Phases
(Continued)

- Information Transfer Phases:

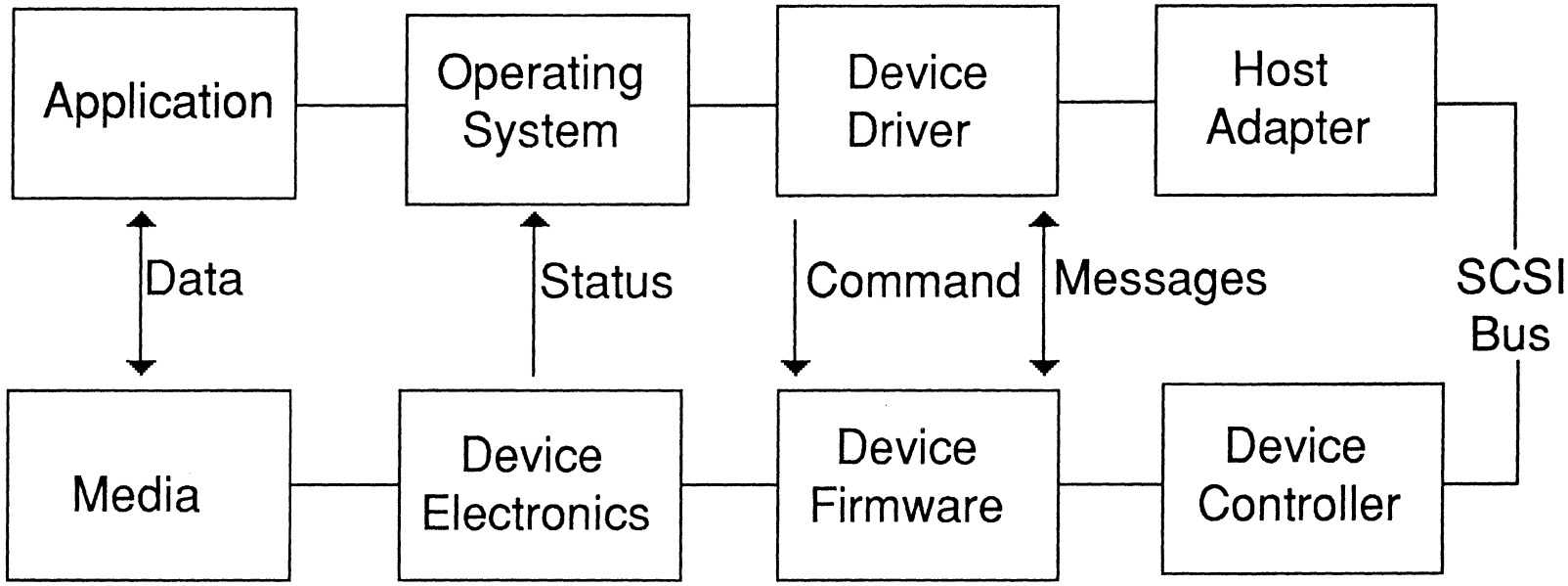
| | |
|---|---|
| - Command | Send Command (CDB) to Target |
| - Data In | Receive Data or Parameters from Target |
| - Data Out | Send Data or Parameters to Target |
| - Status | Receive Completion Information from Target |
| - Message Out | Send Message to Target |
| - Message In | Receive Message from Target |

- In Versus Out




- Target Decides Information Transfer Phase - Initiator Follows

# Bus Phases
## (Continued)
## What Messages Are

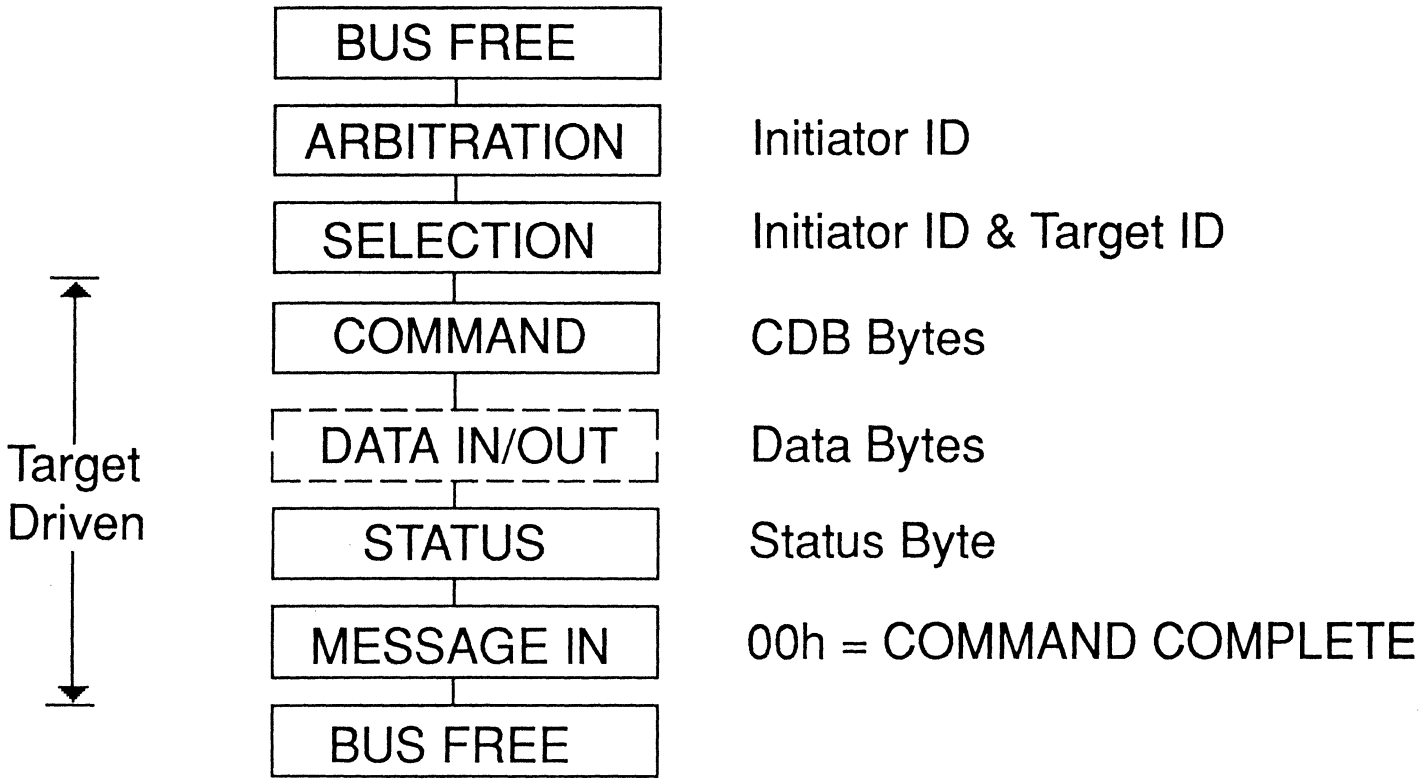


# Bus Phases
(Continued)

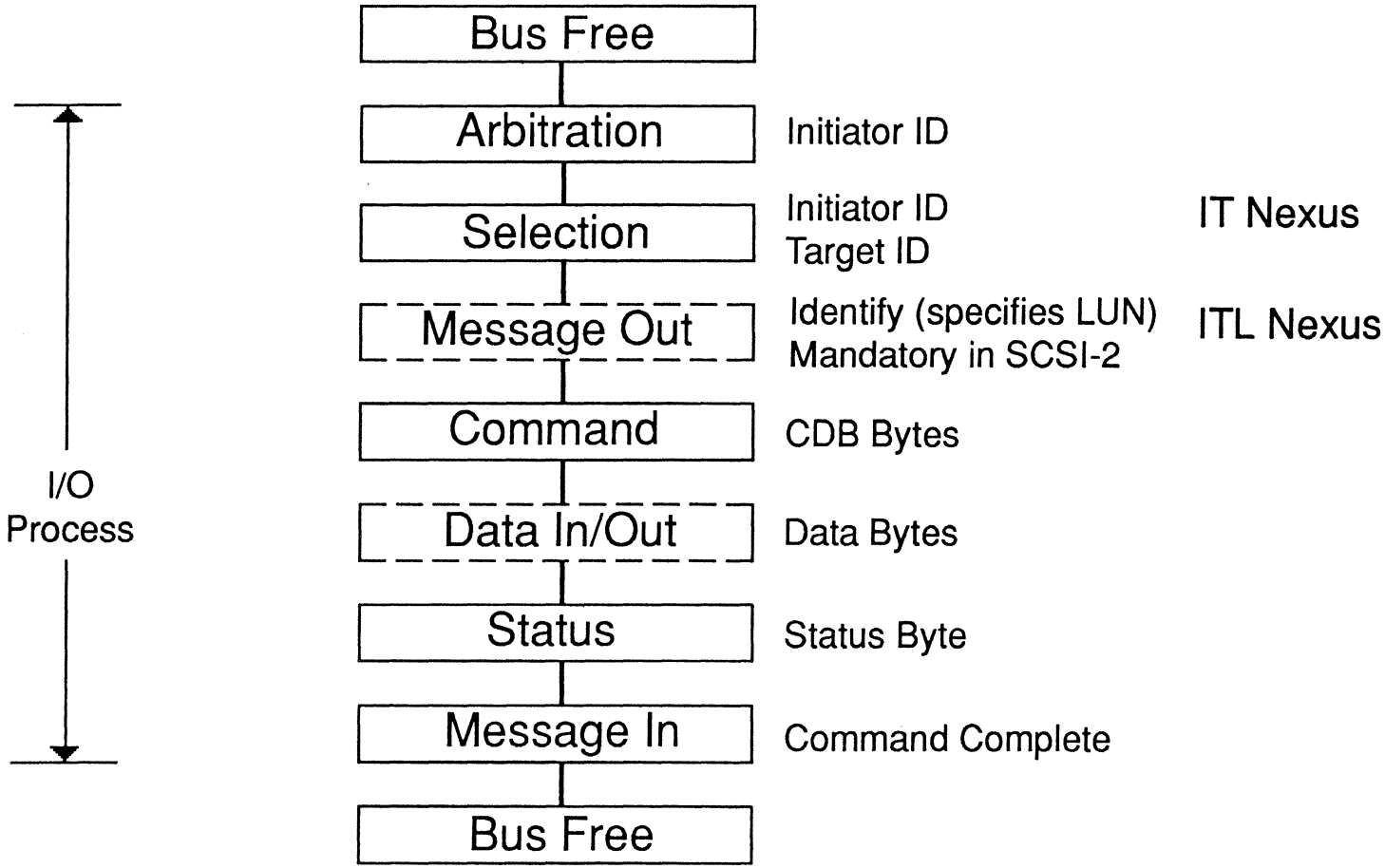
| Bus Phase | Data Bus Contents | Who Supplies Data Bus | Who Decides Bus Phase |
|---|---|---|---|
| Bus Free | 00h | Terminators | Terminators |
| Arbitration | Arbitrating Device ID's | Arbitrators | Arbitrators |
| Selection | Initiator and Target ID's | Initiator | Initiator |
| Reselection | Target and Initiator ID's | Target | Target |
| Command | CDB Byte | Initiator | Target |
| Data In | Data In Byte | Target | Target |
| Data Out | Data Out Byte | Initiator | Target |
| Status | Status Byte | Target | Target |
| Message Out | Message Out Byte | Initiator | Target |
| Message In | Message In Byte | Target | Target |

# Bus Phases
## (Continued)
## Sample Phase Sequence

**(SCSI-1 Example)**



# Bus Phases
## (Continued)
## Sample Phase Sequence



# Nexus and I/O Process

(for now only - definitions will be changed later in the course)

Nexus:

A relationship or connection between devices

IT Nexus:

Nexus between initiator and target
Established with selection phase

ITL Nexus:

Nexus between initiator, target, and logical unit
Established with Identify message

I/O Process:

The process of executing a SCSI command
Involves arbitration, selection, and other phases

# Hexadecimal Notation

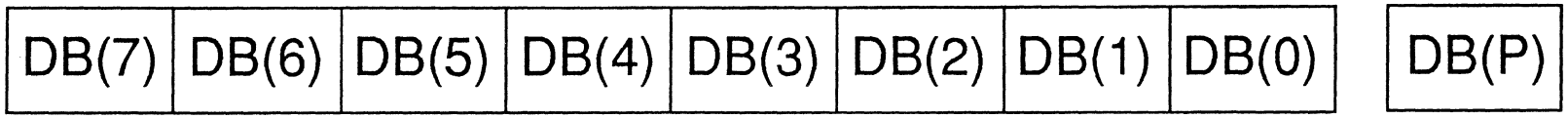
Nibble

| Binary | Hex |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | 8 |
| 1001 | 9 |
| 1010 | A |
| 1011 | B |
| 1100 | C |
| 1101 | D |
| 1110 | E |
| 1111 | F |

Byte Examples

| Binary | Hex |
|---|---|
| 0000 0000 | 00 |
| 0001 0010 | 12 |
| 0011 0100 | 34 |
| 0110 0101 | 65 |
| 1000 0111 | 87 |
| 1100 1011 | CB |
| 1001 1010 | 9A |
| 1110 1101 | ED |
| 1111 1111 | FF |
| 1000 0000 | 80 |
| 1100 0000 | C0 |

# Data Bus




- 9 data signals:
  - 8 for actual data
  - 1 for parity
- Parity is odd when valid

# Data Bus
## (Continued)
## Arbitration Examples

| DB(7) | DB(6) | DB(5) | DB(4) | - | DB(3) | DB(2 ) | DB(1) | DB(0) | Hex | Arbitrating Device(s) | Winner |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 1 | 01 | 0 | 0 |
| 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 0 | 02 | 1 | 1 |
| 0 | 0 | 0 | 0 | | 0 | 1 | 0 | 0 | 04 | 2 | 2 |
| 0 | 0 | 0 | 0 | | 1 | 0 | 0 | 0 | 08 | 3 | 3 |
| 0 | 0 | 0 | 1 | | 0 | 0 | 0 | 0 | 10 | 4 | 4 |
| 0 | 0 | 1 | 0 | | 0 | 0 | 0 | 0 | 20 | 5 | 5 |
| 0 | 1 | 0 | 0 | | 0 | 0 | 0 | 0 | 40 | 6 | 6 |
| 1 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 80 | 7 | 7 |
| 0 | 0 | 0 | 1 | | 0 | 0 | 1 | 0 | 12 | 1,4 | 4 |
| 0 | 1 | 0 | 1 | | 1 | 0 | 0 | 0 | 58 | 3,4,6 | 6 |
| 1 | 0 | 1 | 1 | | 1 | 1 | 0 | 0 | BC | 2,3,4,5,7 | 7 |
| 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | FF | 0,1,2,3,4,5,6,7 | 7 |

# Data Bus
## (Continued)
## Selection and Reselection Examples

| DB(7) | DB(6) | DB(5) | DB(4) | - | DB(3) | DB(2) | DB(1) | DB(0) | Hex | Devices |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 1 | 03 | 0, 1 |
| 0 | 0 | 0 | 1 | | 1 | 0 | 0 | 0 | 18 | 3, 4 |
| 0 | 0 | 1 | 1 | | 0 | 0 | 0 | 0 | 30 | 4, 5 |
| 0 | 1 | 0 | 1 | | 0 | 0 | 0 | 0 | 50 | 4, 6 |
| 0 | 1 | 1 | 0 | | 0 | 0 | 0 | 0 | 60 | 5, 6 |
| 1 | 1 | 0 | 0 | | 0 | 0 | 0 | 0 | C0 | 6, 7 |

Cannot distinguish initiator SCSI ID from target SCSI ID

# Status Values

| | |
|---|---|
| 00h | GOOD |
| 02h | CHECK CONDITION<br>Error, Use REQUEST SENSE Command to Get Error Information |
| 04h | CONDITION MET/GOOD<br>For SEARCH DATA and PREFETCH Commands |
| 08h | BUSY<br>Target is Busy, Retry Command Later |
| 10h | INTERMEDIATE GOOD<br>Linked Commands |
| 14h | INTERMEDIATE CONDITION MET/GOOD<br>Linked Commands |
| 18h | RESERVATION CONFLICT<br>Device or Area Reserved by Another Initiator |
| 22h | COMMAND TERMINATED (SCSI-2)<br>After Terminate I/O Process Message<br>Error, Use REQUEST SENSE Command to Get Error Information |
| 28h | QUEUE FULL (SCSI-2)<br>For Tagged Queueing |

# COMMANDS

# Command Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code | | | | | | | |
| 1 | LUN (SCSI-3: Reserved) | | | | Command Dependent | | | |
| 2 | Command Dependent | | | | | | | |
| • • • | | | | | | | | |
| N-2 | Command Dependent | | | | | | | |
| N-1 | Control Byte | | | | | | | |

N = Command Length

Used for Linking
Normally 0

CDB = Command Descriptor Block
LUN = Logical Unit Number (ignored when Identify message received, best set to 0)
SCSI-2: specify LUN in Identify Message recommended
SCSI-3: specify LUN in Identify Message mandatory
Reserved Fields Must Be Filled With 0, Else Check Condition (Illegal Request)

# Command Format
## (Continued)
## Op Code

- First CDB Byte = Operation Code

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| | Group Code | | | Command Code | | | | |

- Group Codes (Indicating CDB Length):

| | | |
|---|---|---|
| 000 | 0 | 6-Byte Commands |
| 001 | 1 | 10-Byte Commands |
| 010 | 2 | 10-Byte Commands |
| 011 | 3 | Reserved |
| 100 | 4 | Reserved |
| 101 | 5 | 12-Byte Commands |
| 110 | 6 | Vendor Unique |
| 111 | 7 | Vendor Unique<br>(See Product Description Manual) |

# Command Format
## (Continued)
## CDB Length Examples

| Op Code | | Group Code | CDB Length |
|---|---|---|---|
| Hex | Binary | | |
| 00h | 0000 0000 | 0 | 6 |
| 03h | 0000 0011 | 0 | 6 |
| 08h | 0000 1000 | 0 | 6 |
| 12h | 0001 0010 | 0 | 6 |
| 28h | 0010 1000 | 1 | 10 |
| 30h | 0011 0000 | 1 | 10 |
| B1h | 1011 0001 | 5 | 12 |
| FFh | 1111 1111 | 7 | ? |

# Command Format
## (Continued)
## Control Byte

- Last CDB Byte - Control Byte

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| | Vendor Unique | | Reserved | | | | Flag | Link |

- Typically used for linking
- Normally filled with 00h

# Command Format
## (Continued)
## Typical 6 Byte CDB

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code | | | | | | | |
| 1 | LUN | | | | LBA (MSB) | | | |
| 2 | LBA | | | | | | | |
| 3 | LBA (LSB) | | | | | | | |
| 4 | Length | | | | | | | |
| 5 | Control Byte | | | | | | | |

LBA - Logical Block Address (similar to sector number)
Length - Number of Blocks

# Command Format
## (Continued)
## Typical 10 Byte CDB

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code | | | | | | | |
| 1 | LUN | | | Command Dependent | | | | |
| 2 | LBA (MSB) | | | | | | | |
| 3 | LBA | | | | | | | |
| 4 | LBA | | | | | | | |
| 5 | LBA (LSB) | | | | | | | |
| 6 | Command Dependent | | | | | | | |
| 7 | Length (MSB) | | | | | | | |
| 8 | Length (LSB) | | | | | | | |
| 9 | Control Byte | | | | | | | |

# Command Format
## (Continued)
## Typical 12 Byte CDB

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code | | | | | | | |
| 1 | LUN | | | Command Dependent | | | | |
| 2 | LBA (MSB) | | | | | | | |
| 3 | LBA | | | | | | | |
| 4 | LBA | | | | | | | |
| 5 | LBA (LSB) | | | | | | | |
| 6 | Length (MSB) | | | | | | | |
| 7 | Length | | | | | | | |
| 8 | Length | | | | | | | |
| 9 | Length (LSB) | | | | | | | |
| 10 | Command Dependent | | | | | | | |
| 11 | Control Byte | | | | | | | |

# Command Sets

| Device Class | SCSI-1 | SCSI-2 | Notes |
|---|---|---|---|
| General | X | X | Most Devices |
| Direct Access | X | X | Disk, Diskettes, ... |
| Sequential Access | X | X | Tape |
| Printer | X | X | |
| Write Once | X | X | WORM |
| Processor | X | X | Computer |
| CD-ROM | | X | |
| Scanner | | X | |
| Optical Memory | | X | WORM, Erasable, ... |
| Medium Changer | | X | Jukebox |
| Communications | | X | |

# Command Sets
## (Continued)
## General SCSI Commands

(M=Mandatory, O=Optional, - =Unsupported)

| Opcode | Command | SCSI-1 | CCS | SCSI-2 |
|---|---|---|---|---|
| 40h | Change Definition | - | - | O |
| 39h | Compare | O | O | O |
| 18h | Copy | O | O | O |
| 3Ah | Copy and Verify | O | O | O |
| 12h | Inquiry | M | M | M |
| 4Ch | Log Select | - | - | O |
| 4Dh | Log Sense | - | - | O |
| 15h | Mode Select | O | O | M (tape)<br>O (other) |

# Command Sets
## (Continued)
## General SCSI Commands

| Opcode | Command | SCSI-1 | CCS | SCSI-2 |
|---|---|---|---|---|
| 55h | Mode Select (10) | - | - | O |
| 1Ah | Mode Sense | O | O | M (tape)<br>O (other) |
| 5Ah | Mode Sense (10) | - | - | O |
| 3Ch | Read Buffer | - | O | O |
| 1Ch | Receive Diagnostic Results | O | O | O |
| 03h | Request Sense | M | M | M |
| 1Dh | Send Diagnostic | O | M | M |
| 00h | Test Unit Ready | O | M | M |
| 3Bh | Write Buffer | - | O | O |

# Command Sets
## (Continued)
## Direct Access Device Commands

| Opcode | Command | SCSI-1 | CCS | SCSI-2 |
|---|---|---|---|---|
| 04h | Format Unit | M | M | M |
| 36h | Lock-Unlock Cache | - | - | O |
| 34h | Pre-Fetch | - | - | O |
| 1Eh | Prevent-Allow Medium Removal | O | O | O |
| 08h | Read (6) | M | M | M |
| 28h | Read (10) | M | M | M |
| 25h | Read Capacity | M | M | M |
| 37h | Read Defect Data | - | O | O |

# Command Sets
## (Continued)
## Direct Access Device Commands

| Opcode | Command | SCSI-1 | CCS | SCSI-2 |
|---|---|---|---|---|
| 3Eh | Read Long | - | - | O |
| 07h | Reassign Blocks | O | O | O |
| 17h | Release | O | M | M |
| 16h | Reserve | O | M | M |
| 01h | Rezero Unit | O | O | O |
| 31h | Search Data Equal | O | O | O |
| 30h | Search Data High | O | O | O |
| 32h | Search Data Low | O | O | O |
| 0Bh | Seek (6) | O | O | O |
| 2Bh | Seek (10) | O | O | O |

# Command Sets
## (Continued)
## Direct Access Device Commands

| Opcode | Command | SCSI-1 | CCS | SCSI-2 |
|---|---|---|---|---|
| 33h | Set Limits | O | O | O |
| 1Bh | Start Stop Unit | O | O | O |
| 35h | Synchronize Cache | - | - | O |
| 2Fh | Verify | O | O | O |
| 0Ah | Write (6) | M | M | O |
| 2Ah | Write (10) | M | M | O |
| 2Eh | Write and Verify | O | O | O |
| 3Fh | Write Long | - | - | O |
| 41h | Write Same | - | - | O |

# Command Sets
## (Continued)
## Sequential Access Device Commands

| Opcode | Command | SCSI-1 | SCSI-2 |
|---|---|---|---|
| 19h | Erase | O | M |
| 1Bh | Load Unload | O | O |
| 2Bh | Locate | - | O |
| 1Eh | Prevent- Allow Medium Removal | O | O |
| 08h | Read | M | M |
| 05h | Read Block Limits | M | M |
| 34h | Read Position | - | O |
| 0Fh | Read Reverse | O | O |

# Command Sets
## (Continued)
## Sequential Access Device Commands

| Opcode | Command | SCSI-1 | SCSI-2 |
|---|---|---|---|
| 14h | Recover Buffered Data | O | O |
| 17h | Release | O | M |
| 16h | Reserve | O | M |
| 01h | Rewind | M | M |
| 11h | Space | O | M |
| 0Bh | Track Select | O | - |
| 13h | Verify | O | O |
| 0Ah | Write | M | M |
| 10h | Write Filemarks | M | M |

# Command Sets
## (Continued)
## Printer Device Commands

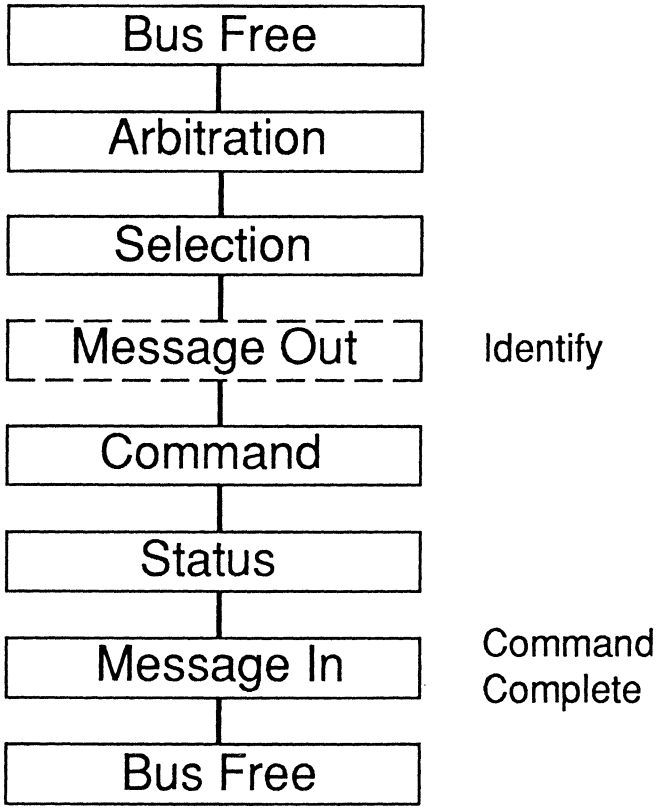
| Opcode | Command | SCSI-1 | SCSI-2 |
|---|---|---|---|
| 04h | Format | O | O |
| 0Ah | Print | M | M |
| 14h | Recover Buffered Data | O | O |
| 17h | Release | O | M |
| 16h | Reserve | O | M |
| 0Bh | Slew and Print | O | O |
| 1Bh | Stop Print | O | O |
| 10h | Synchronize Buffer | O | O |

# Test Unit Ready Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 00h | | | | | | | |
| 1 | LUN | | | | Reserved | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Reserved | | | | | | | |
| 5 | Control Byte | | | | | | | |

- Check if Device is Ready
- All Device Types
- Mandatory Command

# Test Unit Ready Command
## (Continued)
## Bus Phases

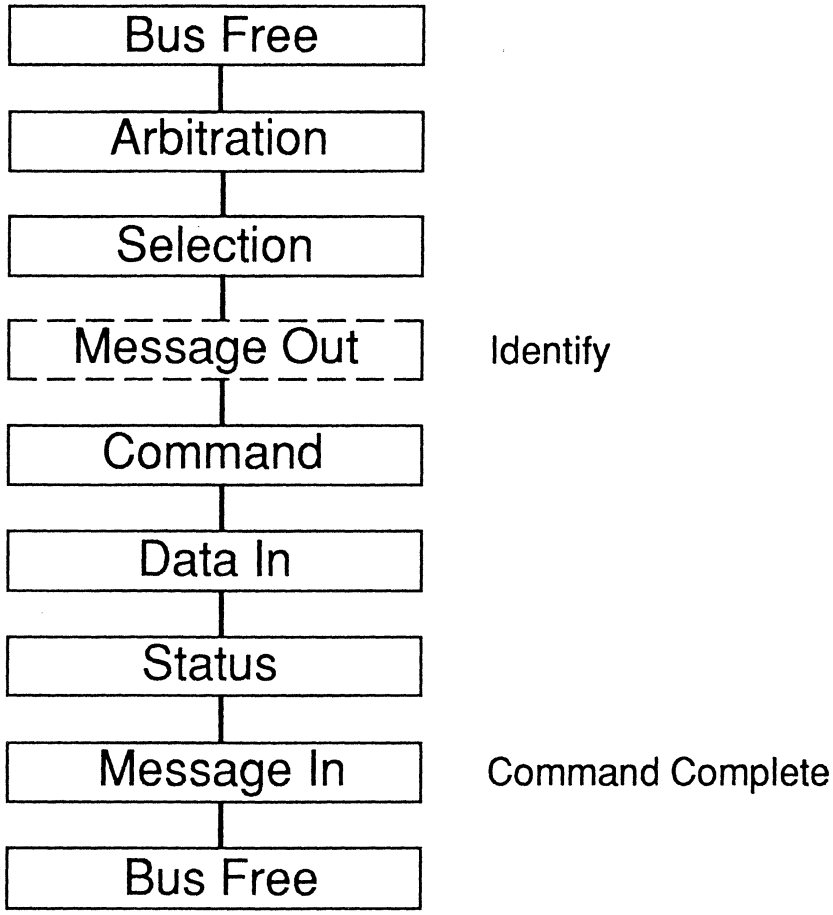


# Inquiry Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 12h | | | | | | | |
| 1 | LUN | | | Reserved | | | | EVPD (SCSI-2) |
| 2 | Vital Page Code (SCSI-2) | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Allocation Length | | | | | | | |
| 5 | Control Byte | | | | | | | |

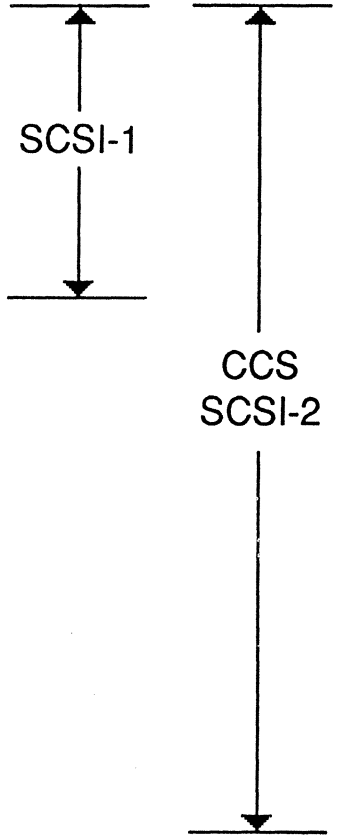
- Mandatory Command
- EVPD = Enable Vital Product Data (Normally 0)
- Optional Vital Pages (normally not supported): Provide Serial Number, Operating Definition, etc.
- Allocation Length = Maximum Number of Data In Bytes Returned

# Inquiry Command
(Continued)
Bus Phases



# Inquiry Command
## (Continued)
## Data In Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier | | | Device Type | | | | |
| 1 | RMB | Device Modifier (SCSI-1) | | | | | | |
| 2 | ISO Ver. | | ECMA Ver. | | | ANSI Ver. | | |
| 3 | AENC | TRM IOP | Reserved | | | Response Data Format | | |
| 4 | Additional Length | | | | | | | |
| 5 | V.U. | | | | | | | |
| 6 | Reserved | | | | | | | |
| 7 | Rel Adr | WB32 | WB16 | Sync | Link | Rsrvd | Cmd Que | Sft Rst |
| 8-15 | Vendor ID (ASCII) | | | | | | | |
| 16-31 | Product ID (ASCII) | | | | | | | |
| 32-35 | Revision (ASCII) | | | | | | | |
| 36-55 | V.U. | | | | | | | |
| 56-97 | Reserved | | | | | | | |
| 98- | V.U. | | | | | | | |




See next pages for description of fields.

# Inquiry Command
## (Continued)

- Device Type:

| | |
|---|---|
| 00h = Direct Access | 05h = CD-ROM |
| 01h = Sequential Access | 06h = Scanner |
| 02h = Printer | 07h = Optical Memory |
| 03h = Processor | 08h = Medium Changer |
| 04h = Write Once | 09h = Communications |

- Device Modifier: usually 00h (no longer supported)

- RMB: 1h = Removable Medium, 0h = Not Removable

- ANSI Versions:
  1h ⟶ SCSI-1, 2h ⟶ SCSI-2, 3h ⟶ SCSI-3

- Response Data Format:
  0h ⟶ SCSI-1, 1h ⟶ CCS, 2h ⟶ SCSI-2

- Additional Length = Number of bytes of the following data that is available

# Inquiry Command
(Continued)

- Qualifier
  - 0h = Logical Unit is Connected
  - 1h = Logical Unit is not Connected
  - 3h = Logical Unit is not Supported

- SCSI-2 Fields (features are described later)

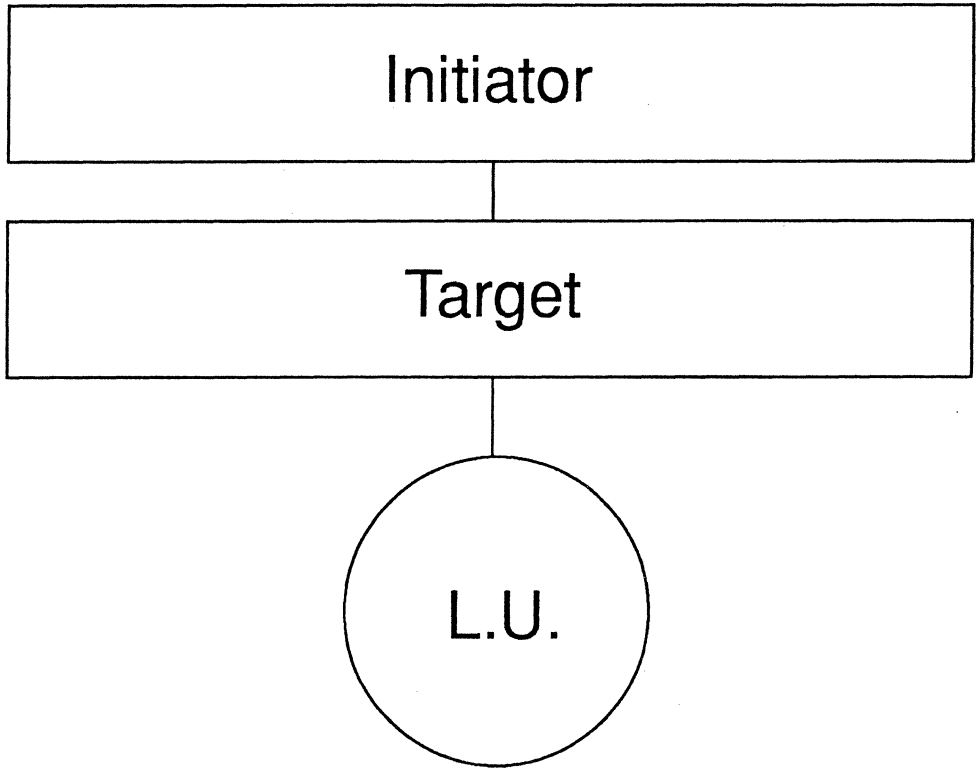
| | |
|---|---|
| AENC | 1=Asynchronous Event Notification Capability Supported |
| TRMIOP | 1=Terminate I/O Process Supported |
| RelAdr | 1=Relative Addressing Supported |
| WB32 | 1=32 Bit Wide Bus Supported |
| WB16 | 1=16 Bit Wide Bus Supported |
| Sync | 1=Synchronous Supported |
| Link | 1=Linked Commands Supported |
| CmdQue | 1=Tagged Queueing Supported |
| SftRst | 1=Soft Reset Supported |

  - Important Note:
    Data Should be Returned even if Device is NOT Ready

# Copy Command

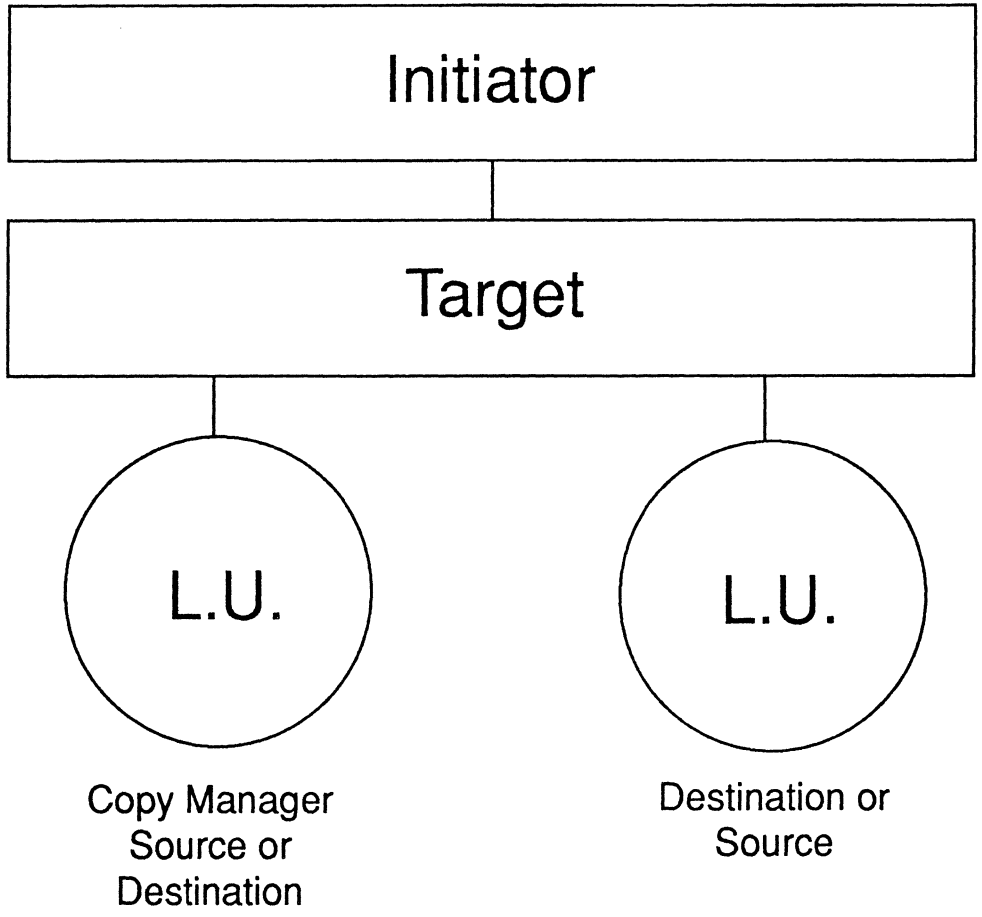
- Optional Command
- Copy Manager — Logical Unit Receiving and Performing the Copy
- Source Device — Logical Unit to Copy from
- Destination Device — Logical Unit to Copy to
- Initiator Gives Copy Manager During Data Out:
  - Source SCSI ID and LUN
  - Destination SCSI ID and LUN
  - What to copy and how

# Copy Command
(Continued)
Example

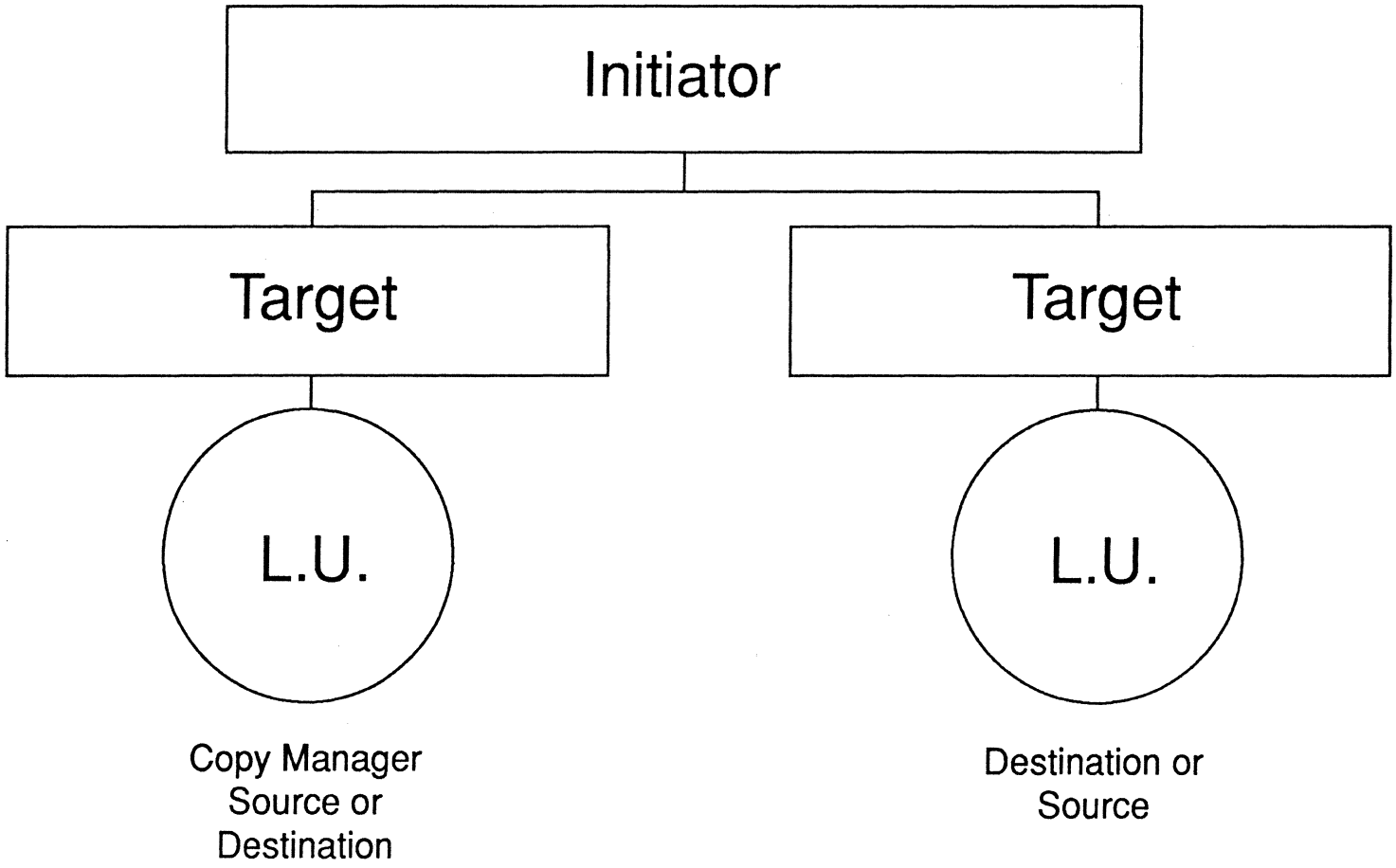



Copy Manager
Source Device
Destination Device

# Copy Command
(Continued)
Example

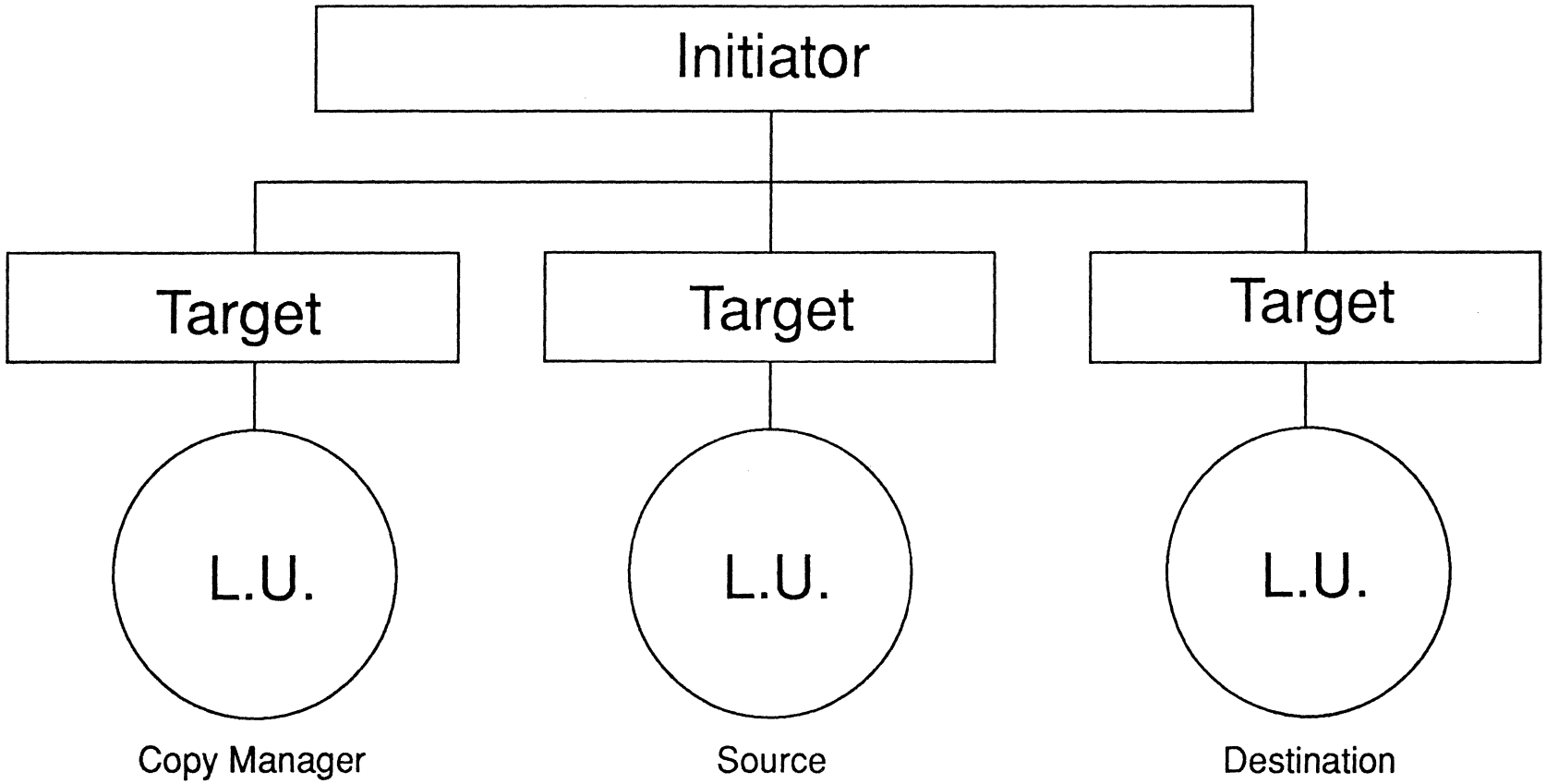


# Copy Command
(Continued)
Example



# Copy Command
(Continued)
Example

**Third Party Copy**



# **Copy Command**
(Continued)
Example

- Initiator 4 Connects to Target 2 LUN 0:
  Copy from Target 6 LUN 0 to Target 2 LUN 0.

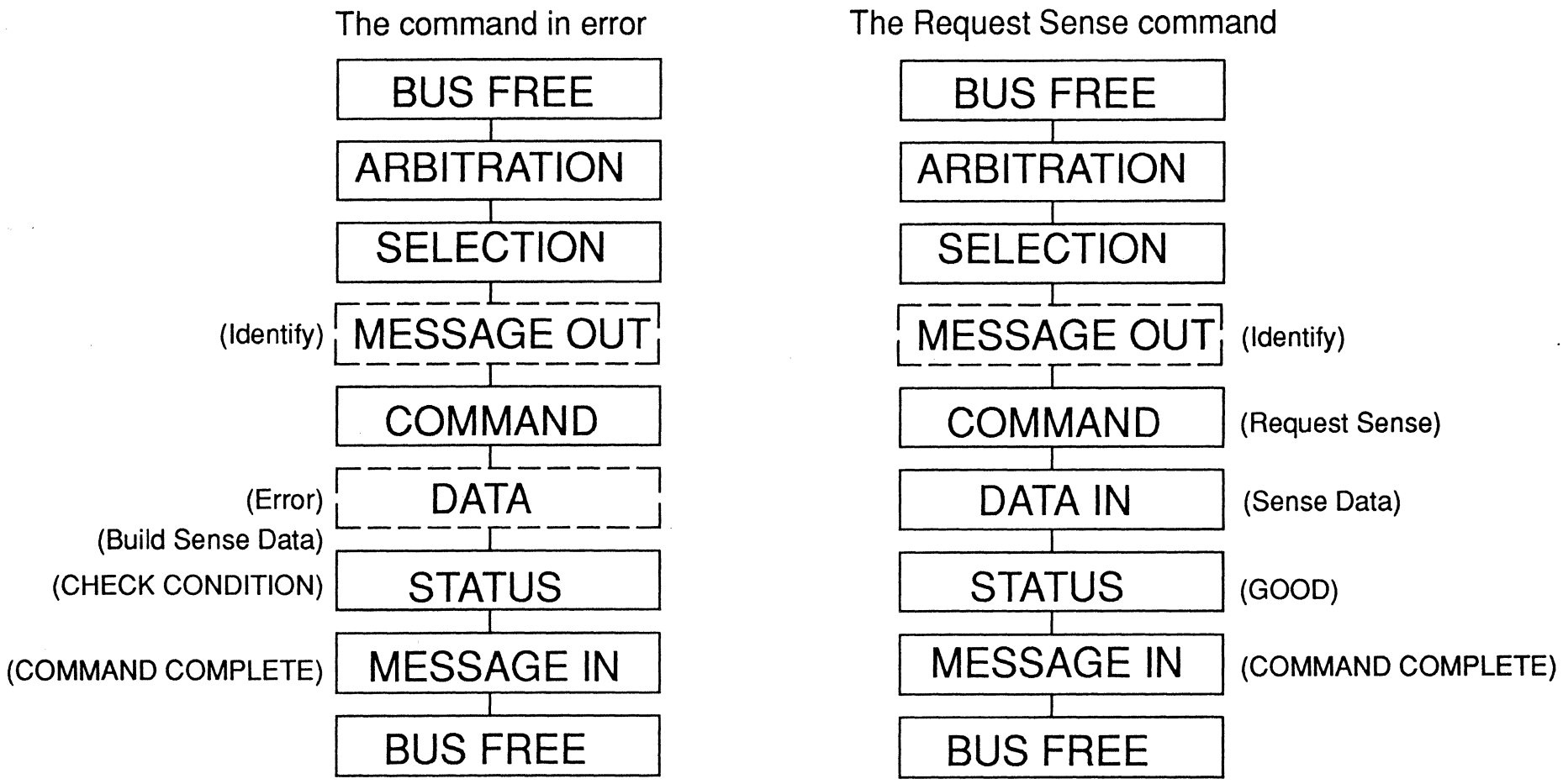
- Target 2 Disconnects.

- Target 2 Becomes Initiator and Connects to Target 6 Lun 0:
  Execute Read Command.

- Target 6 Disconnects after Finishing Read.

- Target 2 Reconnects to Initiator 4 to Report Status.

# Request Sense Command
## Bus Phases



# Request Sense Command
(Continued)
CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 03h | | | | | | | |
| 1 | LUN | | | Reserved | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Allocation Length | | | | | | | |
| 5 | Control Byte | | | | | | | |

# Request Sense Command
(Continued)

- Allocation Length: Max Number of Returned Data In Bytes

  SCSI-1 00h = 4 Bytes (for backward compatibility with SASI)

  SCSI-2 00h = No data

# Request Sense Command
## (Continued)
## Data In Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Valid | Error Code | | | | | | |
| 1 | Segment Number | | | | | | | |
| 2 | FM | EOM | ILI | rsrvd | Sense Key | | | |
| 3-6 | Information Bytes (MSB-LSB) | | | | | | | |
| 7 | Additional Sense Length | | | | | | | |
| 8-11 | Command Specific Data | | | | | | | |
| 12 | Additional Sense Code | | | | | | | |
| 13 | Additional Sense Code Qualifier (SCSI-2) | | | | | | | |
| 14 | Field Replaceable Unit (V.U.) | | | | | | | |
| 15-17 | Sense-Key Specific | | | | | | | |
| 18 - | V.U. | | | | | | | |

SCSI-1

CCS
SCSI-2

See next pages for description of fields.

# Request Sense Command
## (Continued)
## Sense Key (Byte 2, Bits 0-3)

| | |
|---|---|
| 0h | No Sense (No error, FM, EOM, or ILI) |
| 1h | Recovered Error |
| 2h | Not Ready |
| 3h | Medium Error |
| 4h | Hardware Error |
| 5h | Illegal Request |
| 6h | Unit Attention |
| 7h | Data Protect |
| 8h | Blank Check (tape, WORM,...) |
| 9h | Vendor Unique |
| Ah | Copy Aborted (error with COPY, COMPARE, or COPY AND VERIFY) |
| Bh | Aborted Command |
| Ch | Equal (SEARCH DATA command) |
| Dh | Volume Overflow (buffered commands) |
| Eh | Miscompare |
| Fh | Reserved |

# Request Sense Command
## (Continued)
## Additional Sense Code (Byte 12) - Partial List

| | |
|---|---|
| 10h | ID CRC or ECC error |
| 13h | No address Mark found in Data field |
| 15h | Seek Positioning error |
| 17h | Recovered data using retries (not ECC) |
| 18h | Recovered data using ECC |
| 20h | Invalid Command OP Code |
| 21h | Invalid LBA |
| 24h | Invalid field in CDB |
| 28h | Medium Changed |
| 29h | Power On or Reset or Bus Device Reset |
| 2Ah | Mode Select Parameters Changed |
| 43h | Message Error |
| 48h | Initiator Detected Error Message Received |
| 4Ah | Command Phase Error |
| 4Bh | Data Phase Error |

# Request Sense Command
(Continued)
Sense Hierarchy

- sense key (byte 2 - bits 0-3)
- additional sense code (byte 12) - CCS and SCSI-2
- additional sense code qualifier (byte 13) - SCSI-2

# Request Sense Command
(Continued)

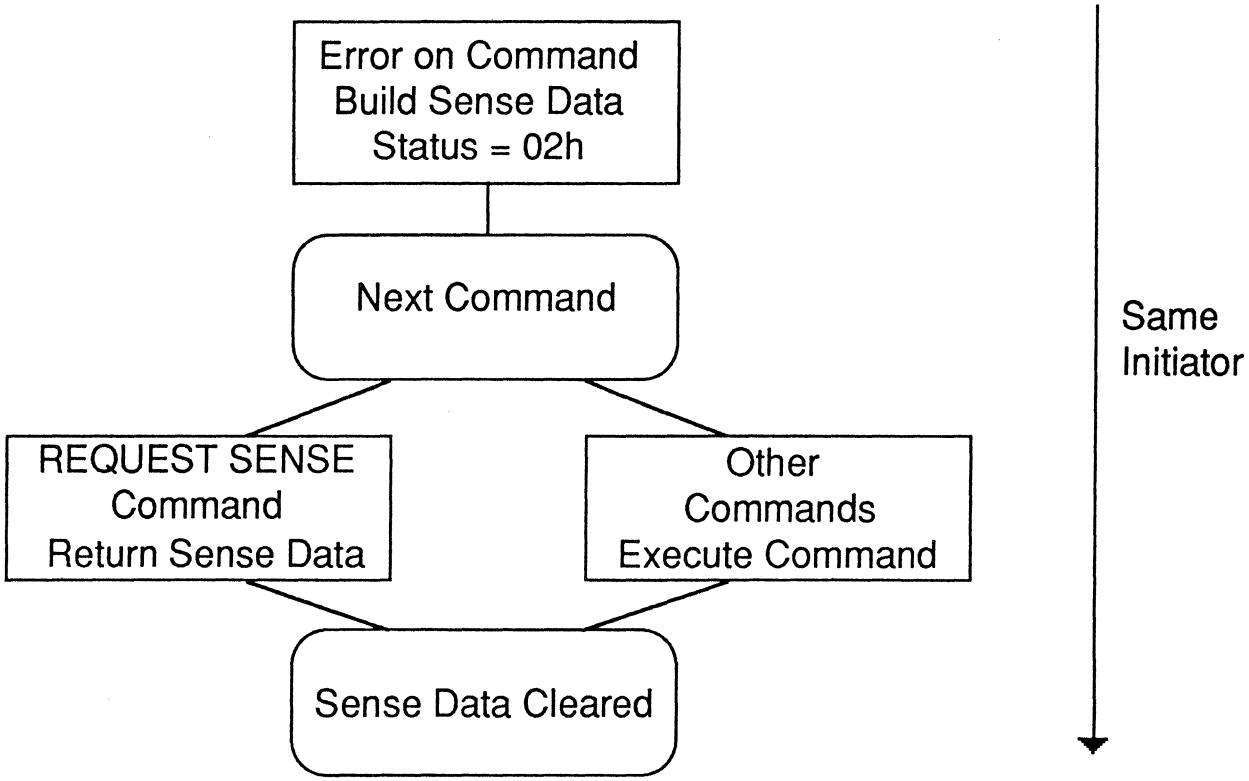
- Error Code — Byte 0, Bits 0 - 6
  - For SCSI-1 and CCS - 70h
  - For SCSI-2 - 70h current
  - For SCSI-2 - 71h deferred
- Segment — Byte 1
  - For COPY and COMPARE commands
- FM — Byte 2, Bit 7
  - Filemark - tape
- EOM — Byte 2, Bit 6
  - End of Medium
    - End of tape, beginning of tape, out of paper, etc.
    - Tape and Printer use only
- ILI — Byte 2, Bit 5
  - Incorrect Length Indicator
    - Requested block length does not match logical block length on medium
    - Normally tape only

# Request Sense Command
## (Continued)

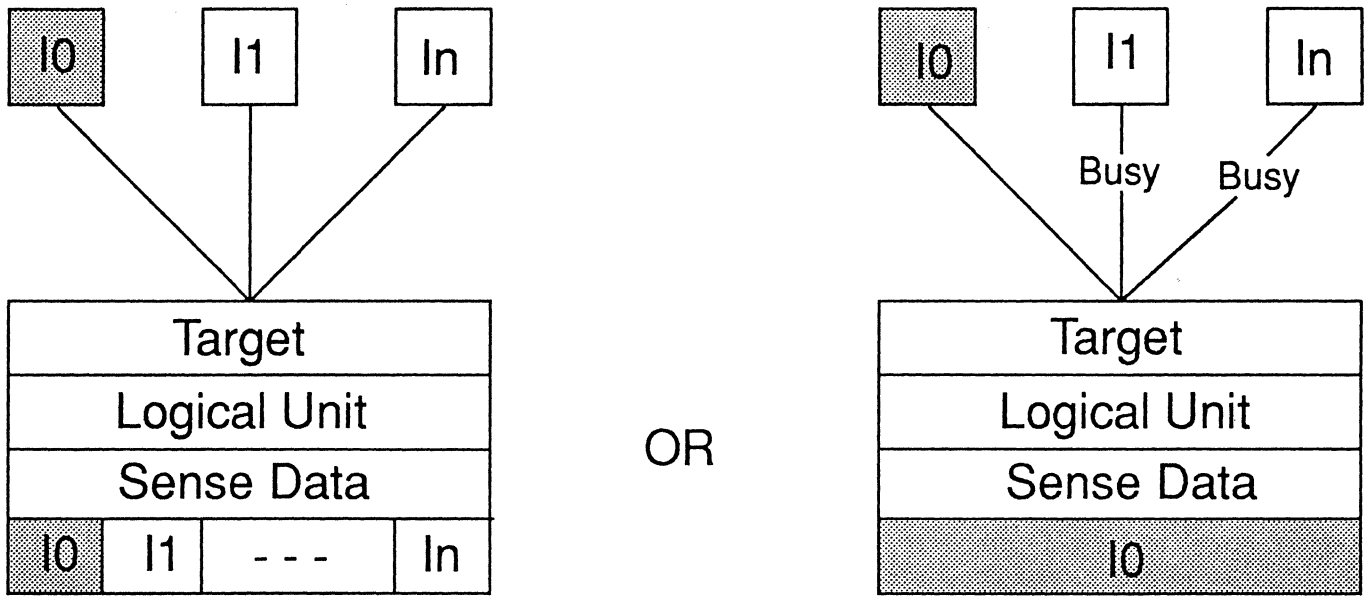
- **Valid** — Byte 0, Bit 7
  Valid Information Bytes
- **Information Bytes** — Bytes 3 - 6
  Used when Valid bit is set to contain:
  - LBA of Error (Direct Access, WORM,...)
  - Residue — Requested minus Actual Length (Tape, Printer,...)
  - Residue — Requested minus Actual Blocks (COPY, COMPARE, COPY and VERIFY)
- **Sense Key Specific** — Bytes 15-17 (Optional)
  Depends on Sense Key value:
  - Field Pointer on Illegal Request
  - Actual Retry Count on Recovered, Medium, and Hardware Errors (SCSI-2)
  - Format Immediate Progress Indication with Not Ready Sense (SCSI-2)

# Contingent Allegiance

(A Feature for Sense Data Preservation)



# Contingent Allegiance
(Continued)




Separate Sense Bucket for Each Initiator

One Sense Bucket

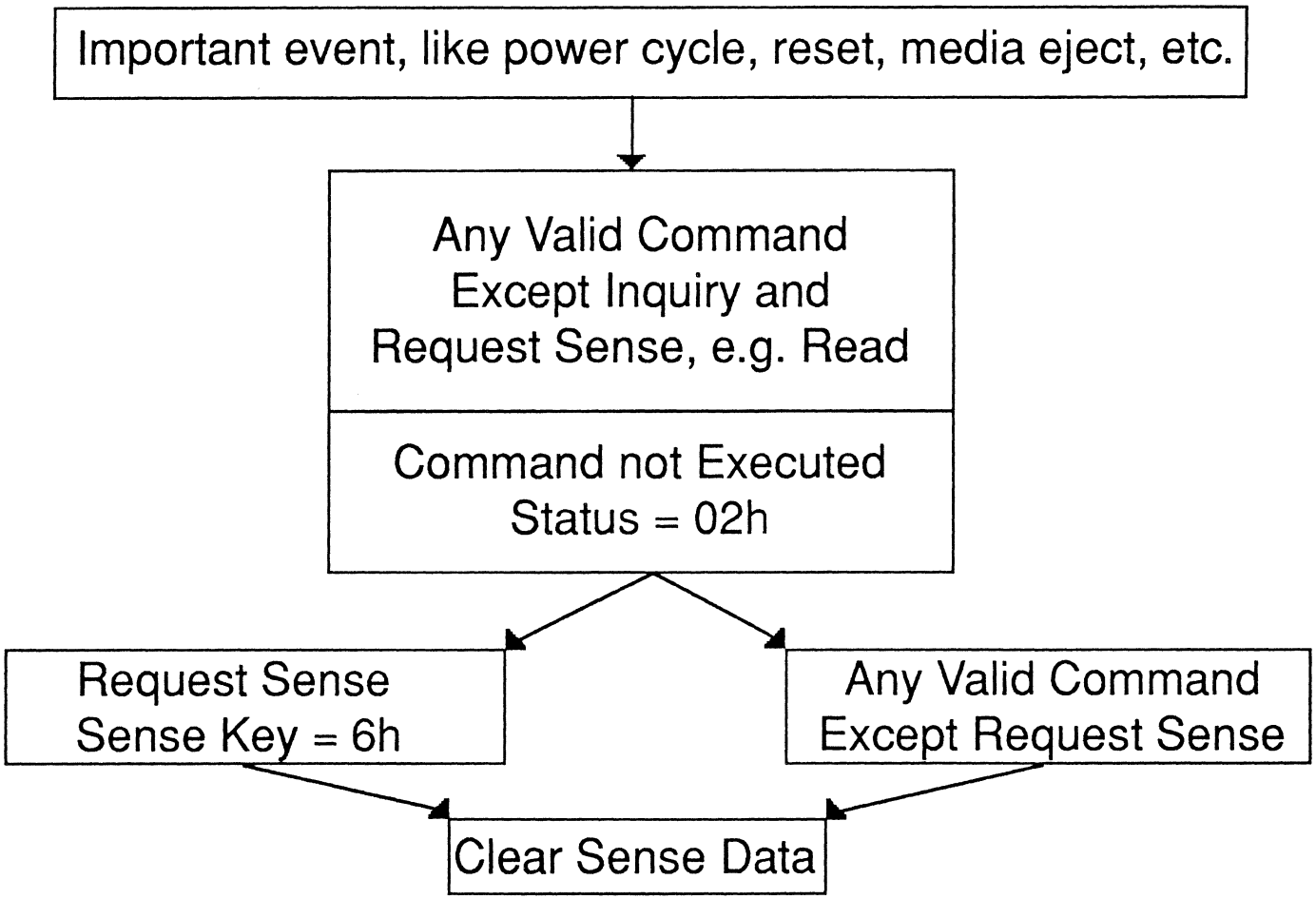
# Contingent Allegiance
(Continued)

- A feature provided by the target to preserve sense data for an initiator after Check Condition or Command Terminated Status, in case other initiators attempt to access the same logical unit in the mean time.

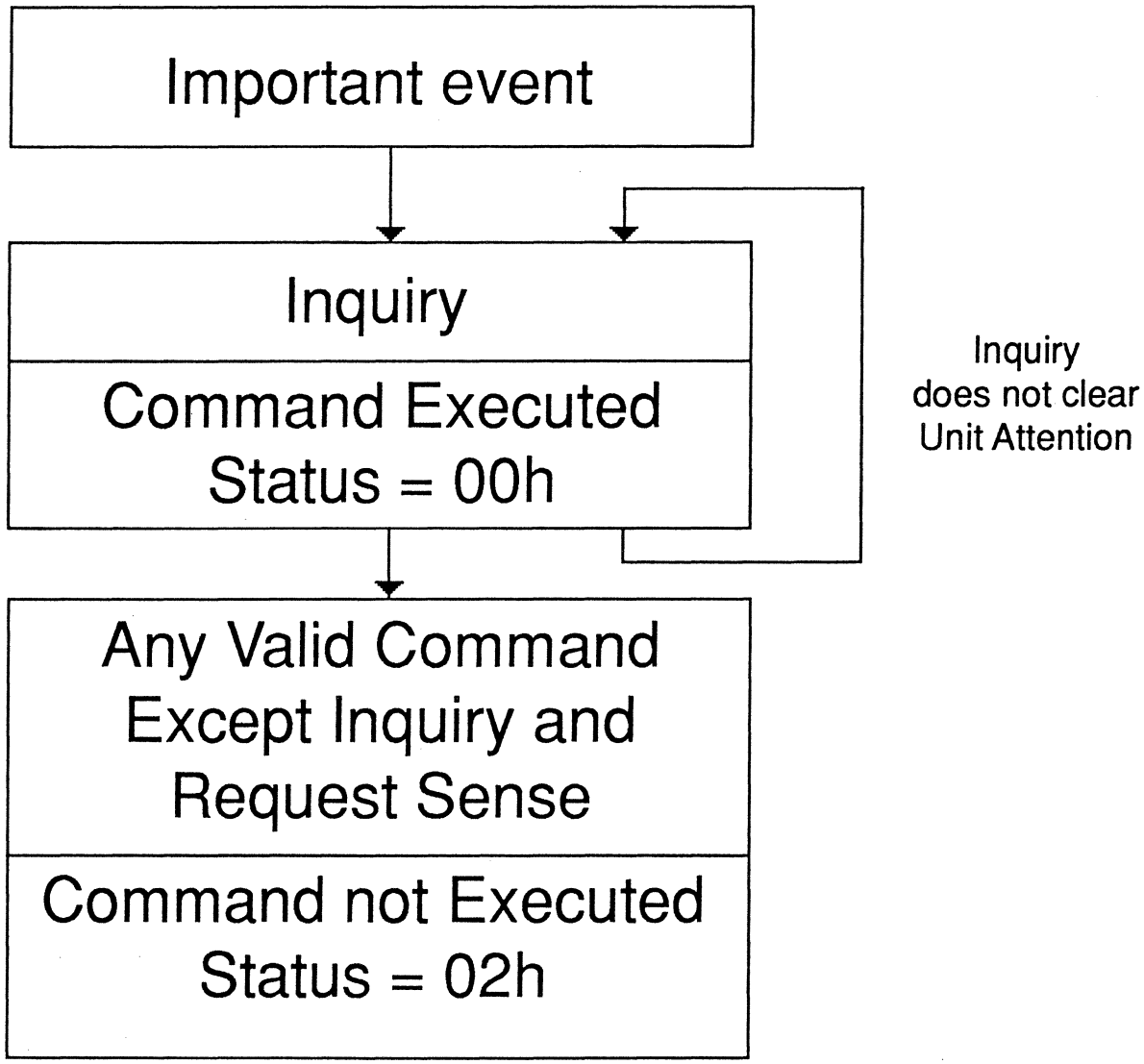
- Implemented using multiple sense buckets or Busy status.

- Cleared By:
  - Power cycle
  - Hard Reset event
  - Bus Device Reset message
  - Abort message
  - Any command other than Request Sense from same initiator
  - After Request Sense from same initiator

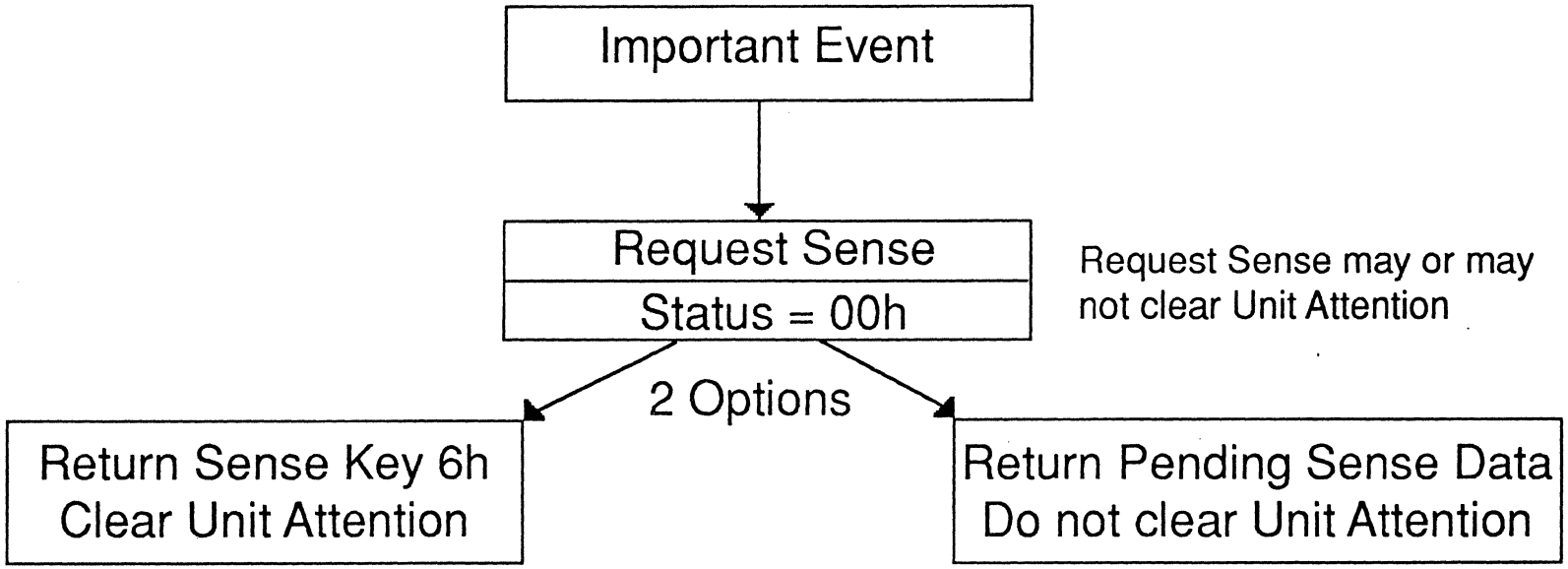
# Unit Attention



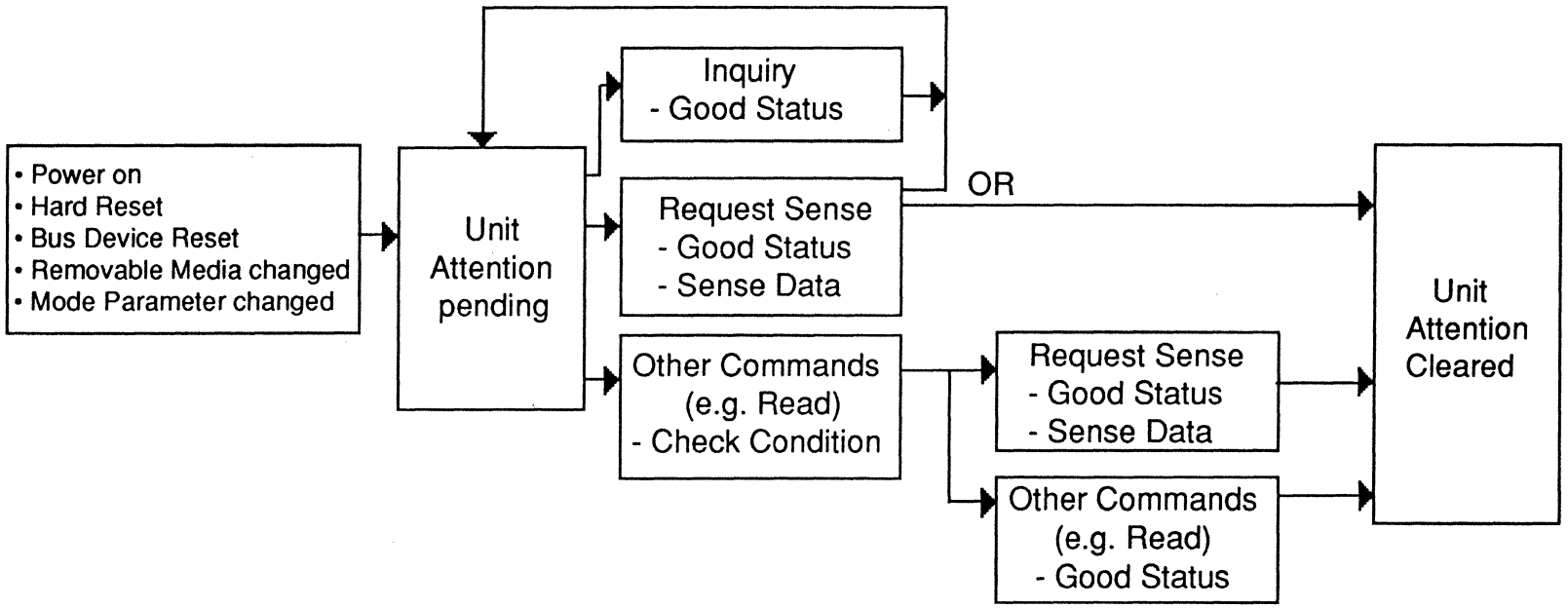
# Unit Attention
(Continued)



# Unit Attention
(Continued)



# Unit Attention
(Continued)
Summary



# Reserve/Release Commands

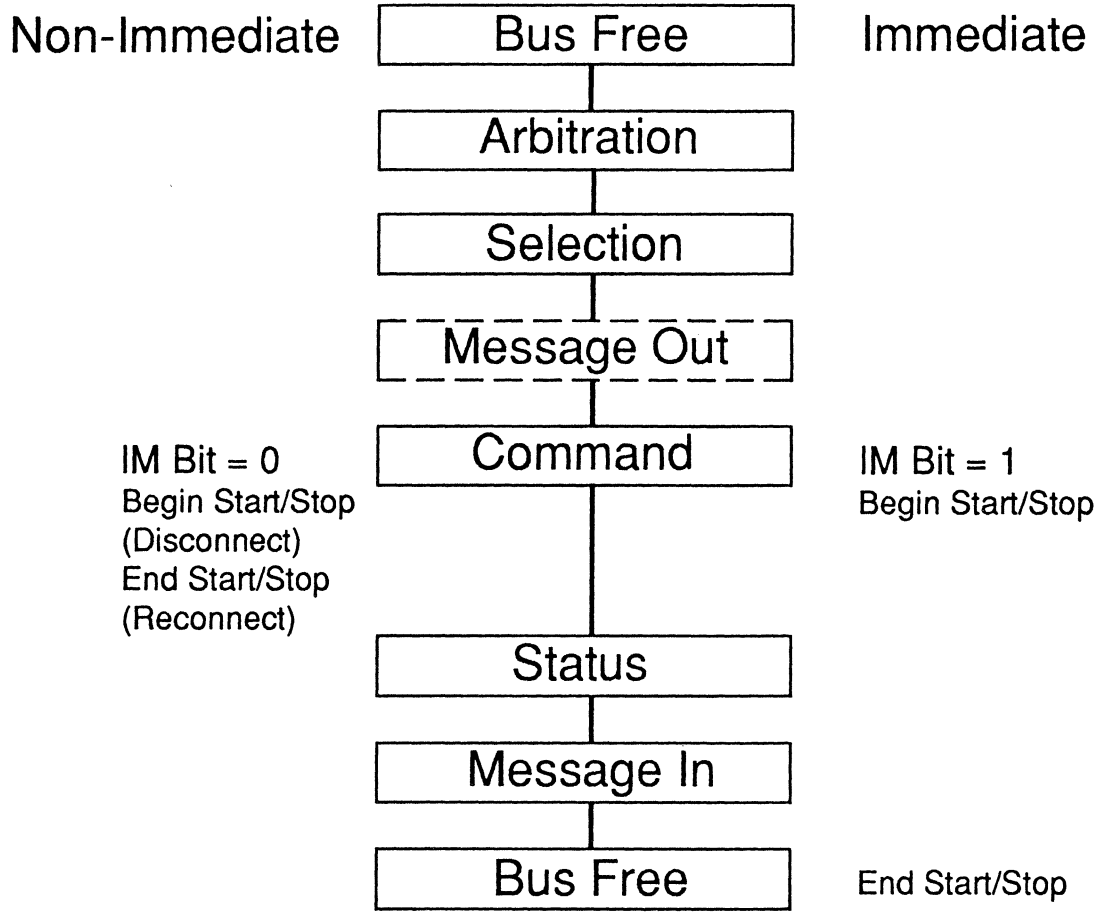
- Reserve logical unit with Reserve command and release with Release command
- When reserved, drive responds with Reservation Conflict status to most commands from other initiators
- Third party reservation:
  - Reserve for another device
  - Copy command application
- A Release command to a device which is not reserved or reserved by another initiator results in Good status and no change to reservation
- SCSI-2: Request Sense, Inquiry, Prevent/Allow Medium Removal (Allow option only), and Release executed even if reserved
- Power cycle, Hard Reset, or Bus Device Reset message clear reservations

# Start/Stop Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 1Bh | | | | | | | |
| 1 | LUN | | | Reserved | | | | IM |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Reserved | | | | | | LoEj | Start |
| 5 | Control Byte | | | | | | | |

- IM Immediate
- Start 1 = Start, 0 = Stop
- LoEj (SCSI-2) 1 = Load removable media (when Start = 1)
  Eject removable media (when Start = 0)

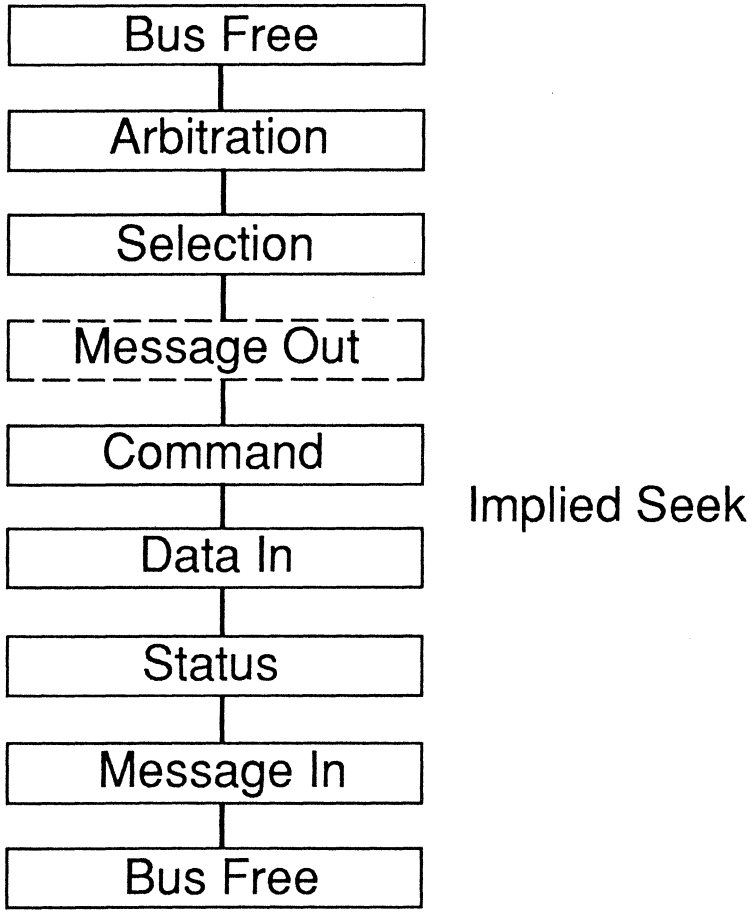
# Start/Stop Command
## (Continued)
## Bus Phases




- In immediate mode, an error detected afterwards is reported on the next command with Check Condition Status and Deferred Error Code Sense

# Disk - Read Command

## Bus Phases



# Disk - Read Command
## (Continued)
## CDB Format
### 6-Byte Read

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 08h | | | | | | | |
| 1 | LUN | | | | LBA (MSB) | | | |
| 2 | LBA | | | | | | | |
| 3 | LBA (LSB) | | | | | | | |
| 4 | Number of Blocks | | | | | | | |
| 5 | Control Byte | | | | | | | |

- LBA = Logical Block Address
- Number of Blocks of 0 Indicates 256

# Disk - Read Command
## (Continued)
## CDB Format
### 10-Byte Read

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 28h | | | | | | | |
| 1 | LUN | | | DPO | FUA | Reserved | | RA |
| 2 | LBA (MSB) | | | | | | | |
| 3 | LBA | | | | | | | |
| 4 | LBA | | | | | | | |
| 5 | LBA (LSB) | | | | | | | |
| 6 | Reserved | | | | | | | |
| 7 | Number of Blocks (MSB) | | | | | | | |
| 8 | Number of Blocks (LSB) | | | | | | | |
| 9 | Control Byte | | | | | | | |

See next page for description of fields.

# Disk - Read Command
(Continued)

- Number of Blocks of 0 means 0 (no data transfer)
- RA = Relative Address (Linked Commands Only) - Normally 0
- FUA Force Unit Access (SCSI-2) - Normally 0

  1 = Read from Media

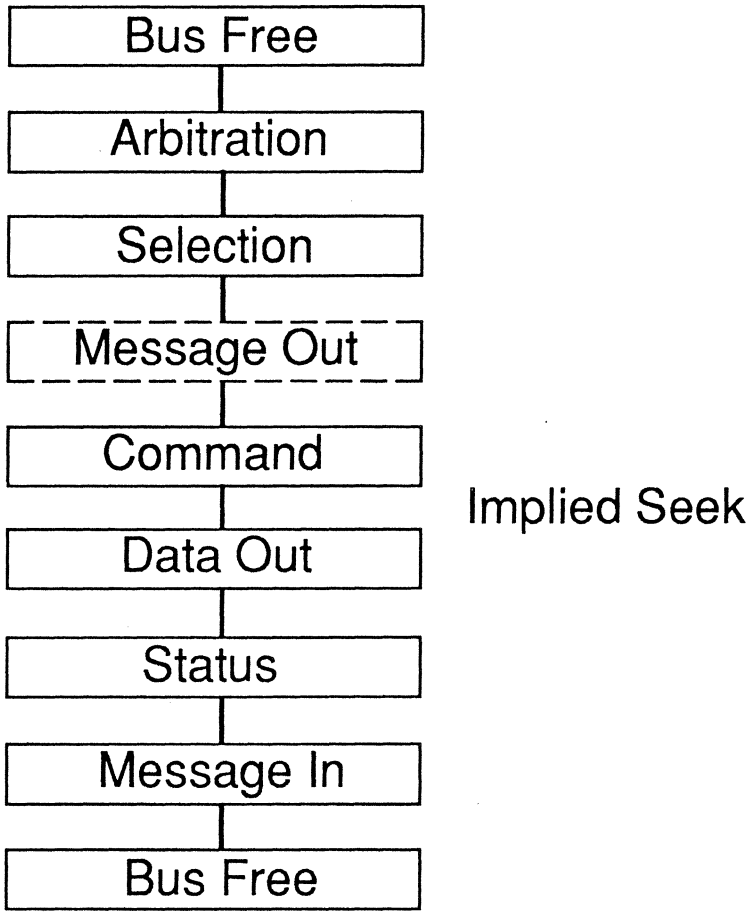
  0 = Read from Cache
- DPO Disable Page Out (SCSI-2) - Normally 0

  1 = Replace Data (will not need block in near future)

  0 = Try to Keep Data in Cache

# Disk - Write Command

## Bus Phases



# Disk - Write Command
## (Continued)
## CDB Format
### 6-Byte Write

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 0Ah | | | | | | | |
| 1 | LUN | | | | LBA (MSB) | | | |
| 2 | LBA | | | | | | | |
| 3 | LBA (LSB) | | | | | | | |
| 4 | Number of Blocks | | | | | | | |
| 5 | Control Byte | | | | | | | |

- Number of Blocks of 0 Indicates 256

# Disk - Write Command
## (Continued)
## CDB Format
### 10-Byte Write

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 2Ah | | | | | | | |
| 1 | LUN | | | DPO | FUA | Reserved | | RA |
| 2 | LBA (MSB) | | | | | | | |
| 3 | LBA | | | | | | | |
| 4 | LBA | | | | | | | |
| 5 | LBA (LSB) | | | | | | | |
| 6 | Reserved | | | | | | | |
| 7 | Number of Blocks (MSB) | | | | | | | |
| 8 | Number of Blocks (LSB) | | | | | | | |
| 9 | Control Byte | | | | | | | |

- Number of Blocks of 0 means 0

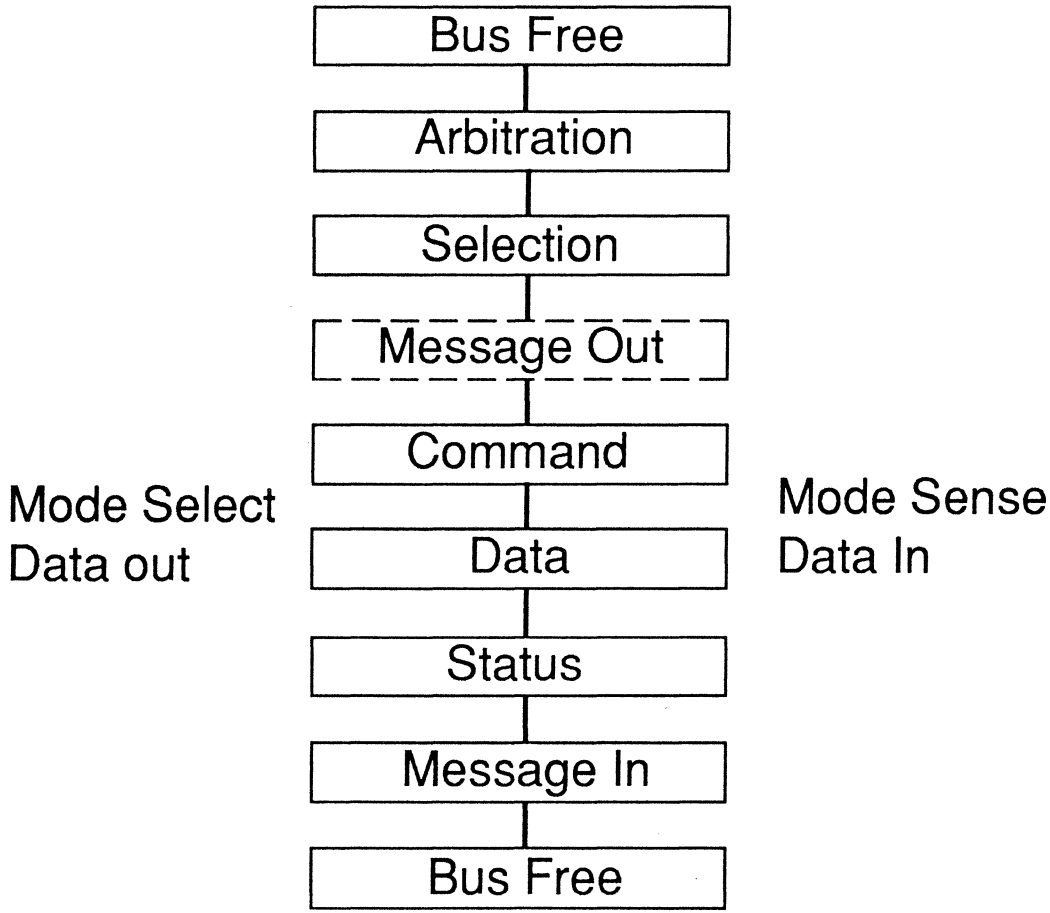
# Mode Select and Mode Sense Commands

- Mode Select — Modify Logical Unit Parameters
- Mode Sense — Query Logical Unit Parameters
- Parameter Values — Current, Default, Saved
- Parameters — Changeable/Not, Saveable/Not
- For Power On or Reset, if Saved Values available, use them, else use Default

# Mode Select and Mode Sense Commands

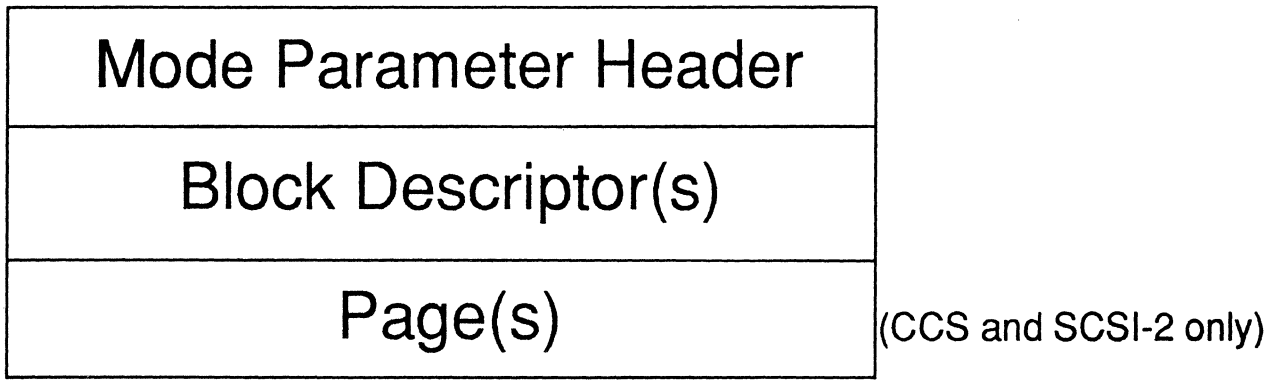
## (Continued)

## Bus Phases



# Mode Select and Mode Sense Data

Data Format



# Mode Select and Mode Sense Data
## (Continued)
## Mode Parameter Header

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Mode Data Length | | | | | | | |
| 1 | Medium Type | | | | | | | |
| 2 | Device-Specific Parameter | | | | | | | |
| 3 | Block Descriptor Length | | | | | | | |

- See next page for description of fields.

# Mode Select and Mode Sense Data
(Continued)

- Mode Data Length:
  - For Mode Select: 00h
  - For Mode Sense: number of bytes of the following data that is available

- Medium Type:
  - Depends on the device type (see SCSI standard)
  - For disk: normally 00h
  - For tape: 00h

- Device Specific Parameter:
  - For disk: normally 00h
  - For tape: buffered mode (described later), etc.

- Block Descriptor Length:
  - Normally 08h

# Mode Select and Mode Sense Data
## (Continued)
## Block Descriptor

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Density Code | | | | | | | |
| 1 | Number of Blocks (MSB) | | | | | | | |
| 2 | Number of Blocks | | | | | | | |
| 3 | Number of Blocks (LSB) | | | | | | | |
| 4 | Reserved | | | | | | | |
| 5 | Block Length (MSB) | | | | | | | |
| 6 | Block Length | | | | | | | |
| 7 | Block Length (LSB) | | | | | | | |

- See next page for description of fields.

# Mode Select and Mode Sense Data
(Continued)

- Density Code:
  - Depends on type of device
  - For disk = 00h
  - For tape = type of media and recording, e.g., DDS (DAT)

- Number of Blocks:
  - Normally 0, which means that all logical blocks of the logical unit have the same medium characteristics.

- Block Length:
  - Number of bytes per logical block

# Mode Select and Mode Sense Data
## (Continued)
## Page Format

| Byte | | | | |
|---|---|---|---|---|
| 0 | PS | R | Page Code | |
| 1 | Page Length<br>(number of bytes following) | | | |
| 2 - | Page Contents | | | |

R = Reserved (0)
PS = Parameters Saveable
for Mode Select: 0
for Mode Sense:
1 = Page is saveable
0 = Page is not saveable

# Mode Select and Mode Sense Data
## (Continued)
## Direct Access Device Pages

| Page Code | SCSI-2 only | Page Contents |
|---|---|---|
| 1h | | Read/Write Error Recovery Parameters |
| 2h | | Disconnect/Reconnect Parameters |
| 3h | | Direct Access Device Format Parameters |
| 4h | | Rigid Disk Drive Geometry Parameters |
| 5h | | Flexible Disk Drive Parameters |
| 7h | X | Verify Error Recovery Parameters |
| 8h | X | Caching Parameters |
| 9h | X | Peripheral Device Parameters |
| Ah | X | Control Mode (Queueing, AEN, ECA, ...) Parameters |
| Bh | X | Medium Types Supported Parameters |
| Ch | X | Notch and Partition Parameters |
| Dh-1Fh | | Reserved |
| 20h-3Eh | | Vendor Unique |

# Mode Select and Mode Sense Data
## (Continued)
## Sequential-Access Device Pages

| Page Code | SCSI-2 only | Page Contents |
|---|---|---|
| 1h | | Read/Write Error Recovery Parameters |
| 2h | | Disconnect/Reconnect Parameters |
| 9h | X | Peripheral Device Parameters |
| Ah | X | Control Mode Parameters |
| 10h | X | Device Configuration Parameters |
| 11h-14h | X | Medium Partition Parameters |
| 20h-3Eh | | Vendor Unique |

# Mode Select Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 15h | | | | | | | |
| 1 | LUN | | | PF | Reserved | | | SP |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Parameter List Length | | | | | | | |
| 5 | Control Byte | | | | | | | |

- PF - Page Format (CCS and SCSI-2), 1 if sending pages, else ignored
- SP - Save Pages (CCS and SCSI-2), 1 to save, 0 not to save
- Parameter List Length: how many data bytes the initiator wants to send

# Mode Select Command
## (Continued)
## CDB Examples

| To send to the target: | Use hex CDB bytes of: |
|---|---|
| Header | 15 00 00 00 04 00 |
| Header + Descriptor | 15 00 00 00 0C 00 |
| Header + Descriptor + Page 20h (10 bytes long) | 15 10 00 00 16 00 |
| Header + Descriptor + Page 22h (5 bytes long) | 15 10 00 00 1B 00 |

# Mode Sense Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 1Ah | | | | | | | |
| 1 | LUN | | | Reserved | DBD | Reserved | | |
| 2 | PC | | Page Code | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Allocation Length | | | | | | | |
| 5 | Control Byte | | | | | | | |

- DBD - Disable Block Descriptors (SCSI-2), not supported normally (0)
- Page Code - desired page code, or 3F = all pages
- PC - Page Control: 0=Current, 1=Changeable, 2=Default, or 3=Saved

# Mode Sense Command
## (Continued)
## CDB Examples

| To receive from the target: | Use hex CDB bytes of: |
|---|---|
| Header | 1A 00 00 00 04 00 |
| Header + Descriptor | 1A 00 00 00 0C 00 |
| Header + Descriptor + Current Page 21h | 1A 00 21 00 FF 00 |
| Header + Descriptor + Default Page 23h | 1A 00 A3 00 FF 00 |
| Header + Descriptor + Saved All Pages | 1A 00 FF 00 FF 00 |

# Mode Sense Command
## (Continued)
## Example of Page Byte Contents

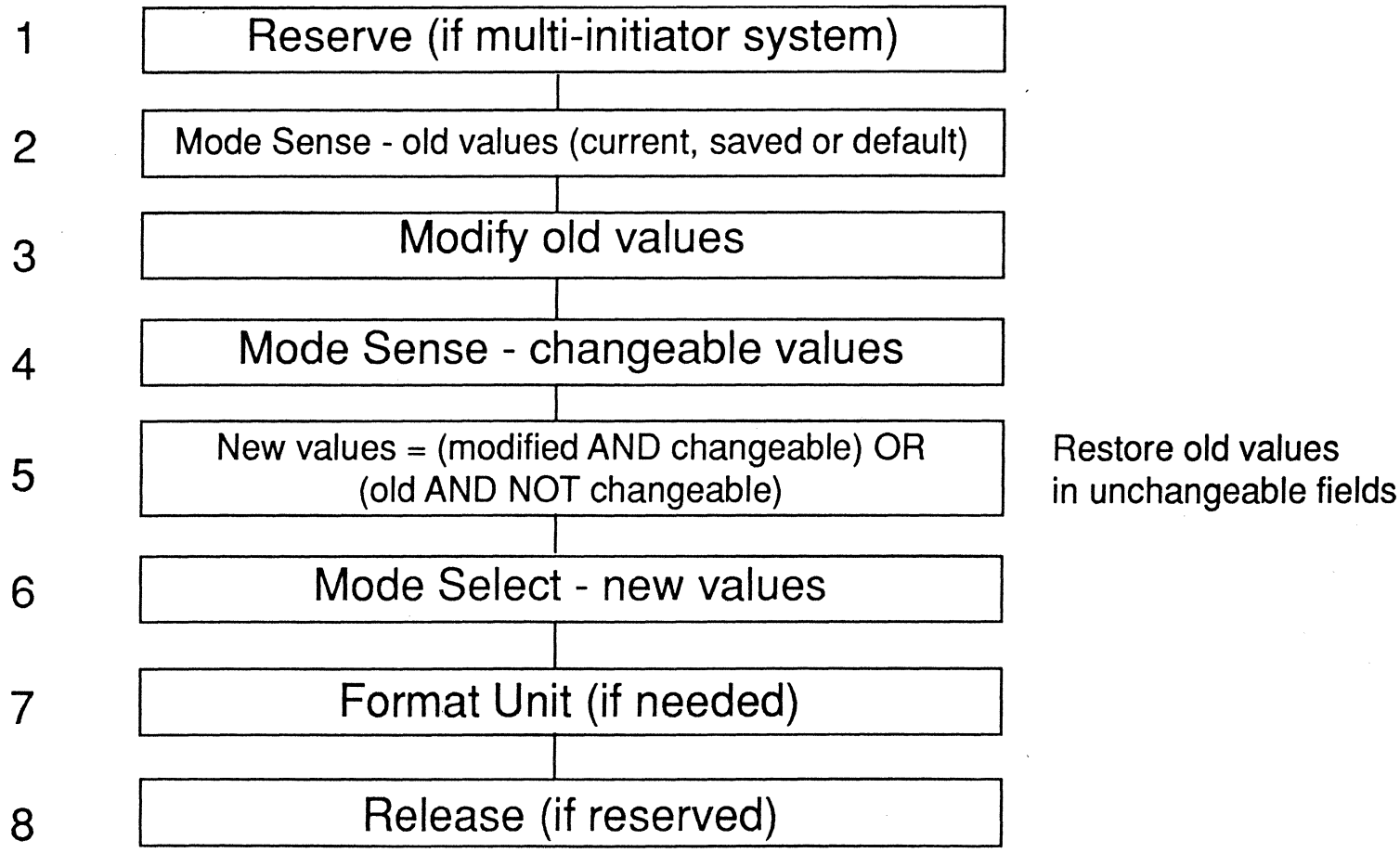
| | | PC =2 Default | PC = 1 Changeable | PC = 0 Current |
|---|---|---|---|---|
| Page Code | 0 | 20 | 20 | 20 |
| Page Length | 1 | 04 | 04 | 04 |
| Page Contents | 2 | FE | 00 | FE |
| | 3 | 23 | FF | xx |
| | 4 | A5 | 0F | Ax |
| | 5 | 47 | F0 | x7 |

Changeable Values:

- Bit field masks
- 00h = No bits changeable
- Any non-zero value means corresponding bits may be changed

# Mode Sense Command
## (Continued)
## Changing Parameters

Sequence: Mode Sense, modify desired parameters, then Mode Select



# Mode Page 1
## Error Recovery

### Disk Logical Block Layout

- ECC - Error Correcting Code
- Block (Sector) Layout

# Mode Page 1
(Continued)

| Bit Name | Description |
|---|---|
| EEC - Enable Early Correction | 1 = Enable Correction Before Retries (a.k.a. EER - Enable Early Recovery) |
| DCR - Disable Correction | 1 = Disable Correction |
| DTE - Disable Transfer on Error | 1 = Stop After Recovered Error |
| PER - Post Error | 1 = Enable Recovered Error Reporting |
| RC - Read Continuous | 1 = Read and Transfer Regardless of Errors |
| TB - Transfer Block | 1 = Transfer Medium Error Data |
| ARRE - Automatic Read Reallocation | 1 = Reassign Recovered Read Blocks |
| AWRE - Automatic Write Reallocation | 1 = Reassign Defective Write Blocks |

Read Retry Count Byte
Write Retry Count Byte

Note: RC, ARRE, and AWRE are not supported by tape

# Mode Page 1
## (Continued)
## ECC Correction Handling

| DCR | EEC | Action |
|---|---|---|
| 1 | 0 | No Correction |
| 0 | 0 | Correct on last retry |
| 0 | 1 | Correct on all retries |
| 1 | 1 | Illegal Request |

# Mode Page 1
## (Continued)
## Recovered Error Handling (Sense Key 1)

| DTE | PER | RC | Action | Status |
|---|---|---|---|---|
| 0 | 0 | 0 | Continue to finish | Good |
| 0 | 1 | 0 | Continue to finish | Check Condition |
| 1 | 0 | ? | Illegal Request | |
| 1 | 1 | 0 | Stop after recovered block | Check Condition |
| ? | ? | 1 | Continue to finish | Not defined |

Notes:

- Recovered block data is always transferred
- Recovered data is obtained using retries or ECC correction depending on DCR and EEC

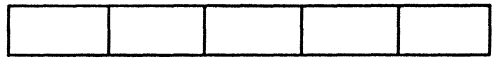
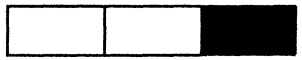
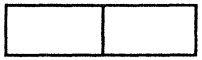
# Mode Page 1
## (Continued)
## Medium Error Handling (Sense Key 3)

| TB | RC | Action | Status |
|---|---|---|---|
| 0 | 0 | Stop and do not transfer block data | Check Condition |
| 1 | 0 | Stop and transfer block data | Check Condition |
| ? | 1 | Continue and transfer block data | Not defined |

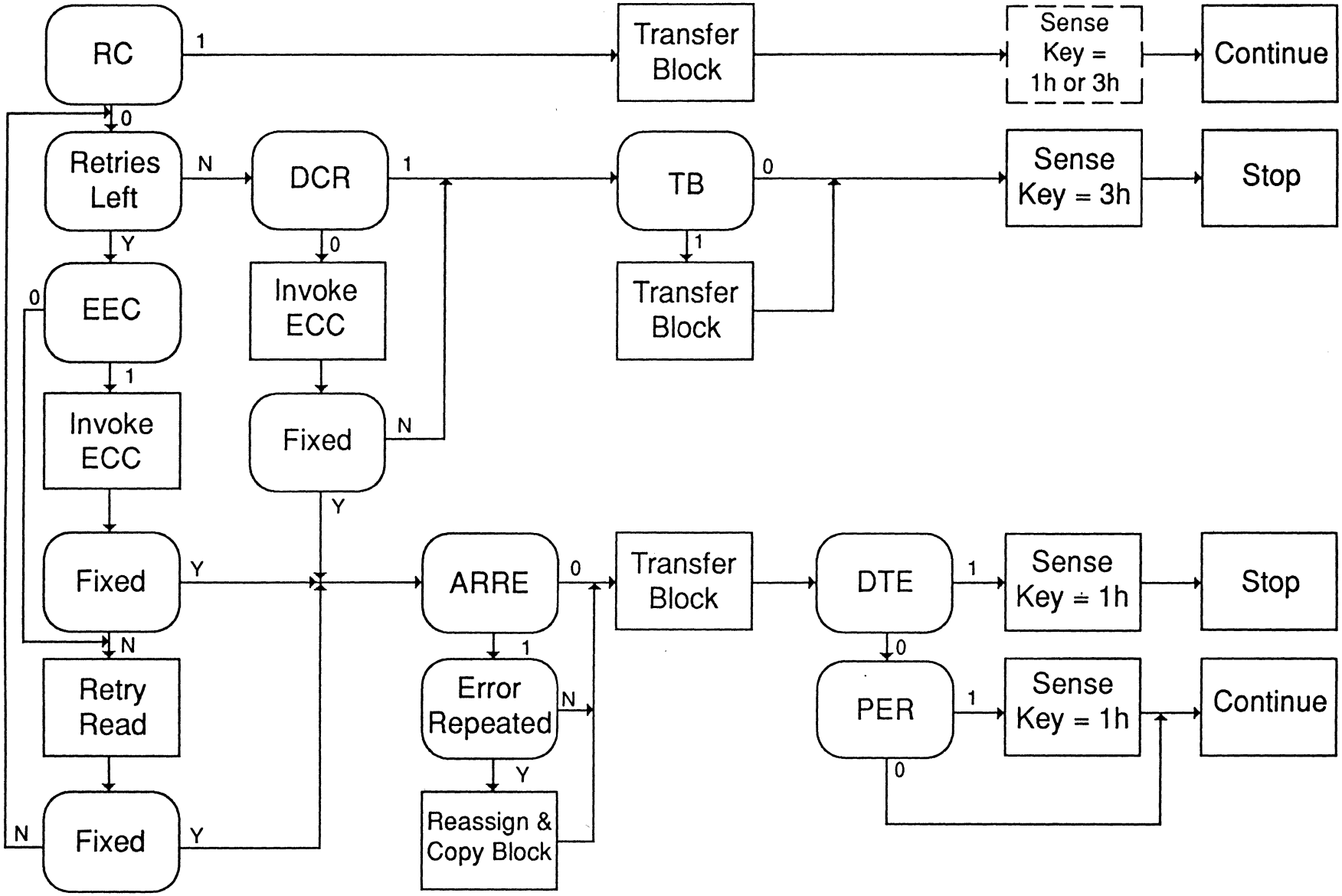
Notes:

- Medium error is an unrecoverable error after retries and correction

# Mode Page 1
## (Continued)
## Example

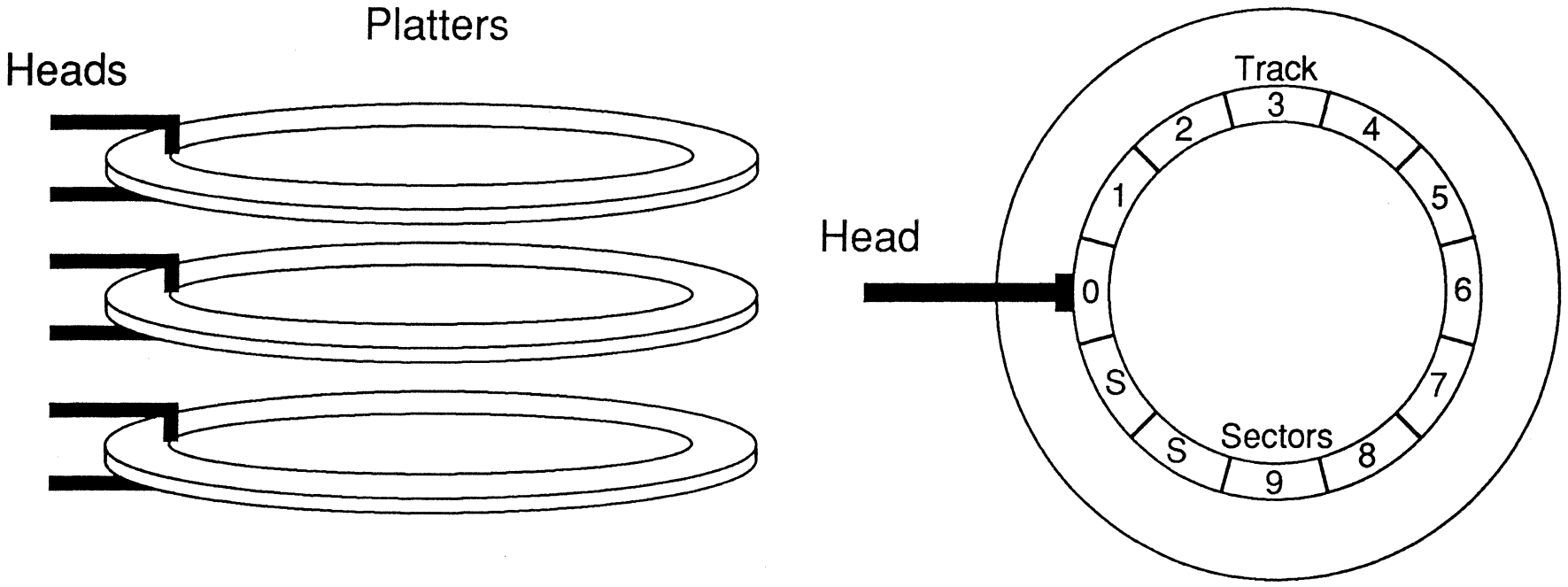
| RC | DTE | TB | PER | Error | Blocks Transferred | Status | Sense Key |
|---|---|---|---|---|---|---|---|
| ? | ? | ? | ? | none |  | 00h | 0 |
| 0 | 0 | ? | 0 | Recovered |  | 00h | 0 |
| 0 | 0 | ? | 1 | Recovered |  | 02h | 1 |
| 0 | 1 | ? | 1 | Recovered |  | 02h | 1 |
| 0 | ? | 1 | ? | Medium |  | 02h | 3 |
| 0 | ? | 0 | ? | Medium |  | 02h | 3 |
| 1 | ? | ? | ? | Recovered or Medium |  | ? | ? |

# Mode Page 1 Summary



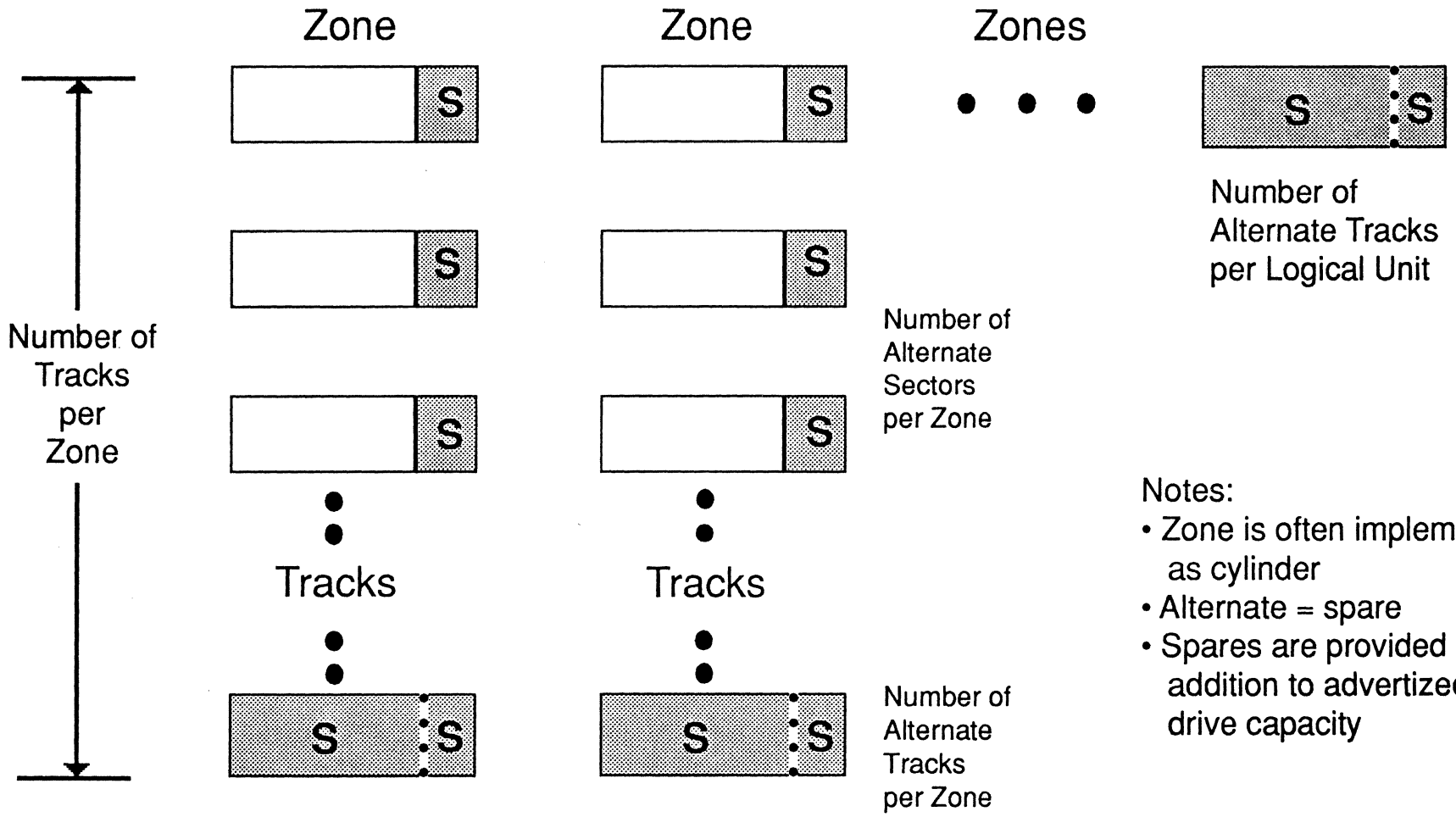
# Mode Page 3
## Direct Access Format

### Disk Geometry




s = spare

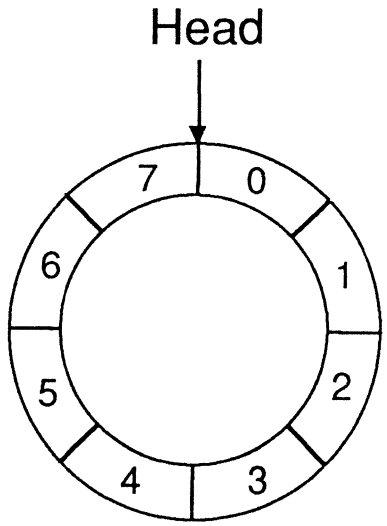
# Mode Page 3
(Continued)



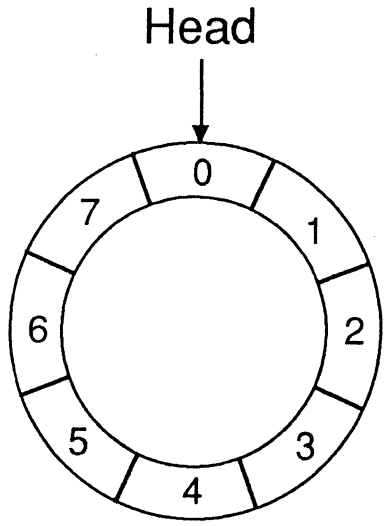

Notes:
- Zone is often implemented as cylinder
- Alternate = spare
- Spares are provided in addition to advertized drive capacity

# Mode Page 3
## (Continued)
## Head Switch Delay Problem

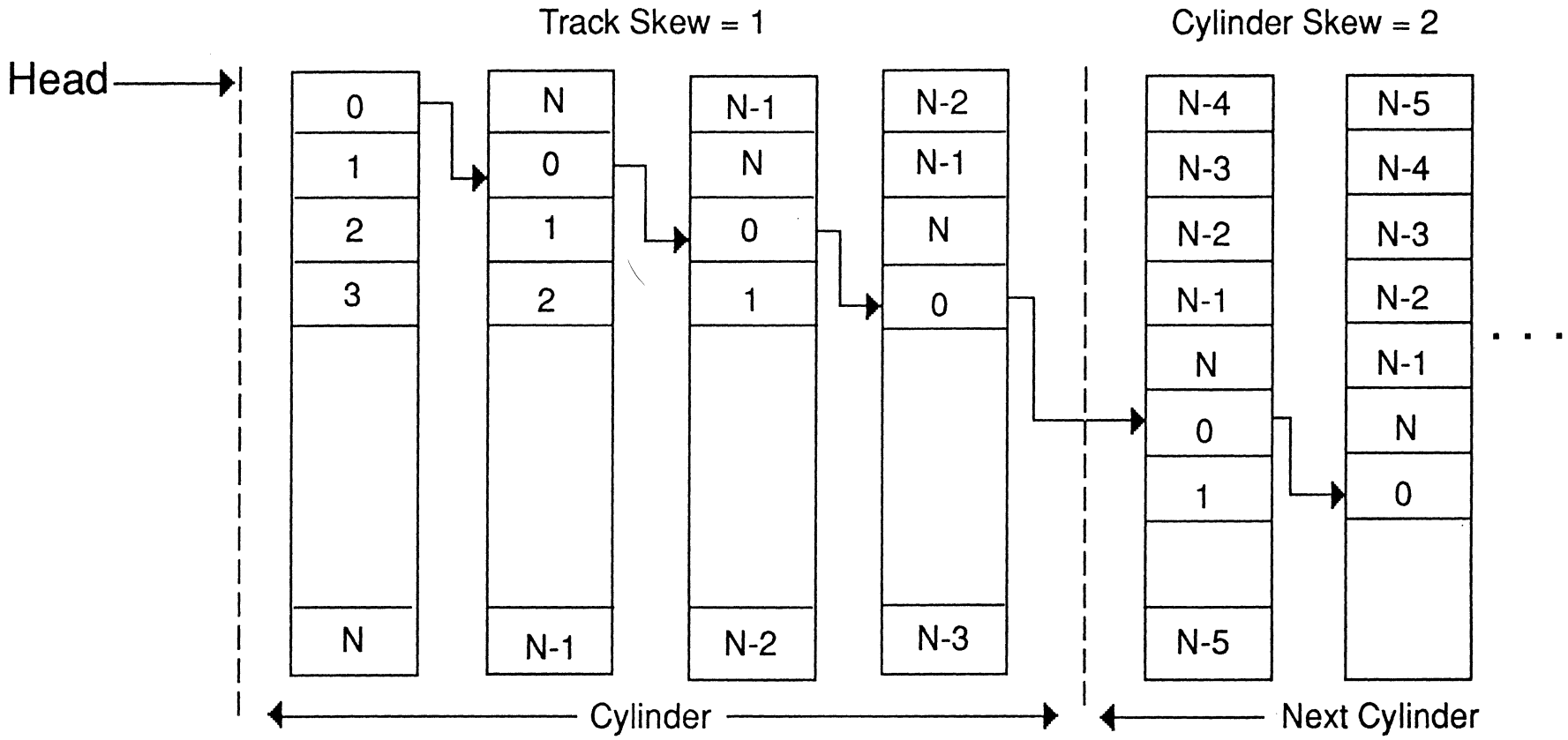
Before head switch




After head switch

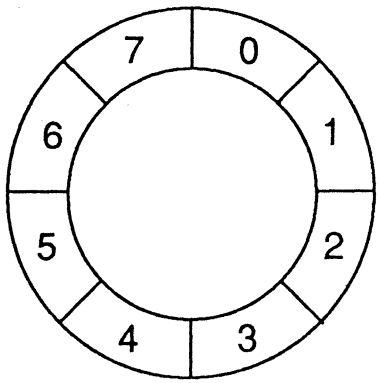


# Mode Page 3
## (Continued)
## Skewing Example



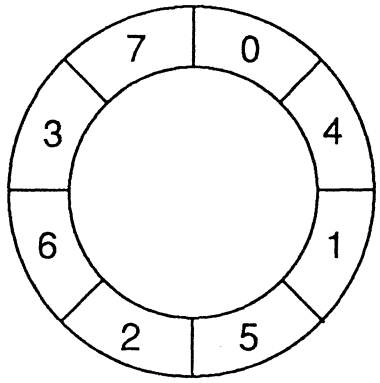
# Mode Page 3
## (Continued)
## Interleaving

1:1



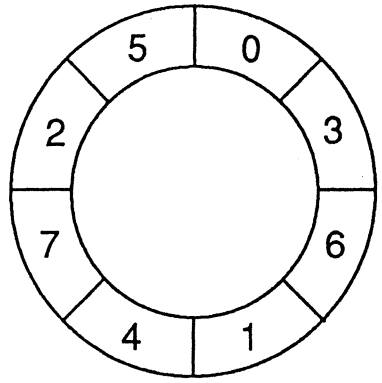

1 revolution per track

2:1




2 revolutions per track

3:1




3 revolutions per track

Notes:

- Traditionally interleaving is used to slow drives down if the system is slower

- Most SCSI drives only support 1:1 interleaving, since there are buffers on the drives

# Mode Page 3
## (Continued)
## Summary of Parameters

- Defect Handling:
  Tracks per Zone, Alternate Sectors per Zone, Alternate Tracks per Zone, Alternate Tracks per Logical Unit.

- Track/Sector Format:
  Sectors per Track, Bytes per Sector, Interleave (sense), Track Skew Factor, Cylinder Skew Factor.

- Drive Type:
  Removable or not
  Hard-sectored or soft-sectored (described later)

# Disk Defect Management

- In older interfaces, the disk defect list used to be printed on a label, which was attached to the drive. The host computer managed defect mapping.

- In SCSI, the defect list is recorded on the disk and maintained by the drive. Multiple copies of the defect list are normally recorded on reserved areas of the disk.

- Defect list types supported:

| Defect List | When Written | How Written/Changed |
|---|---|---|
| P-List<br>(Primary List) | At Factory | - Vendor Unique<br>- User Cannot Change |
| G-List<br>(Grown List) | In Field | - Automatic Reassignment<br>- Format Unit Command<br>- Reassign Blocks Command |

# Disk Defect Management
## (Continued)
## Sector Reallocation

- Terminology:
  Reallocate = reassign, revector, remap, map out, replace, spare

- How it is done:
  Good Track:


  With Reallocated Sector:


Sector Sparing
(normally used with Block Reassignment)

OR


Sector Slipping
(normally used with Format Unit)

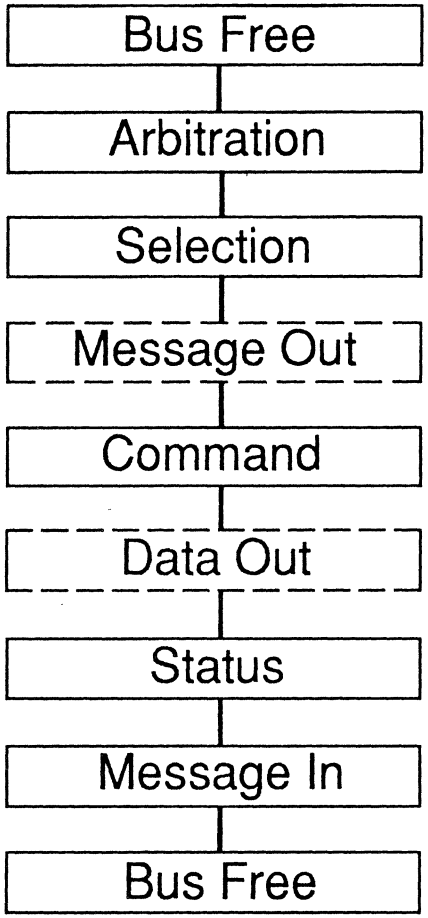
# Disk Defect Management
(Continued)

- Reassigning a block does not reduce drive capacity

- Commands Affecting Defect Management:
  - Format Unit
  - Reassign Blocks - replace block(s) with alternate(s)
  - Read Defect Data:
    - P-List
    - G-List
    - Both
    - Neither

- Defect Address Specification:
  - Logical Block Address
  - Physical - cylinder, head, and sector
  - Physical - cylinder, head, and offset from index (Byte number from beginning of Track)

# Format Unit Command
## Bus Phases



# Format Unit Command
(Continued)

- Before the Format Unit Command is executed, the drive has:

  P-List (if any)
  G-List (if any)

- Format Unit User Options:

  P-List Existing
  G-List Existing
  D-List Supplied by User During Data Out
  C-List Detected During Media Certification

- Media Certification:

  Vendor unique media scan normally using write and read

# Format Unit Command
(Continued)

- During Format Unit:
  - If P Enabled — Map Out P Defects
  - If G Enabled — Map Out G Defects
  - If D Supplied — Map Out D Defects
  - If C Enabled — Map Out C Defects

- After the Format Unit command is executed:
  - Defect Lists contents:
    - P-List — Unchanged
    - G-List — Enabled G, D, and C
  - Mapped Out Defects:
    - All Enabled Lists

- Disabling the G-List causes the old G-List to be overwritten

# Format Unit Command
## (Continued)

| Format Unit Options | | | | After the Command | | |
|---|---|---|---|---|---|---|
| P-List existing primary | G-List existing grown | D-List supplied in data out | C-List target certification | P-List | G-List | MappedOut Defects |
| No | No | No | No | unchanged | - | none |
| No | No | No | Yes | unchanged | C | C |
| No | No | Yes | No | unchanged | D | D |
| No | No | Yes | Yes | unchanged | D+C | D+C |
| No | Yes | No | No | unchanged | G | G |
| No | Yes | No | Yes | unchanged | G+C | G+C |
| No | Yes | Yes | No | unchanged | G+D | G+D |
| No | Yes | Yes | Yes | unchanged | G+D+C | G+D+C |
| Yes | No | No | No | unchanged | - | P |
| Yes | No | No | Yes | unchanged | C | P+C |
| Yes | No | Yes | No | unchanged | D | P+D |
| Yes | No | Yes | Yes | unchanged | D+C | P+D+C |
| Yes | Yes | No | No | unchanged | G | P+G |
| Yes | Yes | No | Yes | unchanged | G+C | P+G+C |
| Yes | Yes | Yes | No | unchanged | G+D | P+G+D |
| Yes | Yes | Yes | Yes | unchanged | G+D+C | P+G+D+C |

# Format Unit Command
## (Continued)
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 04h | | | | | | | |
| 1 | LUN | | | Fmt Data | Cmp Lst | List Format | | |
| 2 | Vendor Unique | | | | | | | |
| 3 | Interleave (MSB) | | | | | | | |
| 4 | Interleave (LSB) | | | | | | | |
| 5 | Control Byte | | | | | | | |

See next page for description of fields.

# Format Unit Command
(Continued)

- Interleave — 0 = default interleave
- Fmt Data — DATA OUT supplied
  should be set to 1
  when 0, drive may format any way it wants
- Cmp Lst — Complete List
  1=Disable old G-List
  0=Enable old G-List
- List Format — D-List format:
  0 = LBA
  5 = Cylinder, Head, Sector
  4 = Cylinder, Head, Offset from Index

# Format Unit Command
## (Continued)
## Data Out Format

| Byte | Bit | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| | Defect List Header | | | | | | | | |
| 0 | Reserved | | | | | | | | Header |
| 1 | FOV | DPRY | DCRT | STPF | IP | DSP | IM | VU | |
| 2 | Defect List Length (MSB) | | | | | | | | |
| 3 | Defect List Length (LSB) | | | | | | | | |
| | Initialization Pattern (if any)<br>(Normally not supplied, self-describing) | | | | | | | | |
| | Defect Descriptor(s) (if any) | | | | | | | | D-List |

See next page for description of fields.

# Format Unit Command
## (Continued)
## Summary

- FOV — 1 = Format Options Valid
  (Must be 1 for bits 2-6 to be valid)
- DPRY — 1 = Disable Primary List
- DCRT — 1 = Disable Certification
- STPF — 1 = Stop on Defect List Error
  (When a defect list cannot be read)
- IP — 1 = Initialization Pattern is supplied (SCSI-2)
- DSP — 1 = Disable Saving Mode Select Parameters (SCSI-2)
- IM — 1 = Immediate Mode (SCSI-2)

# Format Unit Command
## (Continued)
## Summary

| Defect List | Enabled by | Disabled by |
|---|---|---|
| Primary (P-list) | CDB→Fmt Data = 1<br>Data→FOV = 1<br>Data→DPRY = 0 | CDB→Fmt Data = 1<br>Data→FOV = 1<br>Data→DPRY = 1 |
| Grown (G-list) | CDB→Cmp Lst = 0 | CDB→Cmp Lst = 1 |
| Data (D-list) | CDB→Fmt Data = 1<br>Data→Defect List Length > 0 | CDB→Fmt Data = 1<br>Data→Defect List Length = 0<br>or<br>CDB→Fmt Data = 0 |
| Certification (C-list) | CDB→Fmt Data = 1<br>Data→FOV = 1<br>Data→DCRT = 0 | CDB→Fmt Data = 1<br>Data→FOV = 1<br>Data→DCRT = 1 |

# Format Unit Command
(Continued)

## Hard- Versus Soft-Sectored

| Hard-Sectored Drives | Soft-Sectored Drives |
|---|---|
| • Sector ID's written at factory only and not in field | • Sector ID's written at factory and in field |
| • Sector size not changeable | • Sector size changeable |
| • Logical block = 1 or more sectors | • Logical block = sector |
| • Format Unit does not write Sector ID's | • Format Unit may write Sector ID's |
| • Format Unit normally takes short time | • Format Unit normally takes long time |
| • Becoming more common | • Becoming less common |

# Format Unit Command
## (Continued)
## Practical Considerations

- Vendor-unique low-level drive format, which is used to write sector ID's, is different from SCSI Format Unit Command. Operating system format, which is used to check blocks and write directory information, is also different from SCSI Format Unit.

- Disk data may get lost after SCSI Format Unit.

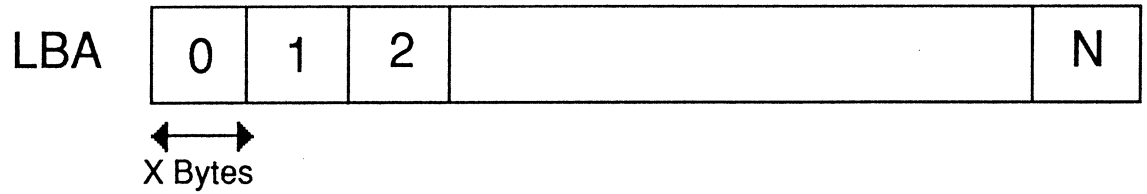
- Drives are formatted with default parameters and all known defects mapped out (P-list) in the factory.

- Usually, system integrator does not need to Format Unit, unless parameters are changed or grown defects found.

- Execute SCSI Format Unit if block length or Mode Select page 3 changed.

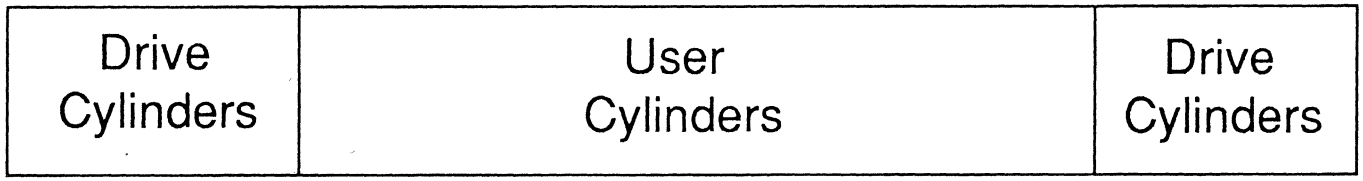
- SCSI Format Unit in the field may cause performance improvement due to reassigned blocks (sector sparing normally changed to sector slipping).

# Logical Block Addressing




- Logical Rather Than Physical Block Addressing
- Hidden Physical Characteristics (e.g., Cylinder, Head, Sector)
- Selectable Logical Block Size, Typical Values: 512, 1024, and 2048
- Defectless Blocks
- Drive Keeps Track of Defects
- Read Capacity Command: Returns Highest Block Address (N) and Block Length (X)
- SCSI-2 Send Diagnostic Command has option for translating LBA to physical location.

# Logical Block Addressing
## (Continued)
## Disk Cylinders




Cylinder 0

Drive Cylinders Contents:

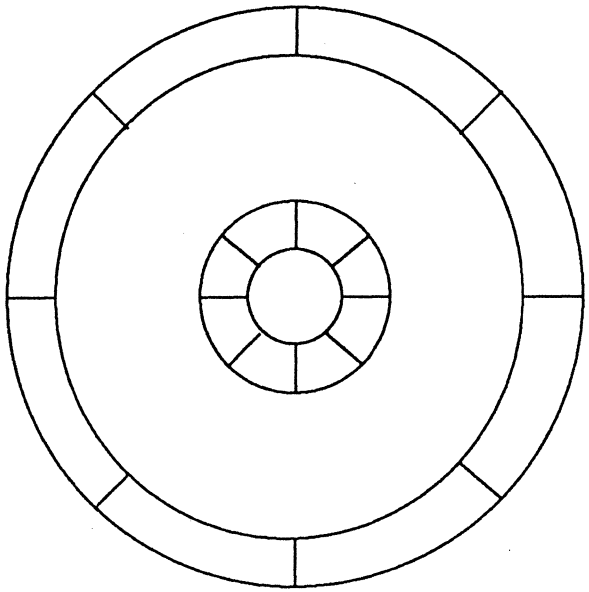
- Firmware Areas (defect lists, mode pages, etc.)
- Diagnostic Areas
- Reserved Areas

User Cylinders Contents:

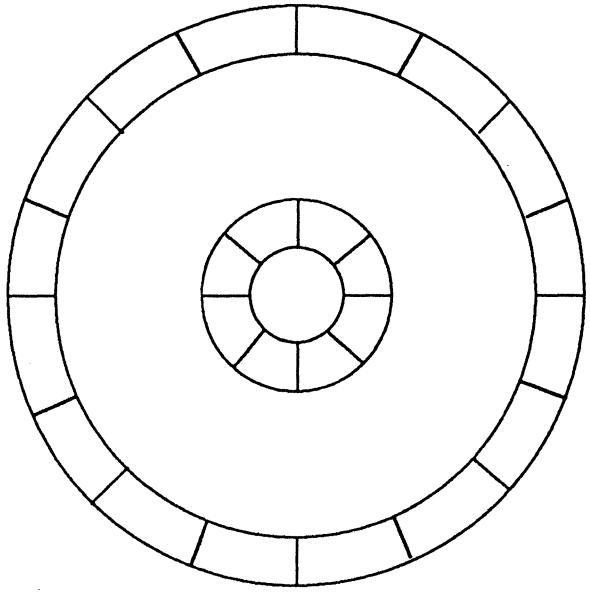
- User Data Areas
- Spare Areas
- Reassigned Areas

# Logical Block Addressing
(Continued)

Non-Zoned Tracks



Zoned Tracks



Constant Bit Density Recording
- Zoned, Notched, or Partitioned
- Technique to increase capacity
- See Mode Select Page 0Ch

# Logical Block Addressing
## (Continued)
## Addressing Schemes

### Logical

| Track | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 2 | 3 | 4 | |
| 1 | | 5 | 6 | 7 | 8 | 9 |
| 2 | 13 | 14 | 10 | | 11 | 12 |
| 3 | 18 | 19 | 17 | 15 | 16 | |

### Physical

| Track | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 2 | 3 | 4 | S |
| 1 | S | 0 | 1 | 2 | 3 | 4 |
| 2 | 3 | 4 | 0 | B | 1 | 2 |
| 3 | 3 | 4 | 2 | 0 | 1 | B |

### Absolute

| Track | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 2 | 3 | 4 | 5 |
| 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| 2 | 0 | 1 | 2 | 3 | 4 | 5 |
| 3 | 0 | 1 | 2 | 3 | 4 | 5 |

- When dealing with cylinder, head, and sector addressing, absolute addressing avoids confusion regardless of how the drive was formatted and where spares and defects are.

# Write Once Devices

- SCSI-1 name: WORM
  SCSI-2 name: Write Once

- Similar to Direct Access Device Commands

- Differences:
  - No Format Unit Command
  - No Read Defect Data Command
  - Check Condition with Blank Check Sense if:
    Reading Blank (Unwritten) Block
    Writing Previously Written Block

- SCSI-2 Additional Commands:
  - Medium Scan Command for finding Written or Blank Blocks
  - 12-byte Read, Search, Set Limits, Verify, Write, and Write Verify Commands

# CD-ROM Devices

- SCSI-2 Only
- Media Contains Data, Audio, or Both
- Similar to Write Once Commands
- Writing Not Supported
- Audio Commands

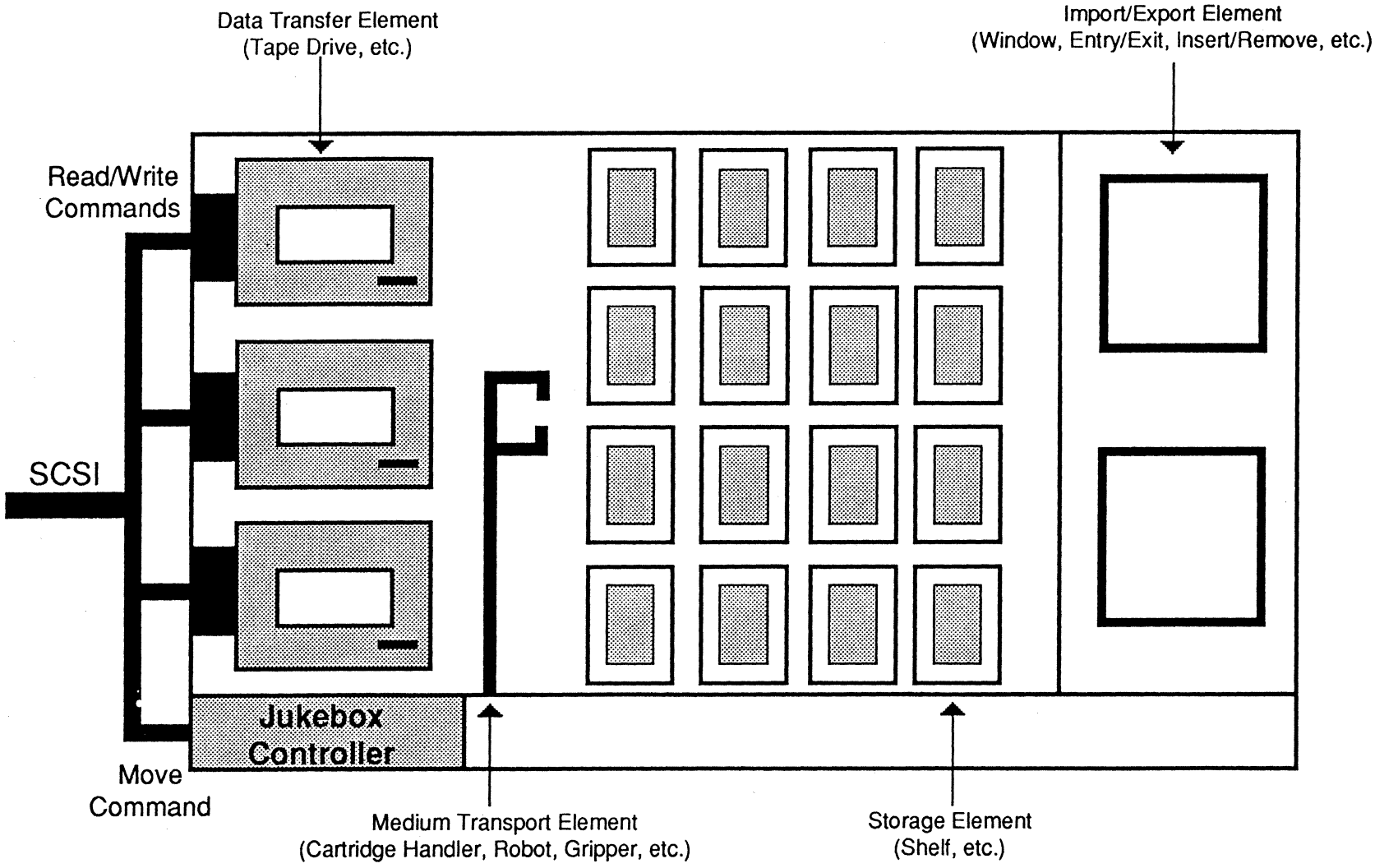
# Optical Memory Devices

- SCSI-2 Only
- Similar to Direct Access Device Commands
- Check Condition with Blank Check Sense if
  - Reading Blank (Unwritten) Block
  - Writing Previously Written Block
- Device Types Supported by Model:
  - Read-Only
  - Write-Once
  - Reversible (erase before rewriting)
- Additional Commands:
  - Erase Command (10-byte and 12-byte)
  - Medium Scan Command for finding Written or Blank Blocks
  - Update Block Command (Similar to Reassign)
  - Read Updated Block Command
  - Read Generation Command (Query Number of Block Revisions)
  - 12-byte Commands to Read, Write,...

# Printer Devices

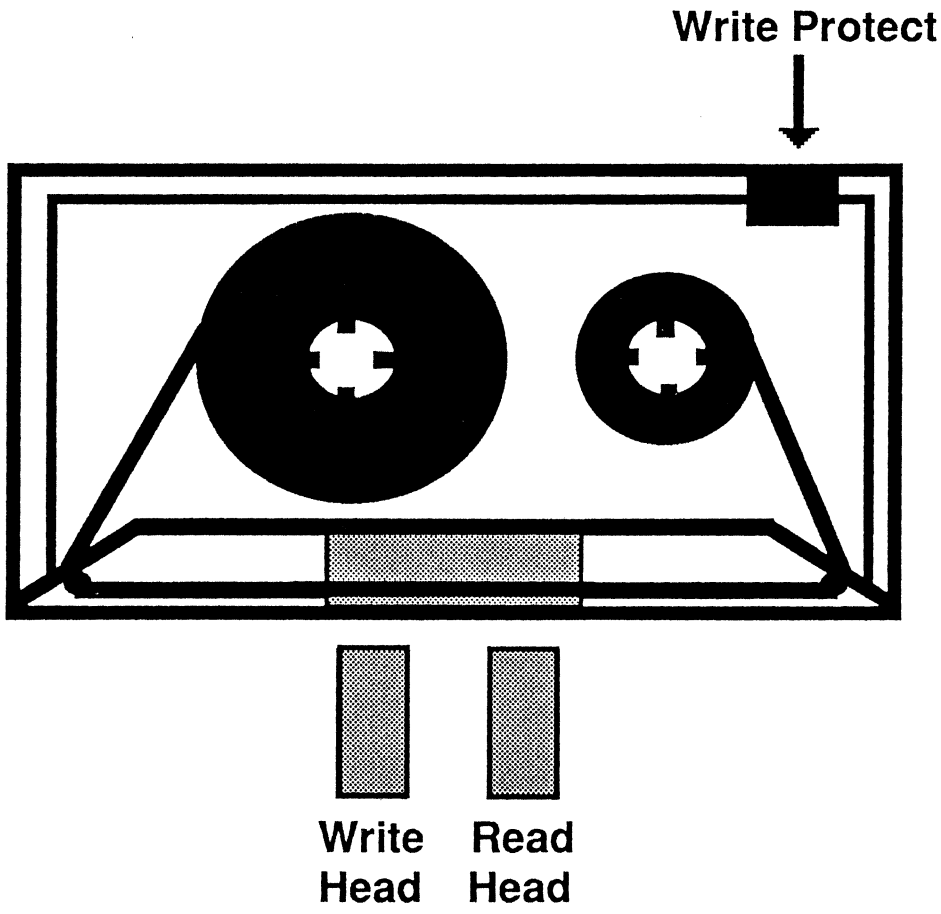
| Opcode | Name | Description |
|---|---|---|
| 04h | Format | Set Form or Font. |
| 0Ah | Print | Send Data Out to be printed.<br>(Escape sequences embedded in data). |
| 0Bh | Slew and Print | Specify number of lines to advance before printing.<br>Send Data Out to be printed.<br>(For printers that do not support forms control information embedded within the print data). |
| 10h | Flush Buffer | Print pending buffer data. |
| 14h | Recover Buffered Data | Recover unprinted data.<br>(For error handling). |
| 1Bh | Stop Print | Option to retain or discard unprinted data. |

# Medium Changer Devices

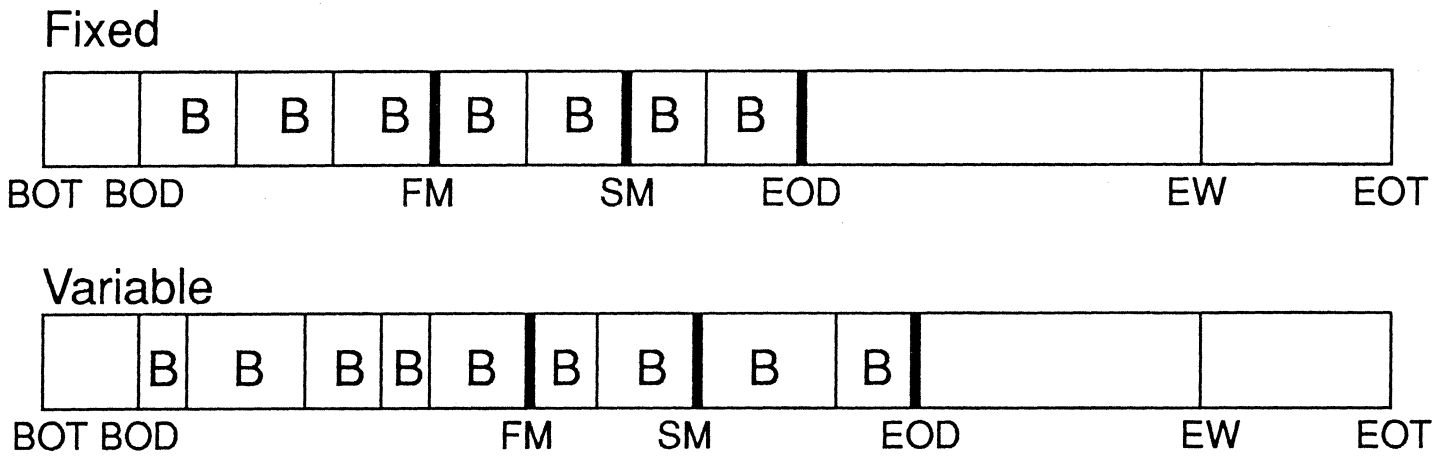



- Elements have unique element addresses
- Data transfer elements can be independent SCSI targets or logical units of the medium changer device

# Tape Device Model



# Tape Device Model
(Continued)




| | |
|---|---|
| BOT | Beginning of Tape |
| EOT | End of Tape |
| BOD | Beginning of Data (Load Point) |
| EOD | End of Data |
| EW | Early Warning (Normally for Write) |
| FM | Filemark |
| SM | Setmark (SCSI-2 only) |
| B | Block (Fixed or Variable) |

# Tape Device Model
(Continued)

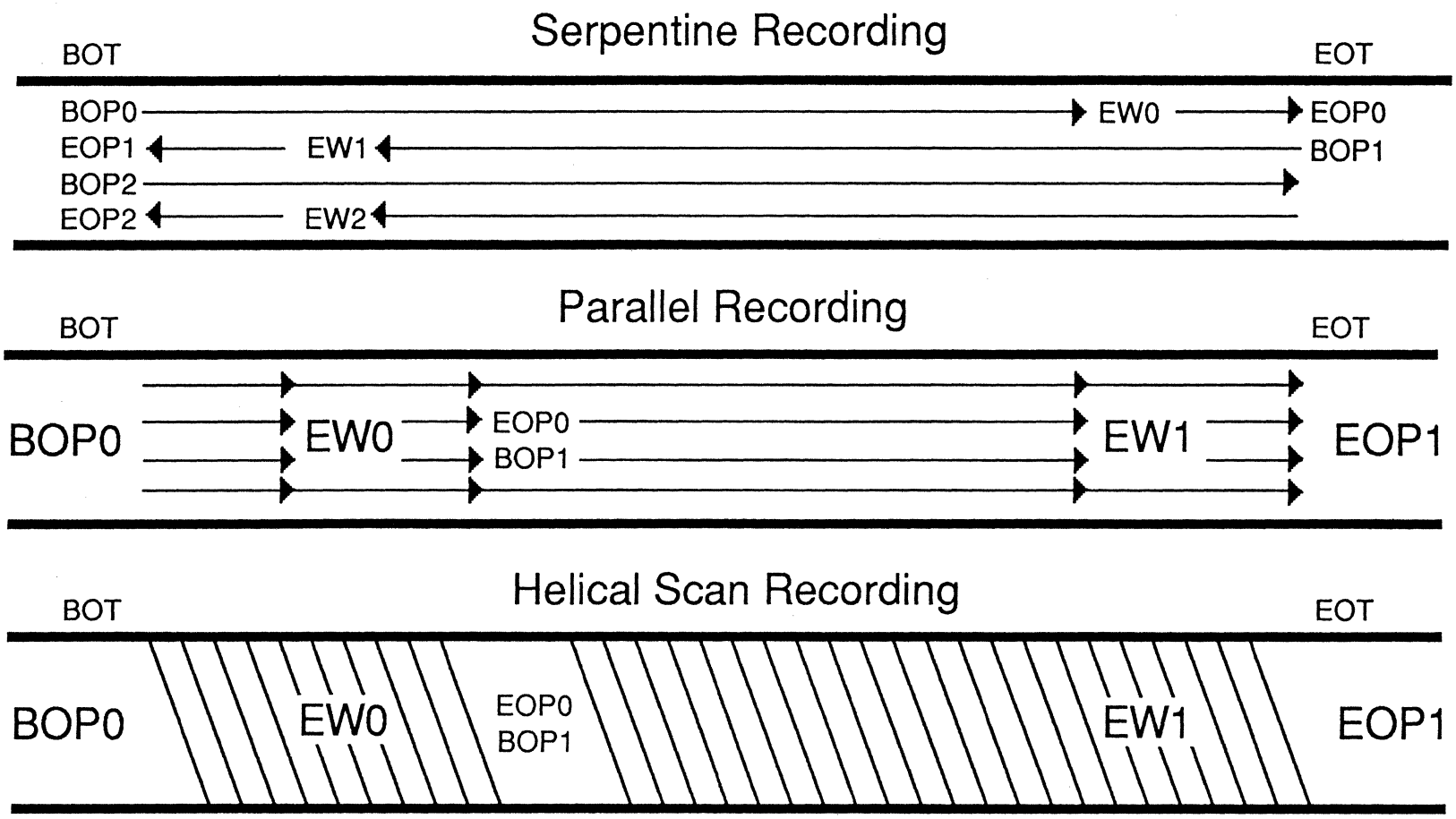
- Selecting Fixed Mode:
  Mode Select - Block Length = N
  (Block Length is in the Block Descriptor section of the Mode Select Data)

- Selecting Variable Mode:
  Mode Select - Block Length = 0

- Sensing Current Mode:
  Mode Sense - Block Length
  N = Fixed
  0 = Variable

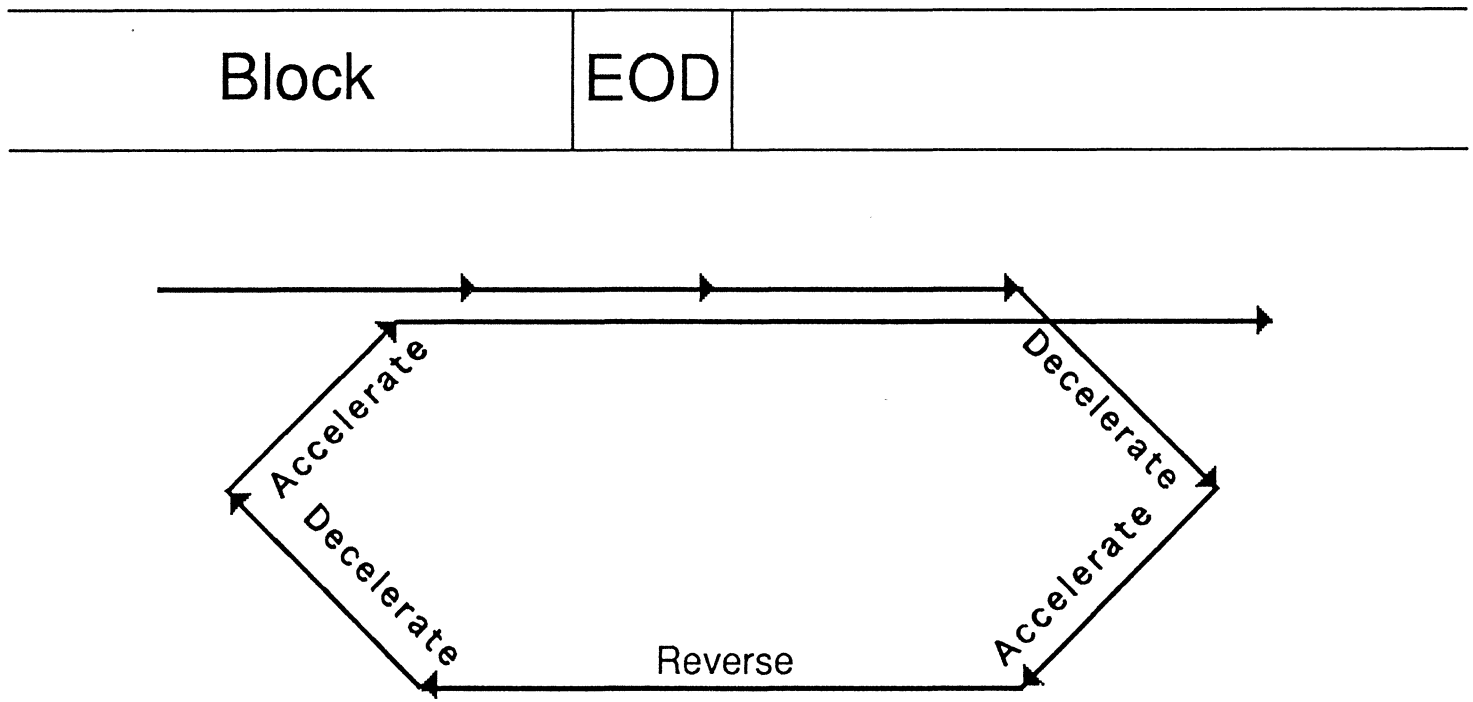
- Sensing Supported Modes:
  Read Block Limits Command returns Min and Max block lengths
  Min = Max ⟶ Fixed Only
  Min < Max ⟶ Variable and Fixed

# Tape Device Model
## (Continued)
## SCSI-2 Partition Examples




BOP = beginning of partition, EOP = end of partition, EW = early warning
Use Mode Select command (page 11h-14h) to define partitions
Use Mode Select command or Locate command to switch partitions

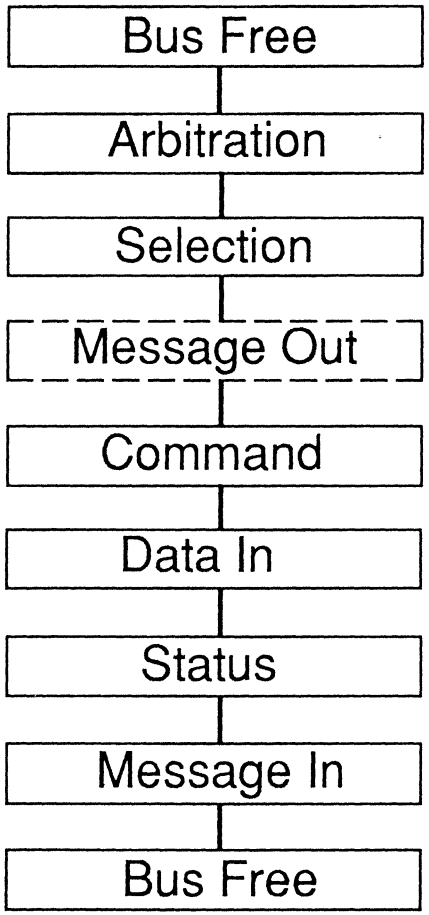
# Tape Device Model
(Continued)
Repositioning



# Tape - Read Block Limits Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 05h | | | | | | | |
| 1 | LUN | | | Reserved | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Reserved | | | | | | | |
| 5 | Control Byte | | | | | | | |

# Tape - Read Block Limits Command
(Continued)
Bus Phases



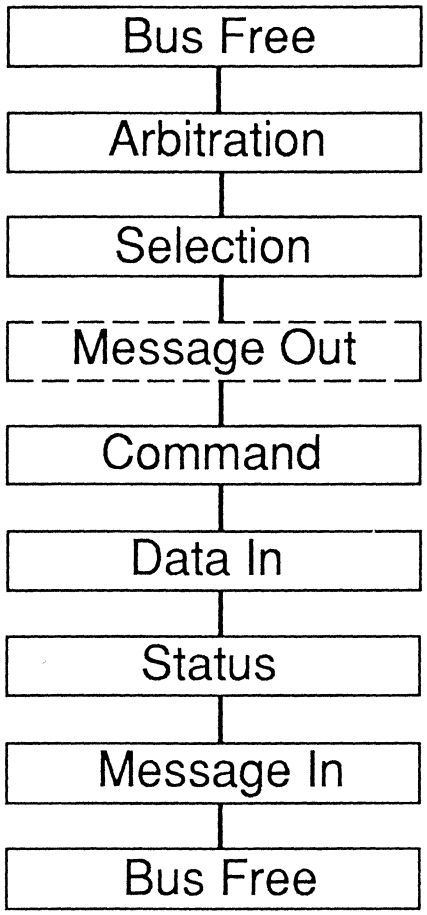
# Tape - Read Block Limits Command
## (Continued)
## Data In Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | | | | | | |
| 1 | Maximum Block Length (MSB) | | | | | | | |
| 2 | Maximum Block Length | | | | | | | |
| 3 | Maximum Block Length (LSB) | | | | | | | |
| 4 | Minimum Block Length (MSB) | | | | | | | |
| 5 | Minimum Block Length (LSB) | | | | | | | |

- Maximum = Minimum means Fixed support only

# Tape - Read Command

## Bus Phases



# Tape - Read Command
## (Continued)
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 08h | | | | | | | |
| 1 | LUN | | | Reserved | | | SILI | F |
| 2 | Transfer Length (MSB) | | | | | | | |
| 3 | Transfer Length | | | | | | | |
| 4 | Transfer Length (LSB) | | | | | | | |
| 5 | Control Byte | | | | | | | |

See next page for description of fields.

# Tape - Read Command
(Continued)

- F: 1 = Fixed, 0 = Variable

- Fixed Block Mode
  - Mode Select Block Length = N
  - F-Bit = 1
  - Transfer Length = Number of Blocks
  - Read Multiple Blocks at a Time

- Variable Block Mode
  - Mode Select Block Length = 0
  - F-Bit = 0
  - Transfer Length = Number of Bytes
  - Read One Block at a Time

- SILI: Suppress Incorrect Length Indicator
  - Variable Block Size Only
  - SCSI-2

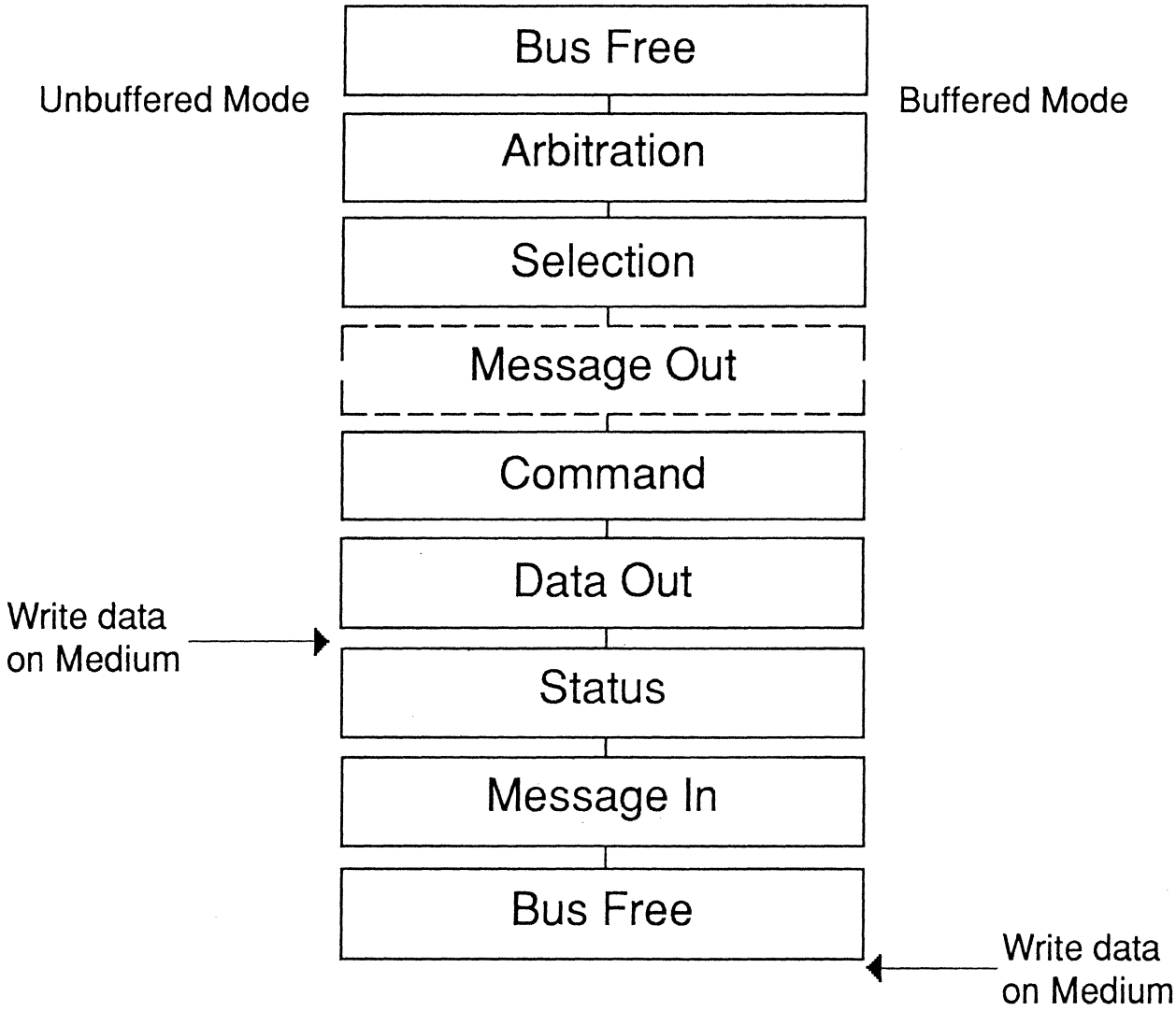
# Tape - Read Command
## (Continued)
## Error Handling

| Tape Mode | Fixed bit | SILI bit | Error Condition | Response Sense | Information Bytes | Tape Position |
|---|---|---|---|---|---|---|
| V | 0 | ? | none | none | none | After Read Block |
| F | 1 | 0 | none | none | none | After Read Block(s) |
| F | 0 | ? | none | none | none | After Read Block |
| V | 0 | 0 | Requested>Actual Length | ILI | Residue in Bytes | After Underrun Block |
| V | 0 | 0 | Requested<Actual Length | ILI | -Residue in Bytes or 0 | After Overrun Block |
| F | 1 | 0 | Incorrect Block Length | ILI | Residue in Blocks | After Error Block |
| ? | 0 | 1 | Requested>Actual Length | none | none | After Underrun Block |
| V | 0 | 1 | Requested<Actual Length | none | none | After Overrun Block |
| F | 0 | 1 | Requested<Actual Length | ILI | -Residue in Bytes or 0 | After Overrun Block |
| ? | 0 | ? | Filemark | FM | Requested Length | After Filemark |
| ? | 1 | 0 | Filemark | FM | Residue in Blocks | After Filemark |
| ? | 0 | ? | End of Data | Blank Check | Requested Length | At EOD |
| ? | 1 | 0 | End of Data | Blank Check | Residue in Blocks | At EOD |
| ? | 0 | ? | End of Tape | EOM, Medium Error | Requested Length | Not Defined |
| ? | 1 | 0 | End of Tape | EOM, Medium Error | Residue in Blocks | Not Defined |
| V | 1 | 0 | none | Illegal Request | none | Not Changed |
| ? | 1 | 1 | none | Illegal Request | none | Not Changed |

# Tape - Write Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 0Ah | | | | | | | |
| 1 | LUN | | | Reserved | | | | F |
| 2 | Transfer Length (MSB) | | | | | | | |
| 3 | Transfer Length | | | | | | | |
| 4 | Transfer Length (LSB) | | | | | | | |
| 5 | Control Byte | | | | | | | |

# Tape - Write Command
## (Continued)
## Bus Phases



# Tape - Write Command
(Continued)

- Buffered/Unbuffered - Mode Selectable

- Buffered mode error handling:
  - Errors detected after Bus Free are reported on subsequent command with CHECK CONDITION
  - Residue in Information Bytes (Sense data bytes 3-6) = Unwritten Blocks (Bytes), Filemarks, and Setmarks
  - Deferred sense error code (71h)
  - Use RECOVER BUFFERED DATA Command to retrieve unwritten data

- Flushing buffered data to media:
  - Use WRITE FILEMARKS command with 0 filemarks, or any tape motion non-write-oriented command (e.g., Rewind)

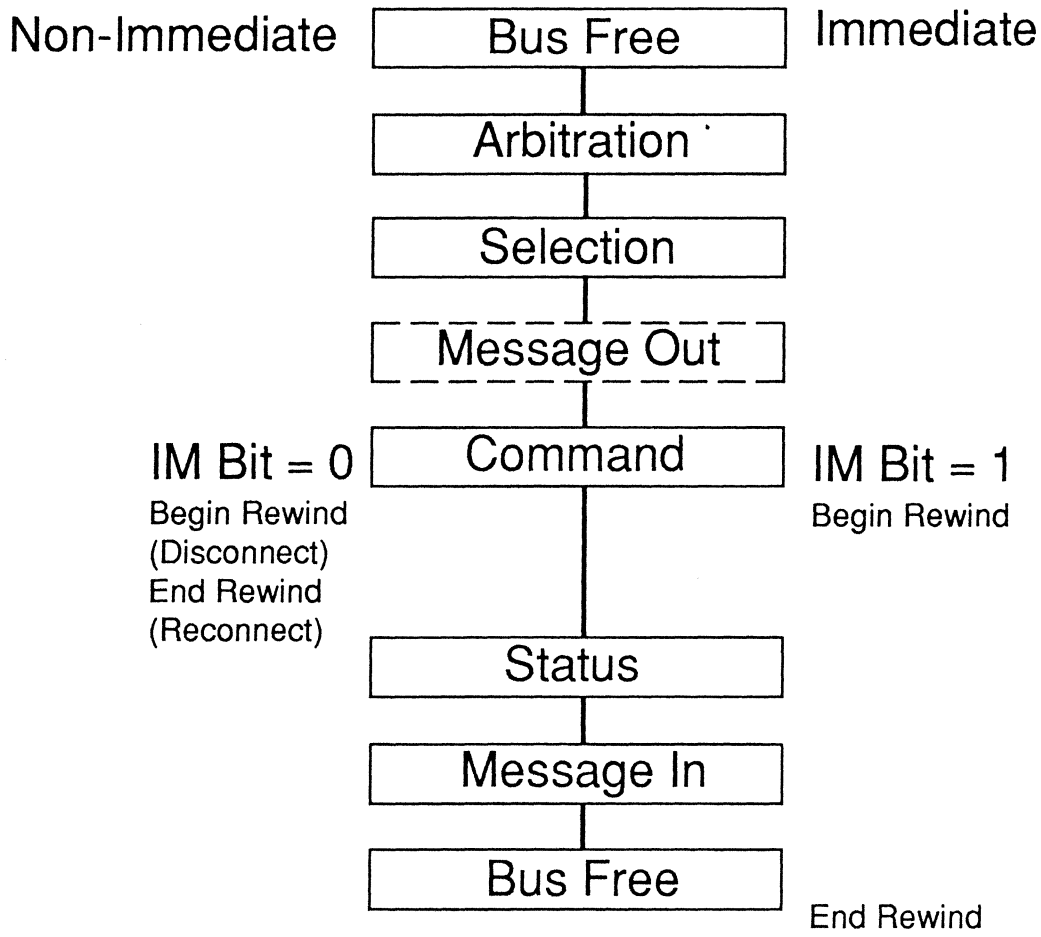
# Tape - Write Command
## (Command)
## Error Handling

| Error Condition | Sense Key |
|---|---|
| Protected Medium | Data Protect |
| Early Warning | No Sense, EOM |
| End Of Tape | Volume Overflow, EOM |
| Write Fixed in Variable Mode | Illegal Request |
| Write Variable in Fixed Mode | Illegal Request (SCSI-1) |

# Tape - Rewind Command
## CDB Format

| Byte | Bit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 01h | | | | | | | |
| 1 | LUN | | | Reserved | | | | IM |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | Reserved | | | | | | | |
| 5 | Control Byte | | | | | | | |

# Tape - Rewind Command
## (Continued)
## Bus Phases



# Other Tape Commands

| | |
|---|---|
| Write Filemarks | Mandatory. Specify Filemark Count in CDB.<br>0 Filemarks Flushes Buffered Data.<br>Option to write Setmarks. Immediate Bit. |
| Space | Mandatory. Space Blocks, Filemarks (Setmarks), or End-of-Data.<br>Space Reverse: Two's Complement Count. |
| Erase | Mandatory. Short/Long Erase. |
| Load/Unload | Optional. Load/Unload Bit. Immediate Bit.<br>Retension Bit. |
| Prevent/Allow Medium Removal | Optional. |
| Locate | Optional (SCSI-2 only). Position to LBA.<br>Change Partition Option. |
| Read Reverse | Optional. Reversed Data Bytes Returned. |

# ELECTRICAL CHARACTERISTICS

# SCSI Cables

- Devices are Daisy-Chained Using Common Cable.

- Single-Ended Drivers and Receivers:
  - Six Meters Max.
  - Most Common.
  - In-Cabinet Application.

- Differential Drivers and Receivers:
  - Twenty-five Meters Max.
  - More Expensive.
  - Consumes More Power and Board Space.

# Connectors

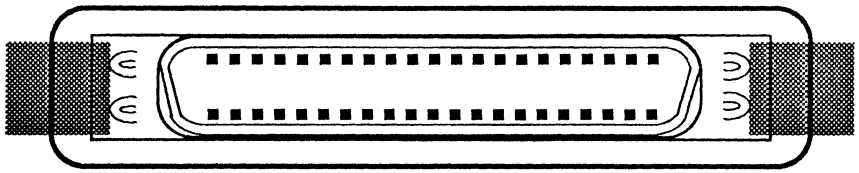
- 50 Pins

- Nonshielded:
  - most common
  - in-cabinet
  - low density alternative (3.2" wide)
  - high density alternative (1.4" wide)

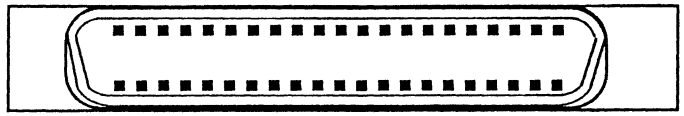
- Shielded:
  - 2 connectors for Daisy-chain
  - low density alternative (2.5" wide)
  - high density alternative (1.4" wide)

# Connectors
(Continued)

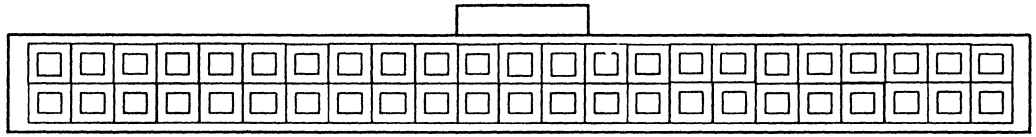
**High-Density Shielded**



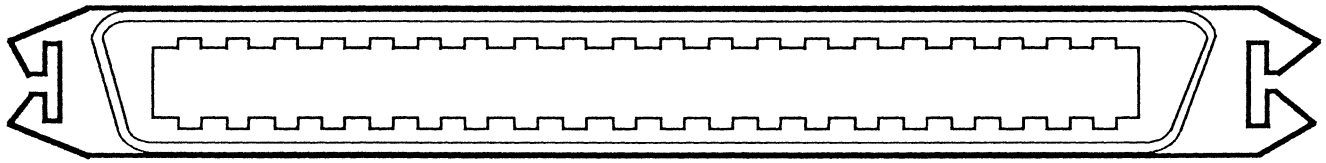
**High-Density Unshielded**



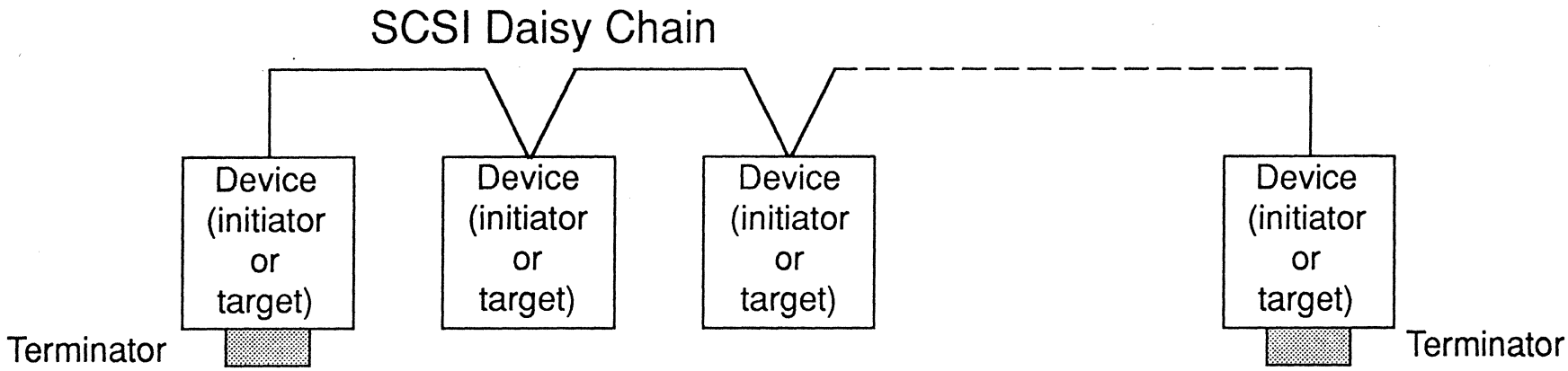
**Low-Density Unshielded**



**Low-Density Shielded**

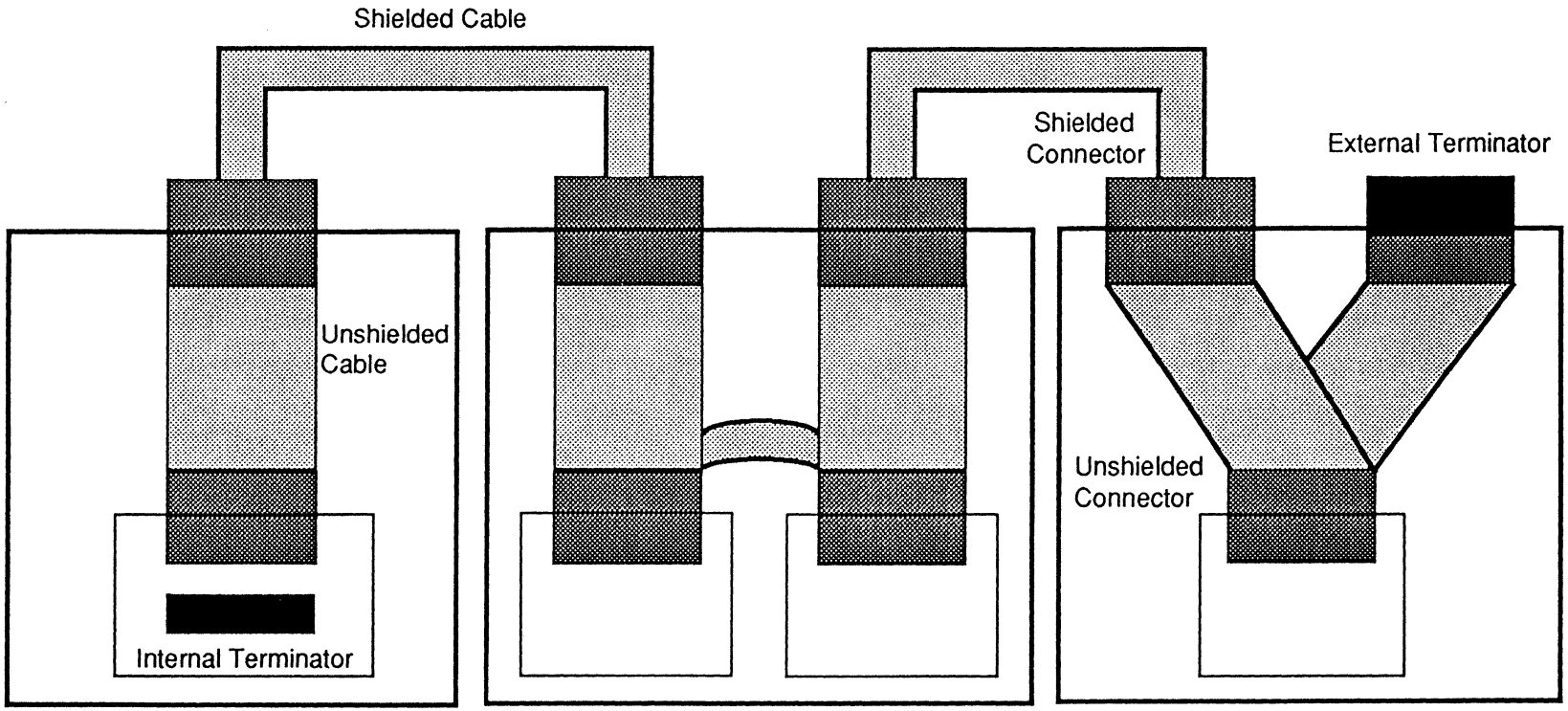


# Termination Devices



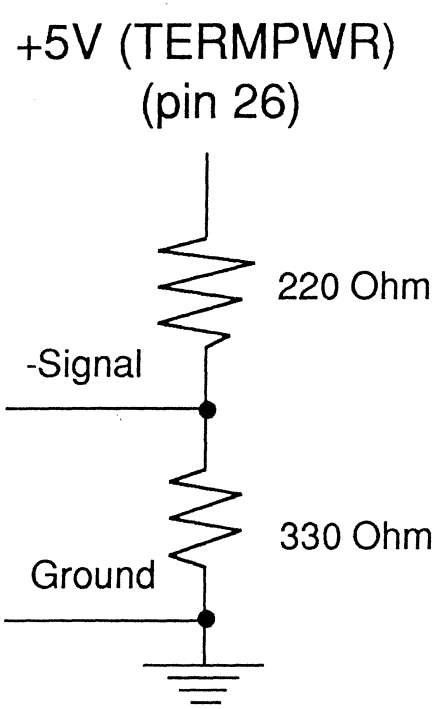

- On end devices only

# Termination Devices
(Continued)
Example

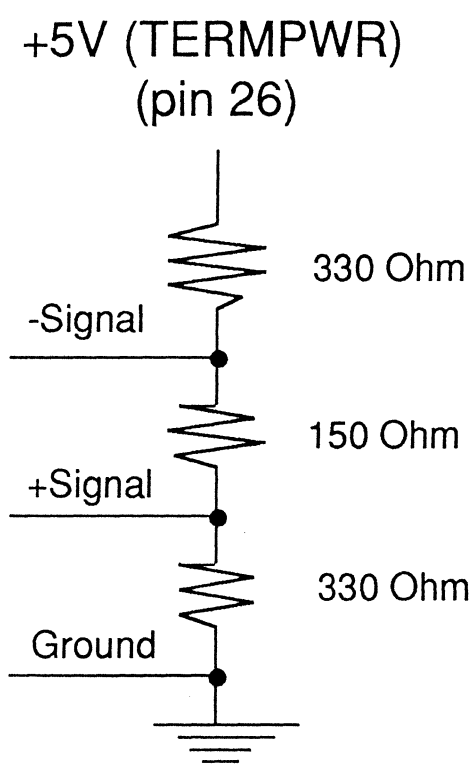


# Passive Termination Devices

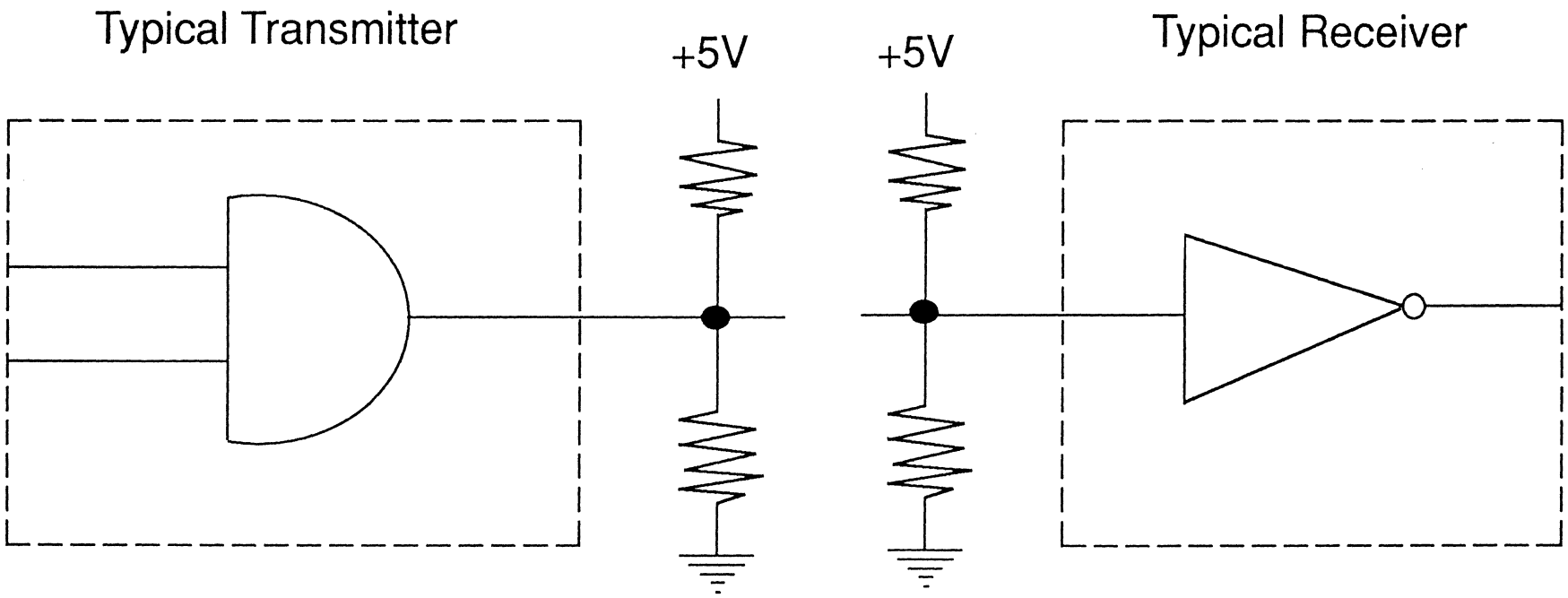
Single- Ended



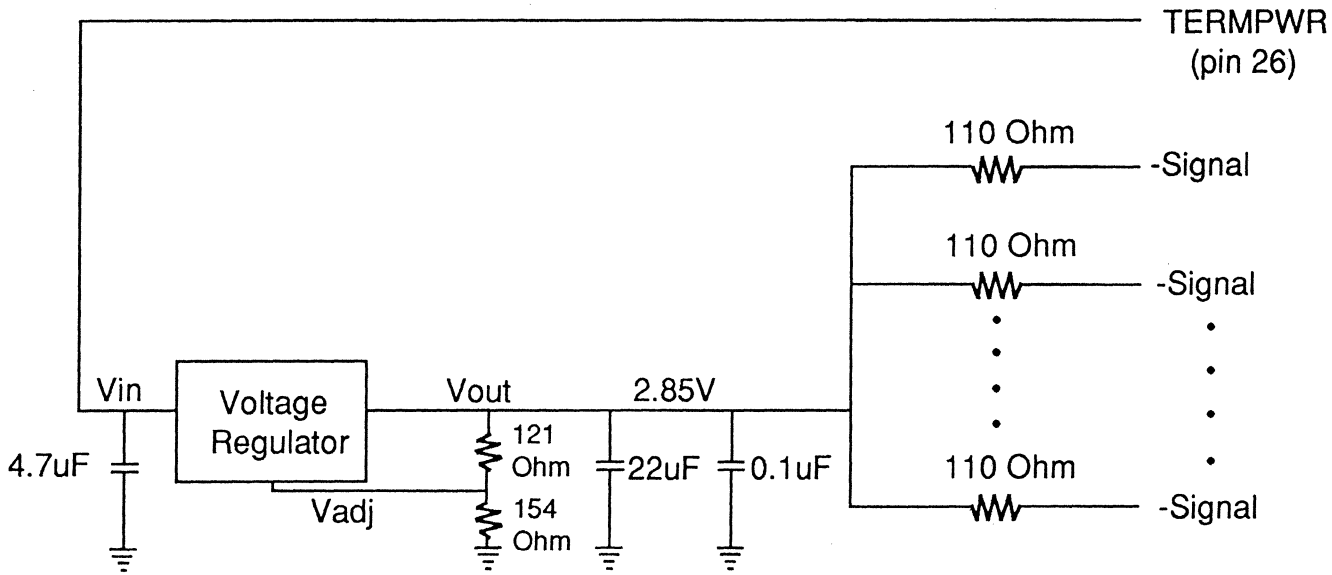

Differential



# Passive Termination Devices
## (Continued)
## Single-Ended Driver/Receiver

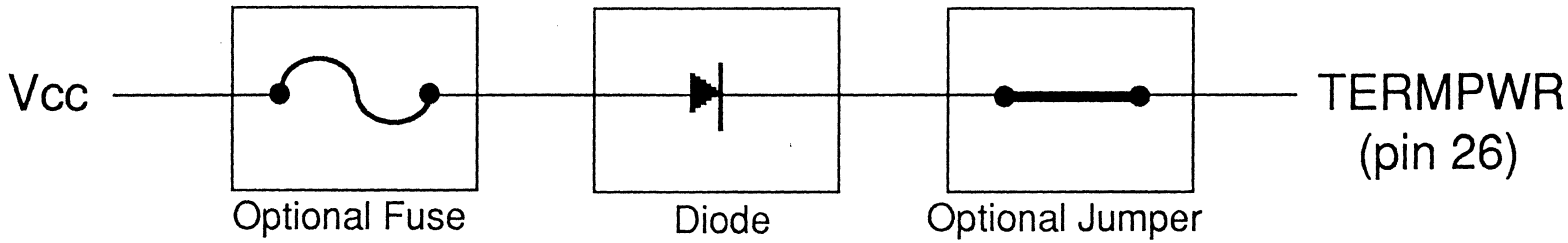


# Active Termination Devices
## SCSI-2 Single-Ended Alternative 2



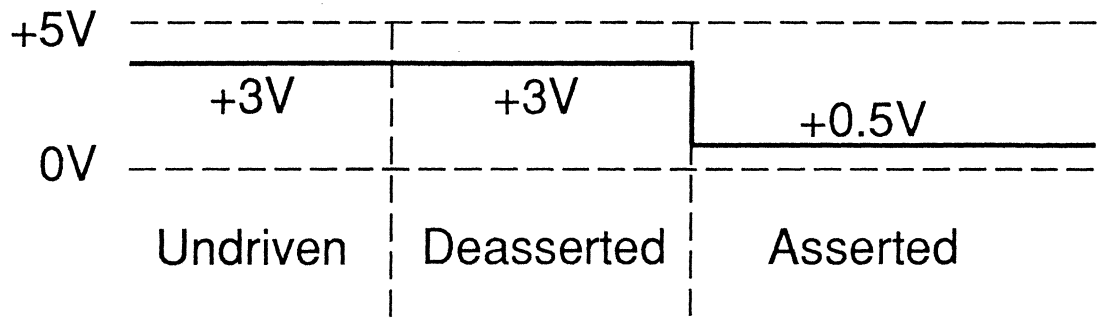
# Terminator Power

- SCSI-1:
  - Any device may supply terminator power.
- SCSI-2:
  - Initiators must supply terminator power to TERMPWR.
  - Targets may supply terminator power.
- At least one device must supply terminator power.
- Terminator power must be supplied through a diode or similar device to prevent backflow of current.
- Fuse protects against accidental grounding.



# Signal Values

- Single-ended is active-low:



# Signal Values
## (Continued)
## Types of Signals

- OR-tied Signals:
  - Asserted (true):
    One or more drivers are asserted.
  - Deasserted (false):
    Terminator bias circuitry pulls the signal false.

- Non-OR-tied Signals:
  - Asserted (true):
    One driver is asserted.
  - Deasserted (false):
    Terminator bias circuitry pulls the signal false (open-collector).
    or
    Signal is actively driven false, (active negation drivers).

- Some signals must be OR-tied, others are non-OR-tied but may be OR-tied.

# Bus Signals
## Introduction

| Signal | Name | Source | Usage |
|---|---|---|---|
| **Control Signals:** | | | |
| RST* | RESET | I & T | Reset Bus |
| BSY* | BUSY | I & T | Bus Busy or Idle |
| SEL* | SELECT | I & T | Select or Reselect |
| C/D | CONTROL/DATA | T | Information Transfer Phase |
| I/O | INPUT/OUTPUT | T | Information Transfer Phase |
| MSG | MESSAGE | T | Information Transfer Phase |
| REQ | REQUEST | T | Transfer Byte |
| ACK | ACKNOWLEDGE | I | Transfer Byte |
| ATN | ATTENTION | I | Request Message Out Phase |
| **Data Signals:** | | | |
| DB(0-7) | Data Bus | I & T | ID's or Bytes |
| DB(P) | Parity (Odd) | I & T | Transmission error detection |

Notes:

* = Or-Tied signal

18 signals, 9 for control and 9 for data

# Connector Pin Assignment

## Single-Ended

( - means active low)

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 1 | GND | 2 | -DB(0) |
| 3 | GND | 4 | -DB(1) |
| 5 | GND | 6 | -DB(2) |
| 7 | GND | 8 | -DB(3) |
| 9 | GND | 10 | -DB(4) |
| 11 | GND | 12 | -DB(5) |
| 13 | GND | 14 | -DB(6) |
| 15 | GND | 16 | -DB(7) |
| 17 | GND | 18 | -DB(P) |
| 19 | GND | 20 | GND |
| 21 | GND | 22 | GND |
| 23 | Reserved (SCSI-1=GND) | 24 | Reserved (SCSI-1=GND) |

# Connector Pin Assignment
## (Continued)
## Single-Ended

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 25 | open | 26 | TERMPWR |
| 27 | Reserved (SCSI-1=GND) | 28 | Reserved (SCSI-1=GND) |
| 29 | GND | 30 | GND |
| 31 | GND | 32 | -ATN |
| 33 | GND | 34 | GND |
| 35 | GND | 36 | -BSY |
| 37 | GND | 38 | -ACK |
| 39 | GND | 40 | -RST |
| 41 | GND | 42 | -MSG |
| 43 | GND | 44 | -SEL |
| 45 | GND | 46 | -C/D |
| 47 | GND | 48 | -REQ |
| 49 | GND | 50 | -I/O |

# Connector Pin Assignment
## (Continued)
## Differential

(TRUE = + SIGNAL more positive than - SIGNAL)

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 1 | GND | 2 | GND |
| 3 | +DB(0) | 4 | -DB(0) |
| 5 | +DB(1) | 6 | -DB(1) |
| 7 | +DB(2) | 8 | -DB(2) |
| 9 | +DB(3) | 10 | -DB(3) |
| 11 | +DB(4) | 12 | -DB(4) |
| 13 | +DB(5) | 14 | -DB(5) |
| 15 | +DB(6) | 16 | -DB(6) |
| 17 | +DB(7) | 18 | -DB(7) |
| 19 | +DB(P) | 20 | -DB(P) |
| 21 | DIFFSENS | 22 | GND |
| 23 | Reserved (SCSI-1=GND) | 24 | Reserved (SCSI-1=GND) |

# Connector Pin Assignment
## (Continued)
## Differential

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 25 | TERMPWR | 26 | TERMPWR |
| 27 | Reserved (SCSI-1=GND) | 28 | Reserved (SCSI-1=GND) |
| 29 | +ATN | 30 | -ATN |
| 31 | GND | 32 | GND |
| 33 | +BSY | 34 | -BSY |
| 35 | +ACK | 36 | -ACK |
| 37 | +RST | 38 | -RST |
| 39 | +MSG | 40 | -MSG |
| 41 | +SEL | 42 | -SEL |
| 43 | +C/D | 44 | -C/D |
| 45 | +REQ | 46 | -REQ |
| 47 | +I/O | 48 | -I/O |
| 49 | GND | 50 | GND |

# Bus Timings

| | | | |
|---|---|---|---|
| Arbitration Delay | 2.4 us | min | for Arbitration |
| Assertion Period | 90 ns | min | for Synchronous |
| Bus Clear Delay | 800 ns | max | for Arbitration and others |
| Bus Free Delay | 800 ns | min | for Arbitration |
| Bus Set Delay | 1.8 us | max | for Arbitration |
| Bus Settle Delay | 400 ns | min | for some control signals |
| Cable Skew Delay | 10 ns | max | described later |
| Data Release Delay | 400 ns | max | for initiator when driving DB |
| Deskew Delay | 45 ns | min | described later |
| Disconnection Delay | 200 us | min | for Disconnect Message Out |
| Fast Assertion Period | 30 ns | min | for Fast Bus |
| Fast Cable Skew Delay | 5 ns | max | for Fast Bus |

# Bus Timings
(Continued)

| | | | |
|---|---|---|---|
| Fast Deskew Delay | 20 ns | min | for Fast Bus |
| Fast Hold Time | 10 ns | min | for Fast Bus |
| Fast Negation Period | 30 ns | min | for Fast Bus |
| Hold Time | 45 ns | min | for Synchronous |
| Negation Period | 90 ns | min | for Synchronous |
| Power-On to Selection Time | 10 sec | max | for target power-up (recommended) |
| Reset to Selection Time | 250 ms | max | for target reset (recommended) |
| Reset Hold Time | 25 us | min | for Bus Reset |
| Selection Abort Time | 200 us | max | for Selection timeout |
| Selection Timeout Delay | 250 ms | min | for Selection timeout (recommended) |
| Transfer Period | negotiated | min | for Synchronous |

# Bus Timings
(Continued)

Cable Skew Delay (10 ns)

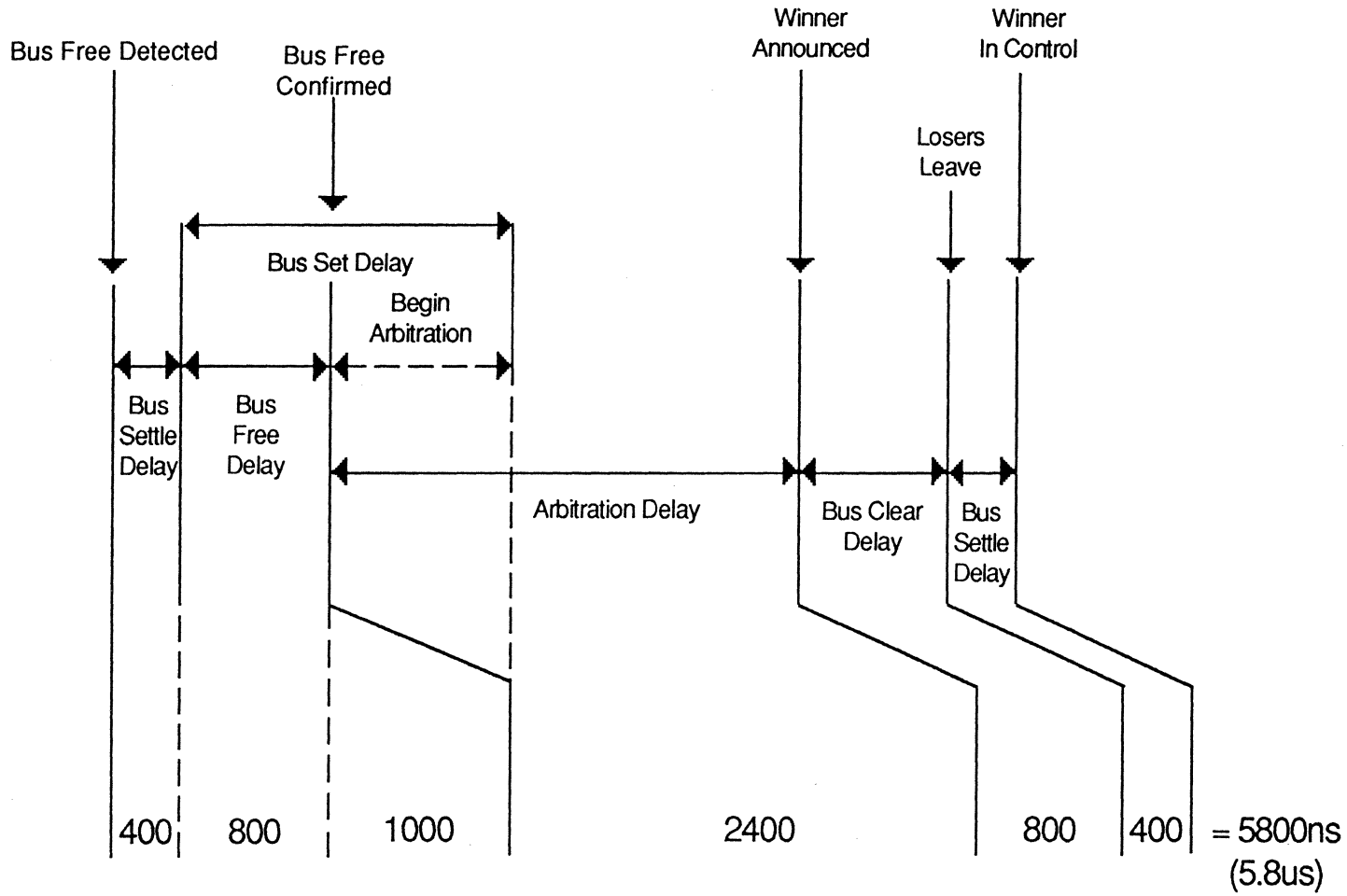
- To allow for propagation of signals on the cable

Deskew Delay (45 ns)

- To allow for the difference between rising and falling edges

- Rise times are much slower than fall times. Data is latched on assertion of REQ or ACK (falling edge - fast). But data itself may be changing from assertion to deassertion (rising edge - slow).

# Bus Timings
(Continued)



# Bus Reset

- To Reset, Assert RST Line for Reset Hold Time (25us) min
- Hard Reset Option (Harsh Response to Reset)
  - Release All SCSI Bus Signals
  - Clear Uncompleted Commands
  - Release Device Reservations
  - Restore Mode Select Parameters to Saved (or Default) Values
- Soft Reset Option (Gentle Response to Reset)
  - Release All SCSI Bus Signals
  - Attempt to Complete Uncompleted Commands
  - Preserve Reservations and Parameters
- SCSI Devices May Respond with Hard Reset or Soft Reset Option (may be jumper-selectable)
- Determine which option is implemented using Inquiry command
- Hard Reset is most Common
- Either Hard or Soft may be used within a system, but not both

# Parity

- Used for detecting transmission errors.
- Optional in SCSI-1 and CCS, but Mandatory in SCSI-2.
- Valid during Selection, Reselection, and Information Transfer Phases.
- Invalid (not driven) during Bus Free and Arbitration.
- Always odd when supported (total number of 1 bits, including parity, must be odd).
- Sender generates parity and receiver checks it.
- Examples:

| DB (hex) | DB (binary) | DB-P |
|---|---|---|
| 00h | 0000 0000 | 1 |
| 01h | 0000 0001 | 0 |
| 15h | 0001 0101 | 0 |
| 22h | 0010 0010 | 1 |
| FFh | 1111 1111 | 1 |

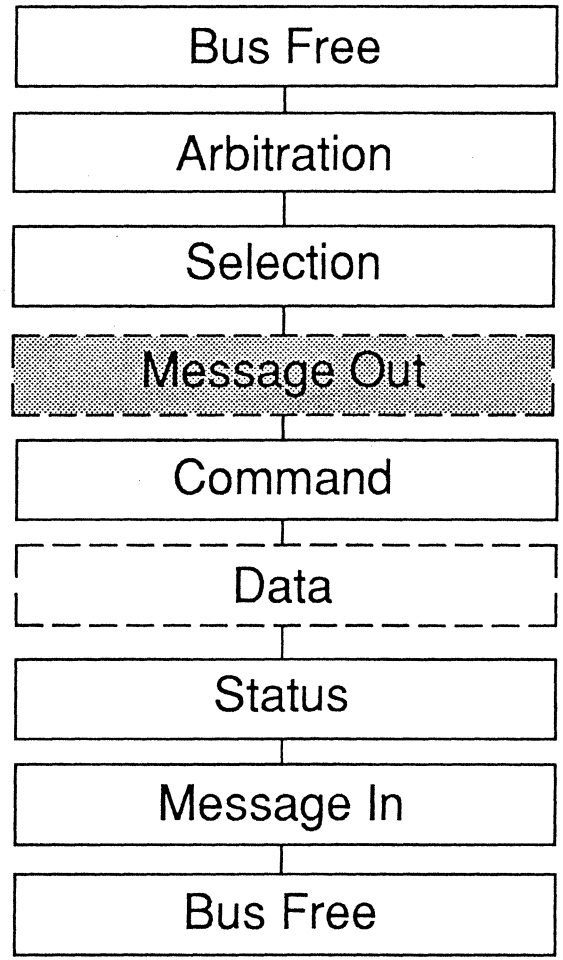
# Attention Condition

- Remember that the Target Determines the Information Transfer Phases, and the Initiator Follows.

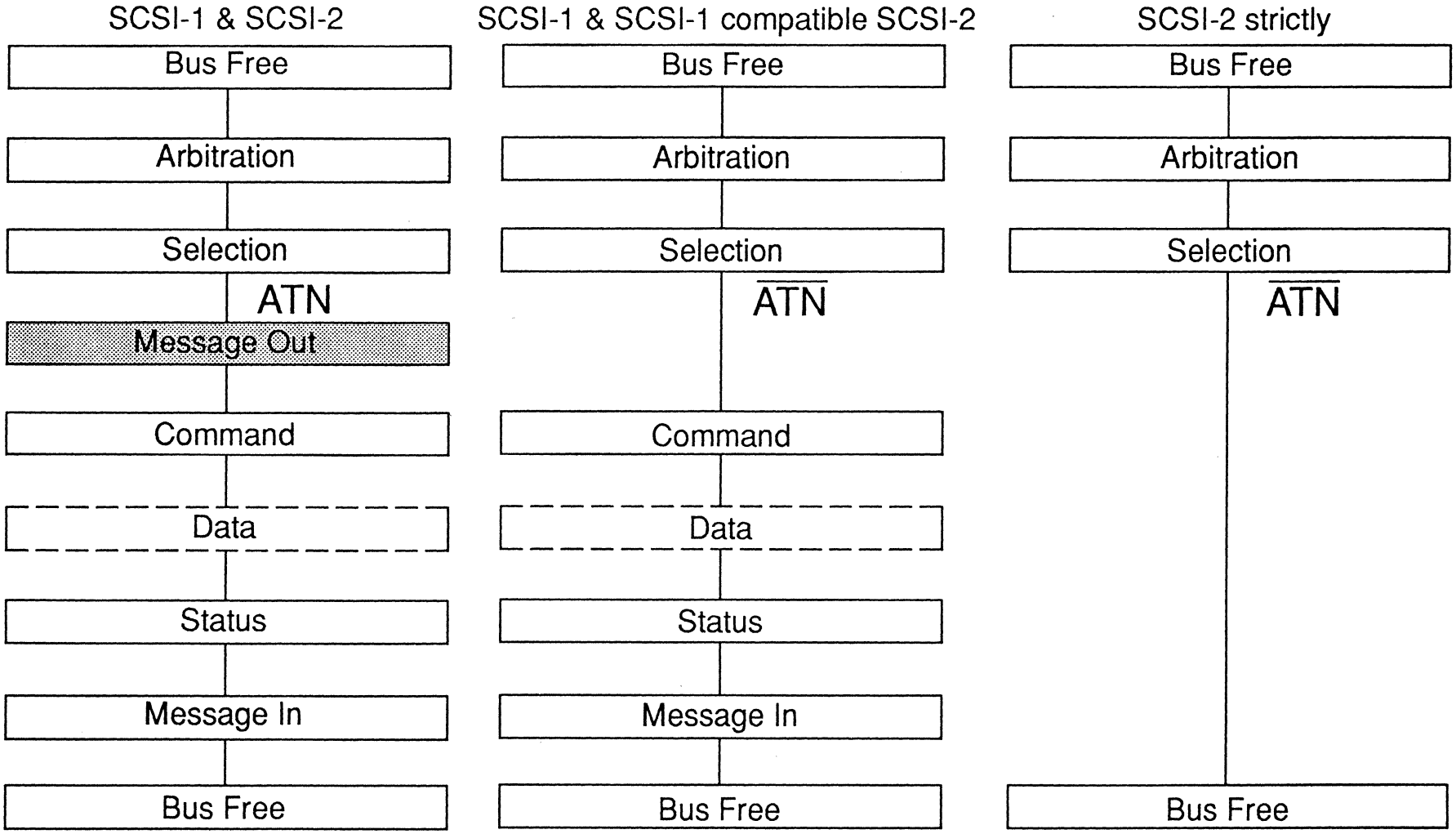
- But what if the Initiator wants to tell the Target something (e.g., Parity Error was Detected)?

- How
  - Initiator Asserts the ATN signal
  - Only during a connection
    (all phases except during Bus Free and Arbitration)
  - Target Responds With MESSAGE OUT Phase
  - Initiator Sends Message Out Byte(s) and Drops ATN on Last Byte

# Attention Condition
## (Continued)
## Remember the Phases

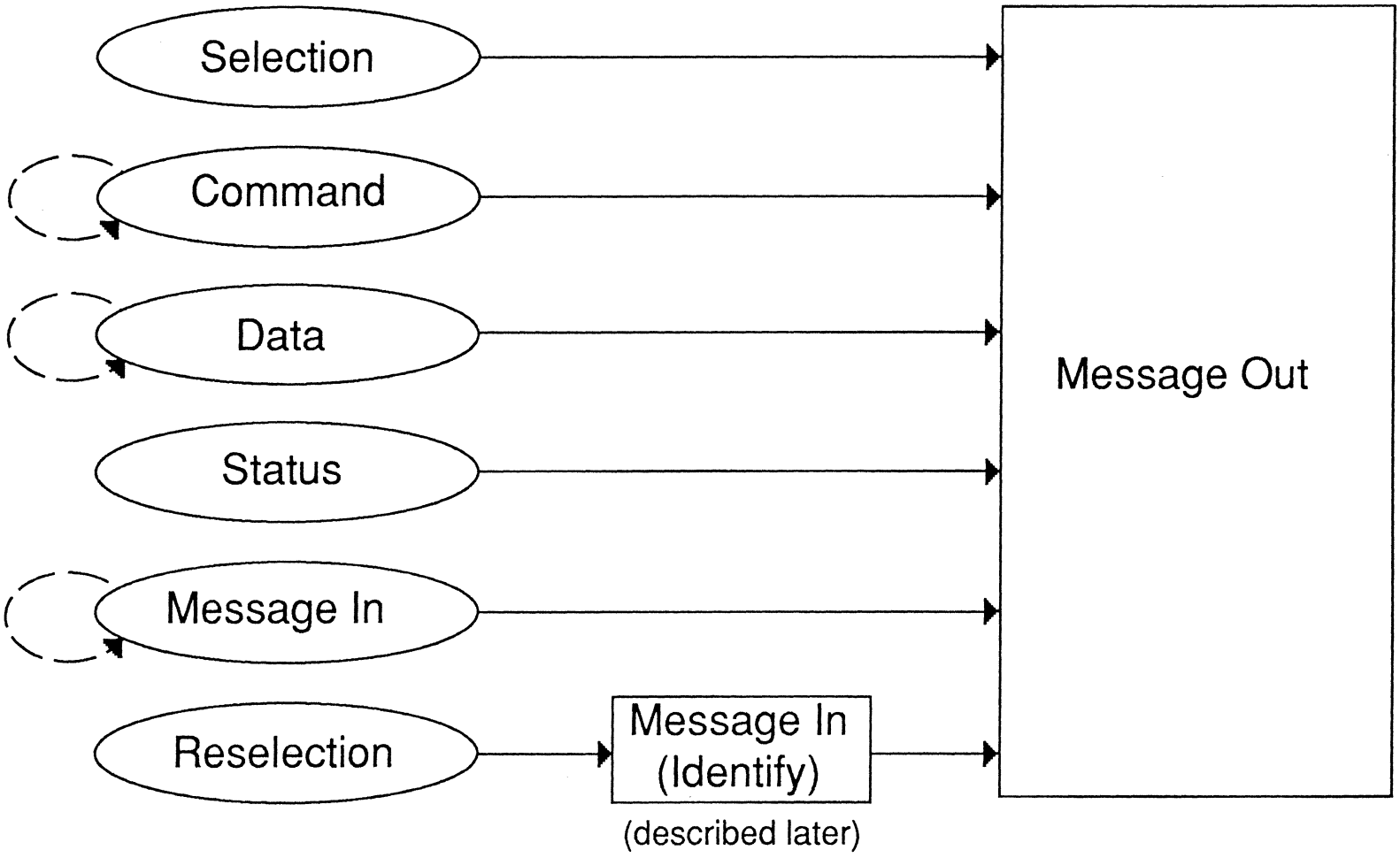


# Attention Condition
## (Continued)
## Handling Attention After Selection Phase




Note: SCSI-2 initiators must assert ATN during selection.

# Attention Condition
## (Continued)
### SCSI-2 Target Attention Response



# Information Transfer Phases

| | | |
|---|---|---|
| C/D | 1 | Control (Not Data) |
| | 0 | Data |
| I/O | 1 | In |
| | 0 | Out |
| Msg | 1 | Message |
| | 0 | Not Message |

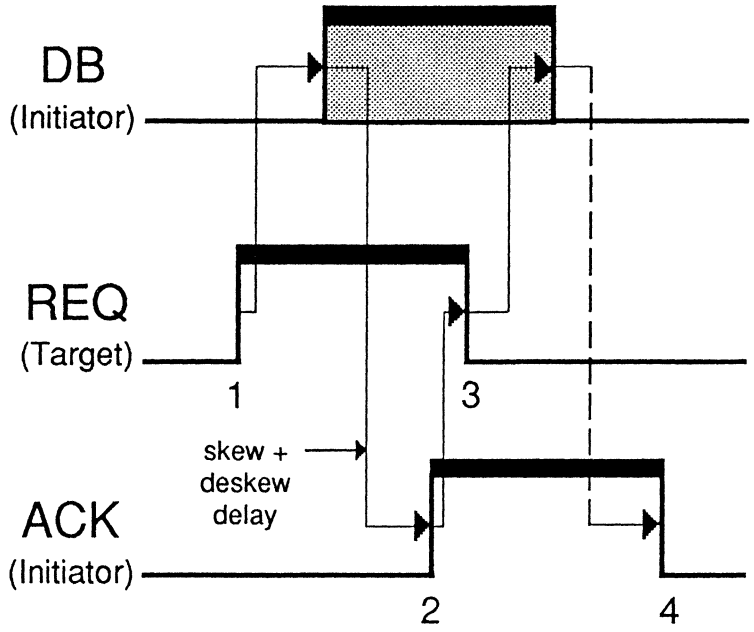
# Information Transfer Phases
(Continued)

| C/D | I/O | MSG | Phase |
|---|---|---|---|
| 1 | 0 | 0 | COMMAND |
| 1 | 1 | 0 | STATUS |
| 0 | 0 | 0 | DATA OUT |
| 0 | 1 | 0 | DATA IN |
| 1 | 0 | 1 | MESSAGE OUT |
| 1 | 1 | 1 | MESSAGE IN |
| 0 | 0 | 1 | Reserved |
| 0 | 1 | 1 | Reserved |

# Asynchronous REQ/ACK Handshake

(Note: there are no timeouts in handshake transitions)

## OUT DIRECTION

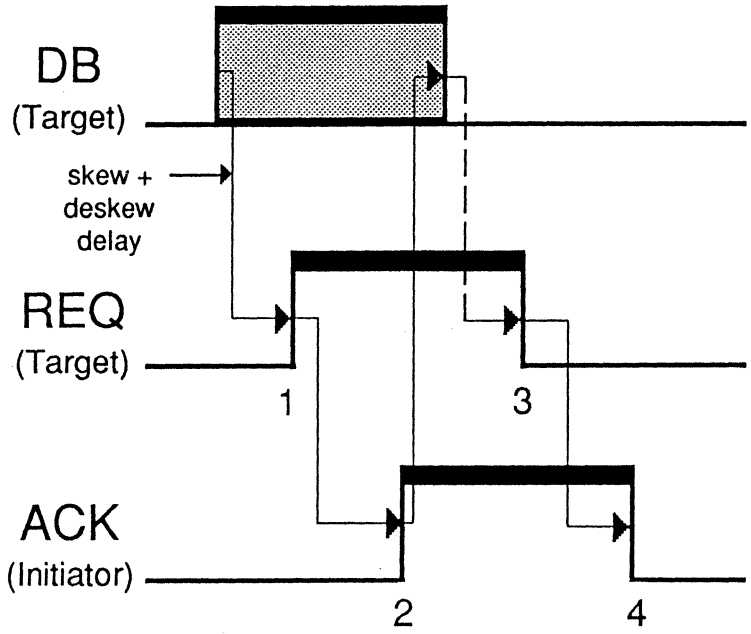



1 - Target says: Give Me
2 - Initiator says: Take It
3 - Target says: Got It
4 - Initiator says: Finished

# Asynchronous REQ/ACK Handshake
## (Continued)

(Note: there are no timeouts in handshake transitions)

## IN DIRECTION




1 - Target says: Take It
2 - Initiator says: Got It
3 - Target says: Finished
4 - Initiator says: Finished

# Bus Signals and Phase Sequences

I1 = asserted by initiator, T1 = asserted by target, - = not driven (deasserted), IT1 = asserted by initiator and target

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| BUS FREE | - | - | - | - | - | - | - | - | - | |
| ARBITRATION | I1 | - | - | - | - | - | - | - | I(iid) | |
| | I1 | I1 | - | - | - | - | - | - | I(iid) | (If Highest ID) |
| SELECTION | I1 | I1 | I1 | - | - | - | - | - | I(iid,tid) | With ATN |
| | - | I1 | I1 | - | - | - | - | - | I(iid,tid) | |
| | T1 | I1 | I1 | - | - | - | - | - | I(iid,tid) | |
| | T1 | - | I1 | - | - | - | - | - | - | |
| SELECTION | I1 | I1 | - | - | - | - | - | - | I(iid,tid) | Without ATN (SCSI-1) |
| | - | I1 | - | - | - | - | - | - | I(iid,tid) | |
| | T1 | I1 | - | - | - | - | - | - | I(iid,tid) | |
| | T1 | - | - | - | - | - | - | - | - | |

# Bus Signals and Phase Sequences
(Continued)

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SELECTION | I1 | I1 | I1 | - | - | - | - | - | I(iid,tid) | |
| TIMEOUT | - | I1 | I1 | - | - | - | - | - | I(iid,tid) | |
| | - | I1 | I1 | - | - | - | - | - | - | After 250ms min |
| | - | - | - | - | - | - | - | - | - | After 200 us max |
| SELECTION | - | - | - | - | - | - | - | - | I(iid,tid) | Non-Arbitrating Systems |
| (history) | - | I1 | - | - | - | - | - | - | I(iid,tid) | (SCSI-1) |
| | T1 | I1 | - | - | - | - | - | - | I(iid,tid) | |
| | T1 | - | - | - | - | - | - | - | - | |
| SELECTION | - | - | - | - | - | - | - | - | I(tid) | SASI Selection (SCSI-1) |
| (history) | - | I1 | - | - | - | - | - | - | I(tid) | |
| | T1 | I1 | - | - | - | - | - | - | I(tid) | |
| | T1 | - | - | - | - | - | - | - | - | |

# Bus Signals and Phase Sequences
(Continued)

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| BUS FREE | - | - | - | - | - | - | - | - | - | |
| ARBITRATION | T1 | - | - | - | - | - | - | - | T(tid) | |
| | T1 | T1 | - | - | - | - | - | - | T(tid) | (If Highest ID) |
| RESELECTION | T1 | T1 | - | - | T1 | - | - | - | T(iid,tid) | (I/O Indicates Reselection) |
| | - | T1 | - | - | T1 | - | - | - | T(iid,tid) | |
| | I1 | T1 | - | - | T1 | - | - | - | T(iid,tid) | |
| | IT1 | T1 | - | - | T1 | - | - | - | T(iid,tid) | |
| | IT1 | - | - | - | - | - | - | - | - | |
| | T1 | - | - | - | - | - | - | - | - | |
| RESELECTION | T1 | T1 | - | - | T1 | - | - | - | T(iid,tid) | |
| TIMEOUT | - | T1 | - | - | T1 | - | - | - | T(iid,tid) | |
| | - | T1 | - | - | T1 | - | - | - | - | After 250 ms min |
| | - | - | - | - | - | - | - | - | - | After 200 us max |

# Bus Signals and Phase Sequences
## (Continued)
## Selection and Reselection Timeout

- Wait for Response with ID's on Data Bus
  Min: Selection Time-out Delay (250ms)

- Release Data Bus (ID's)
  Now the phase is still Selection (or Reselection)
  Wait Two Deskew Delays (45 ns each)
  Wait Selection Abort Time (200 us)
  (needed to avoid connecting/reconnecting to the wrong device)
  If No Reply, Drop SEL (I/O, ATN)
  Now the phase is Bus Free

- Optionally Reset Bus

# Bus Signals and Phase Sequences
(Continued)

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| MSG OUT | T1 | - | I1 | T1 | T0 | T1 | - | - | - | |
| | T1 | - | I1 | T1 | T0 | T1 | T1 | - | - | |
| | T1 | - | I1 | T1 | T0 | T1 | T1 | - | I(msg) | (Message Byte) |
| | T1 | - | I1 | T1 | T0 | T1 | T1 | I1 | I(msg) | |
| | T1 | - | I1 | T1 | T0 | T1 | - | I1 | I(msg) | |
| | T1 | - | I1 | T1 | T0 | T1 | - | I1 | - | |
| | T1 | - | - | T1 | T0 | T1 | - | I1 | - | Drop ATN before ACK |
| | T1 | - | - | T1 | T0 | T1 | - | - | - | |
| COMMAND | T1 | - | - | T1 | T0 | T0 | - | - | - | |
| | T1 | - | - | T1 | T0 | T0 | T1 | - | - | |
| | T1 | - | - | T1 | T0 | T0 | T1 | - | I(cmd) | (CDB Byte) |
| | T1 | - | - | T1 | T0 | T0 | T1 | I1 | I(cmd) | |
| | T1 | - | - | T1 | T0 | T0 | - | I1 | I(cmd) | |
| | T1 | - | - | T1 | T0 | T0 | - | I1 | - | |
| | T1 | - | - | T1 | T0 | T0 | - | - | - | |

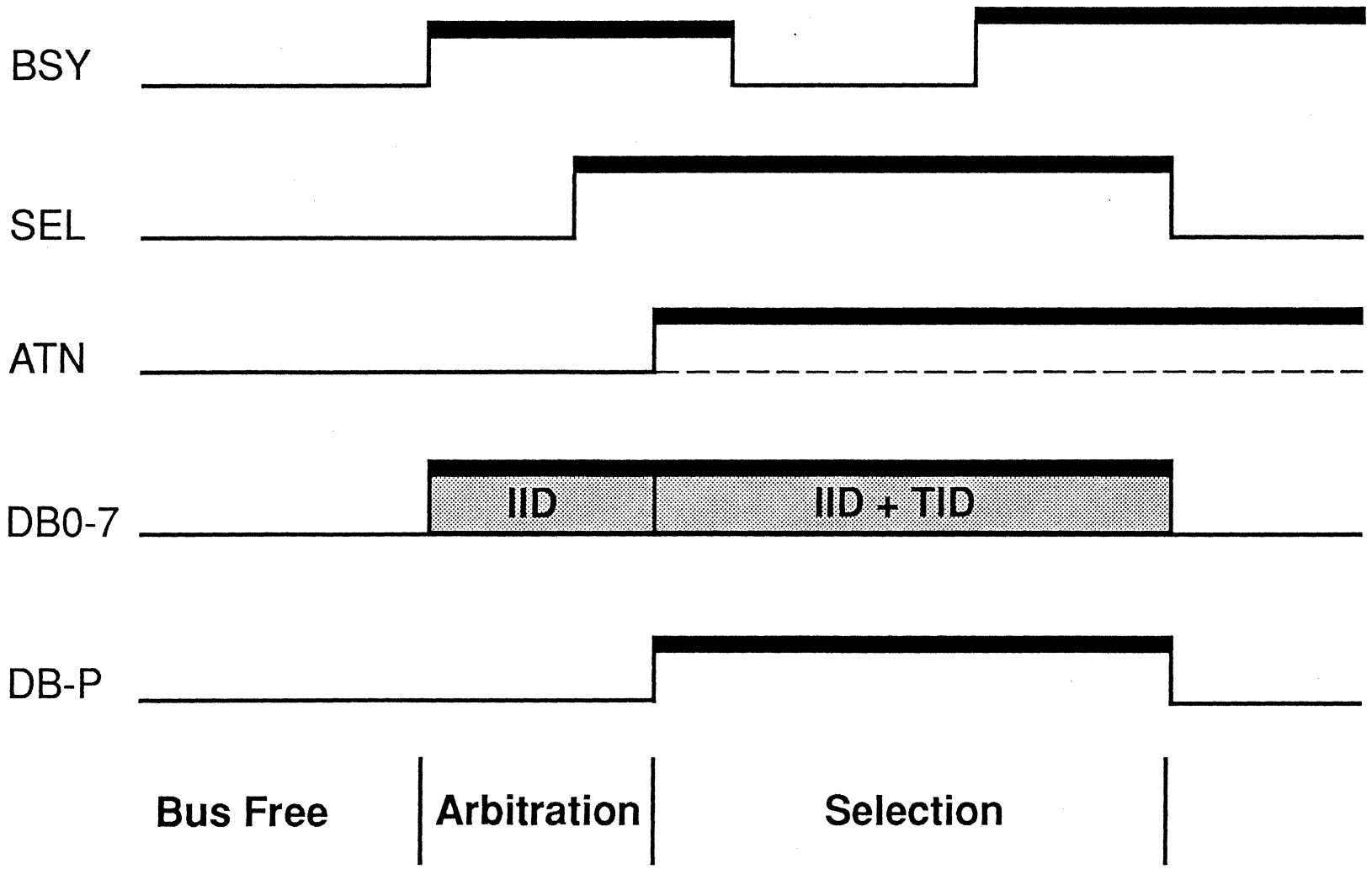
# Bus Signals and Phase Sequences
(Continued)

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| DATA OUT | T1 | - | - | T0 | T0 | T0 | - | - | - | |
| | T1 | - | - | T0 | T0 | T0 | T1 | - | - | |
| | T1 | - | - | T0 | T0 | T0 | T1 | - | I(data) | (Data Byte) |
| | T1 | - | - | T0 | T0 | T0 | T1 | I1 | I(data) | |
| | T1 | - | - | T0 | T0 | T0 | - | I1 | I(data) | |
| | T1 | - | - | T0 | T0 | T0 | - | I1 | - | |
| | T1 | - | - | T0 | T0 | T0 | - | - | - | |
| DATA IN | T1 | - | - | T0 | T1 | T0 | - | - | - | |
| | T1 | - | - | T0 | T1 | T0 | - | - | T(data) | (Data Byte) |
| | T1 | - | - | T0 | T1 | T0 | T1 | - | T(data) | |
| | T1 | - | - | T0 | T1 | T0 | T1 | I1 | T(data) | |
| | T1 | - | - | T0 | T1 | T0 | T1 | I1 | - | |
| | T1 | - | - | T0 | T1 | T0 | - | I1 | - | |
| | T1 | - | - | T0 | T1 | T0 | - | - | - | |

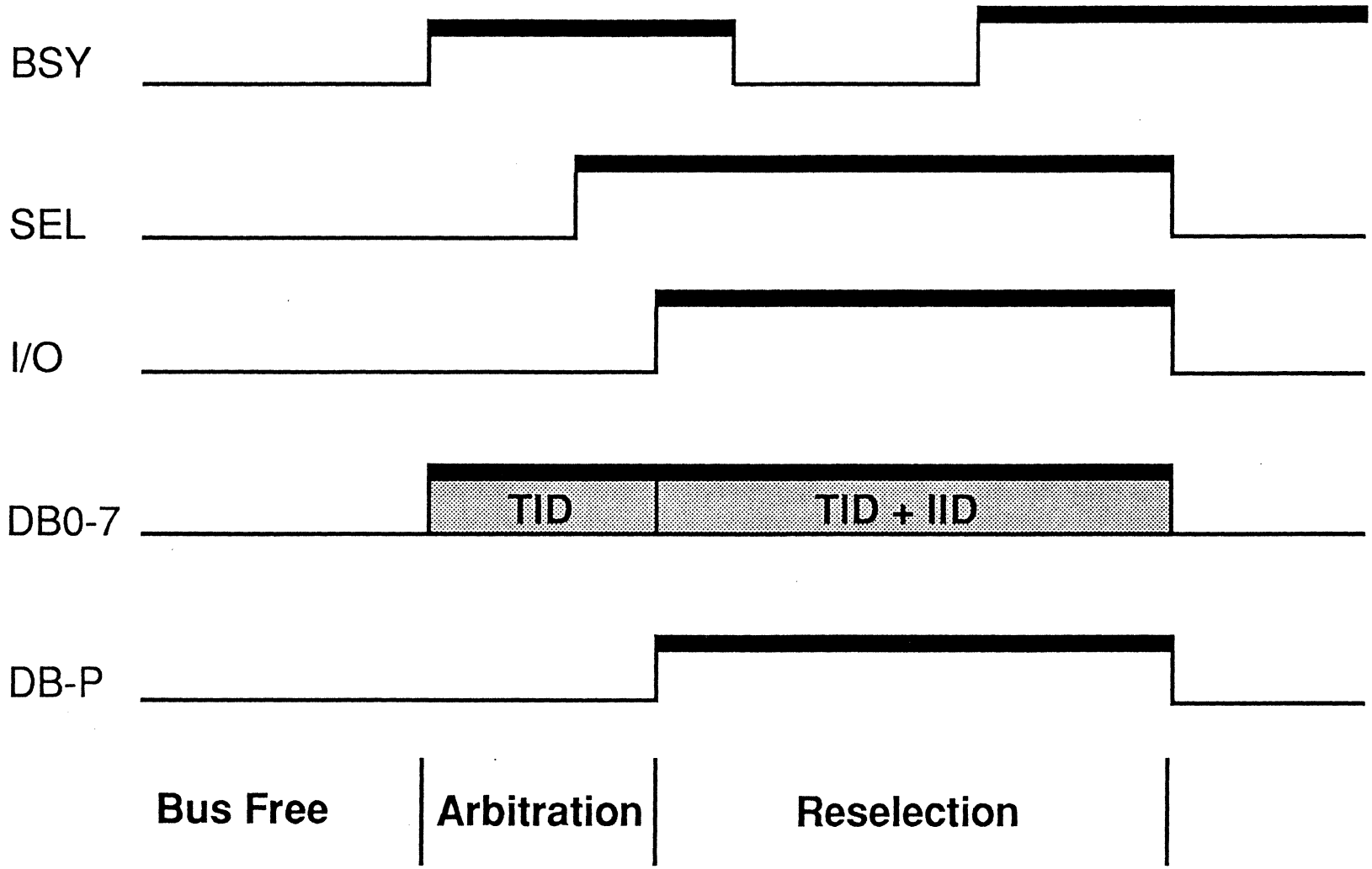
# Bus Signals and Phase Sequences
(Continued)

| Phase | BSY | SEL | ATN | C/D | I/O | MSG | REQ | ACK | DB(0-7) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| STATUS | T1 | - | - | T1 | T1 | T0 | - | - | - | |
| | T1 | - | - | T1 | T1 | T0 | - | - | T(stat) | (Status Byte) |
| | T1 | - | - | T1 | T1 | T0 | T1 | - | T(stat) | |
| | T1 | - | - | T1 | T1 | T0 | T1 | I1 | T(stat) | |
| | T1 | - | - | T1 | T1 | T0 | T1 | I1 | - | |
| | T1 | - | - | T1 | T1 | T0 | - | I1 | - | |
| | T1 | - | - | T1 | T1 | T0 | - | - | - | |
| MSG IN | T1 | - | - | T1 | T1 | T1 | - | - | - | |
| | T1 | - | - | T1 | T1 | T1 | - | - | T(msg) | (Message Byte) |
| | T1 | - | - | T1 | T1 | T1 | T1 | - | T(msg) | |
| | T1 | - | - | T1 | T1 | T1 | T1 | I1 | T(msg) | |
| | T1 | - | - | T1 | T1 | T1 | T1 | I1 | - | |
| | T1 | - | - | T1 | T1 | T1 | - | I1 | - | |
| | T1 | - | - | T1 | T1 | T1 | - | - | - | |
| BUS FREE | - | - | - | - | - | - | - | - | - | |

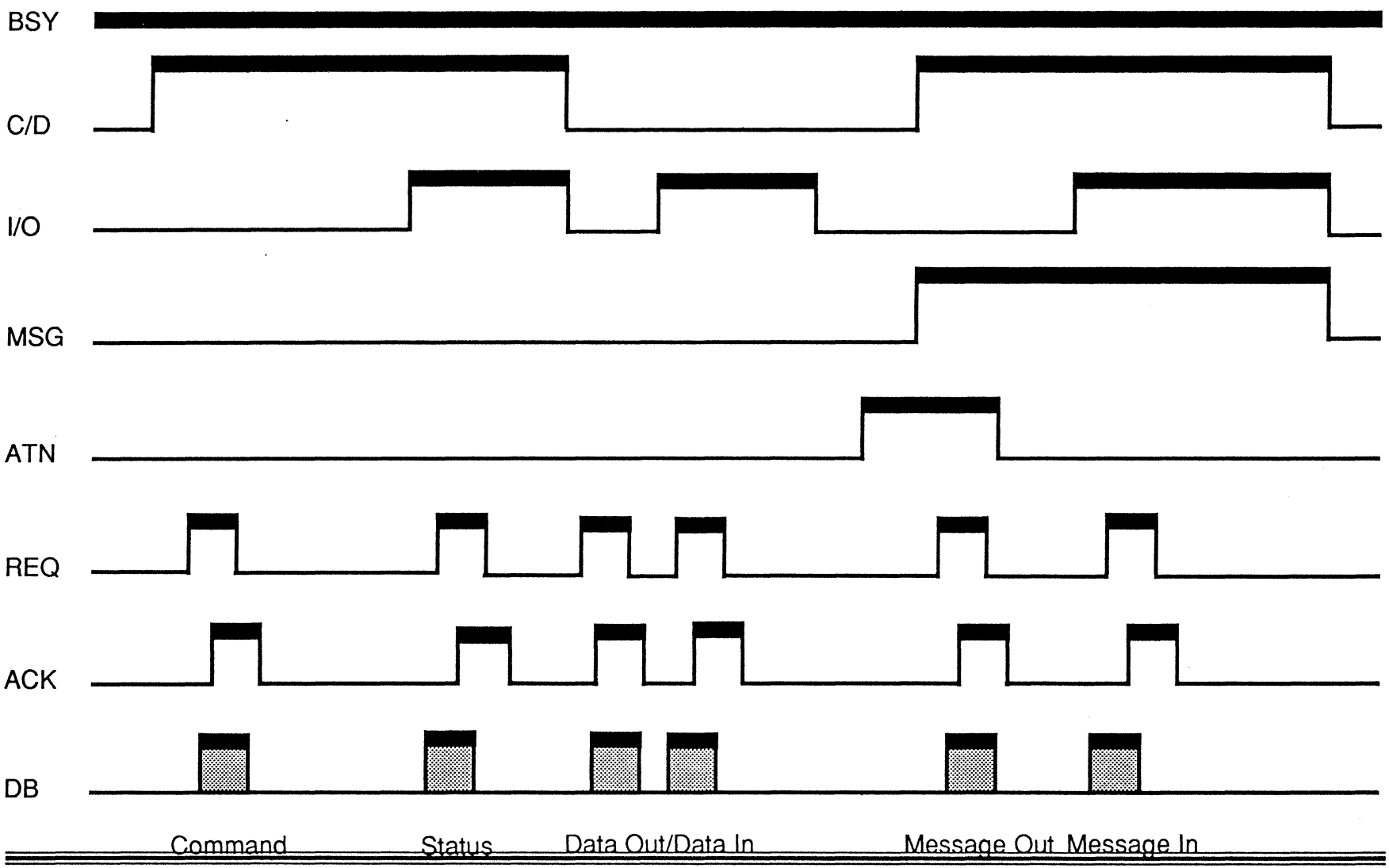
# Signal Transitions
## Arbitration/Selection



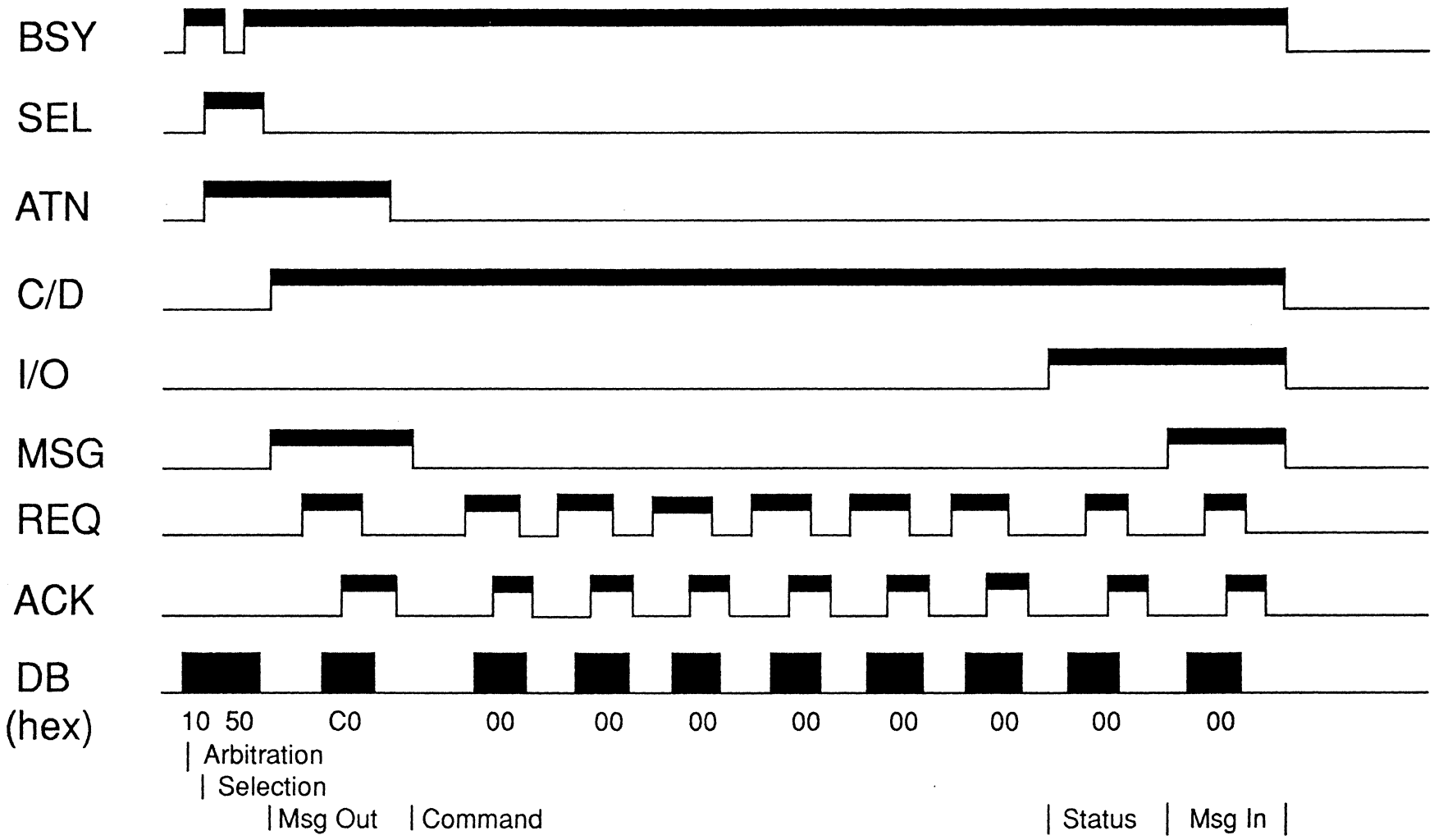
# Signal Transitions
## (Continued)
## Arbitration/Reselection



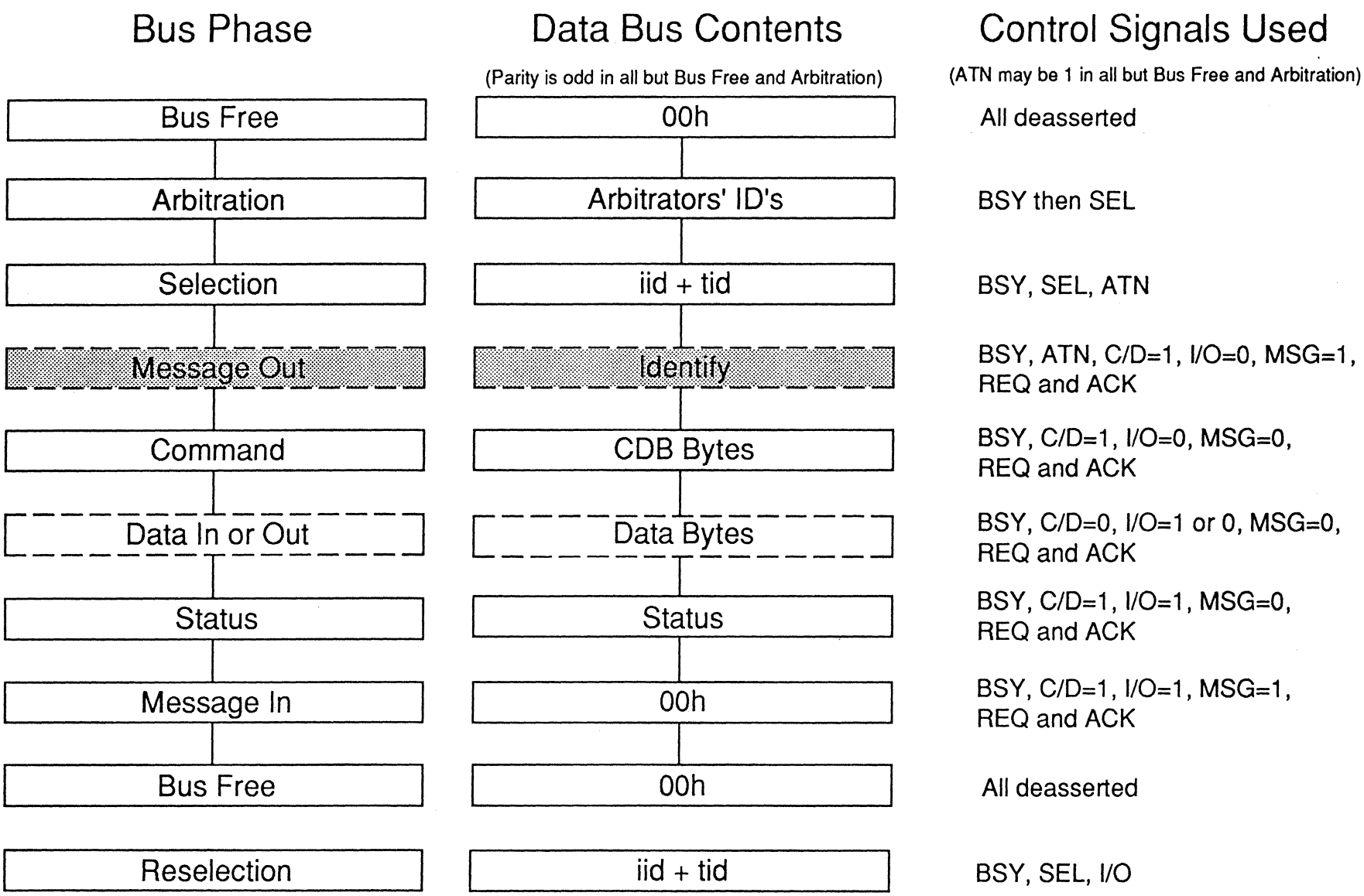
# Signal Transitions
## (Continued)
## Information Transfer Phases



# Signal Transitions
## (Continued)
## Test Unit Ready Command

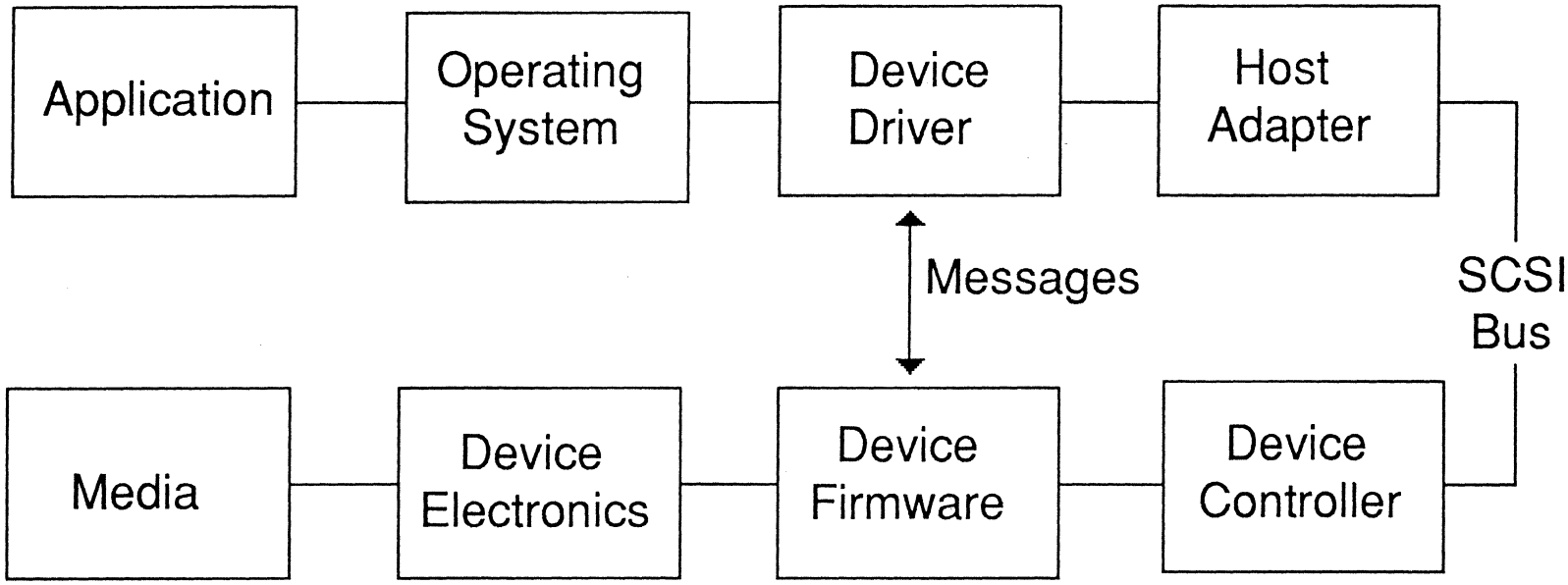


# Signal and Phase Summary



# ADVANCED FEATURES

# Message System
## Where Messages Fit



# Message System
## (Continued)
## Types of Messages

| First Byte of Message | Message Format |
|---|---|
| 00h | One-Byte (Command Complete) |
| 01h | Extended (Multiple-Byte) |
| 02h-1Fh | One-Byte |
| 20h-2Fh | Two-Byte (SCSI-1: Reserved) |
| 30h-7Fh | Reserved |
| 80h-FFh | One-Byte (Identify) |

# Message System
## (Continued)
## Extended Message Format

| Byte | Value | Description |
|---|---|---|
| 0 | 01h | Extended message |
| 1 | | Extended message length |
| 2 | | Extended message code |
| : | | Extended message arguments |

number of bytes to follow

see next page

**Example**

| | | |
|---|---|---|
| 0 | 01h | Extended |
| 1 | 03h | Length |
| 2 | 01h | Synchronous |
| 3 | xxh | Period/4 |
| 4 | yyh | Offset |

# Message System
## (Continued)

| Message | Code | Dir | SCSI-1 | CCS | SCSI-2 I | SCSI-2 T | Notes |
|---|---|---|---|---|---|---|---|
| Command Complete | 00h | In | M | M | M | M | Command Done - Bus Free |
| Extended Message | 01h | I/O | O | O | O | O | Multiple Bytes |
| Modify Data Pointer | 00h | In | O | O | O | O | Pointer Management |
| Synchronous Transfer | 01h | I/O | O | O | O | O | Synchronous Negotiation |
| Extended Identify | 02h | I/O | O | O | - | - | Sub-LUN's |
| Wide Bus Transfer | 03h | I/O | - | - | O | O | Wide Bus Negotiation |
| Save Data Pointer | 02h | In | O | O | O | O | Pointer Management |
| Restore Pointers | 03h | In | O | M | O | O | Pointer Management |
| Disconnect | 04h | In | O | O | O | O | Bus Free, Reconnect Later |
| | | Out | - | - | O | O | Request a Disconnect |
| Initiator Detected Error | 05h | Out | O | O | M | M | Parity Error Detected |

# Message System
(Continued)

| Message | Code | Dir | SCSI-1 | CCS | SCSI-2 I | SCSI-2 T | Notes |
|---|---|---|---|---|---|---|---|
| Abort | 06h | Out | O | M | O | M | Clear Command, Bus Free |
| Message Reject | 07h | I/O | O | M | M | M | Inappropriate Message Received |
| No Operation | 08h | Out | O | M | M | M | No Msg Out Available |
| Message Parity Error | 09h | Out | O | O | M | M | Parity Err During Msg In |
| Linked Command Comp. | 0Ah | In | O | O | O | O | Linked Commands |
| Linked C.C. with Flag | 0Bh | In | O | O | O | O | Linked Commands |
| Bus Device Reset | 0Ch | Out | O | M | O | M | Reset Selected Device |
| Abort Tag | 0Dh | Out | - | - | O | O | Abort Queued Command |

# Message System
(Continued)

| Message | Code | Dir | SCSI-1 | CCS | SCSI-2 I | SCSI-2 T | Notes |
|---|---|---|---|---|---|---|---|
| Clear Queue | 0Eh | Out | - | - | O | O | Clear All Queued Commands |
| Initiate Recovery | 0Fh | I/O | - | - | O | O | Extended Contingent Allegiance (ECA) |
| Release Recovery | 10h | Out | - | - | O | O | Clear ECA |
| Terminate I/O Process | 11h | Out | - | - | O | O | Terminate with Status |
| Simple Queue Tag | 20h | I/O | - | - | O | O | Tagged Queueing |
| Head of Queue Tag | 21h | Out | - | - | O | O | Tagged Queueing |
| Ordered Queue Tag | 22h | Out | - | - | O | O | Tagged Queueing |
| Ignore Wide Bus Residue | 23h | In | - | - | O | O | Wide Bus Alignment |
| Identify | 80h-FFh | Out | O | O-M | M | M | LUN, Disconnect |
| | 80h-FFh | In | O | ? | M | O | LUN, Pointers |

# Identify Message

| Bits | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|

7 1 indicates Identify Message

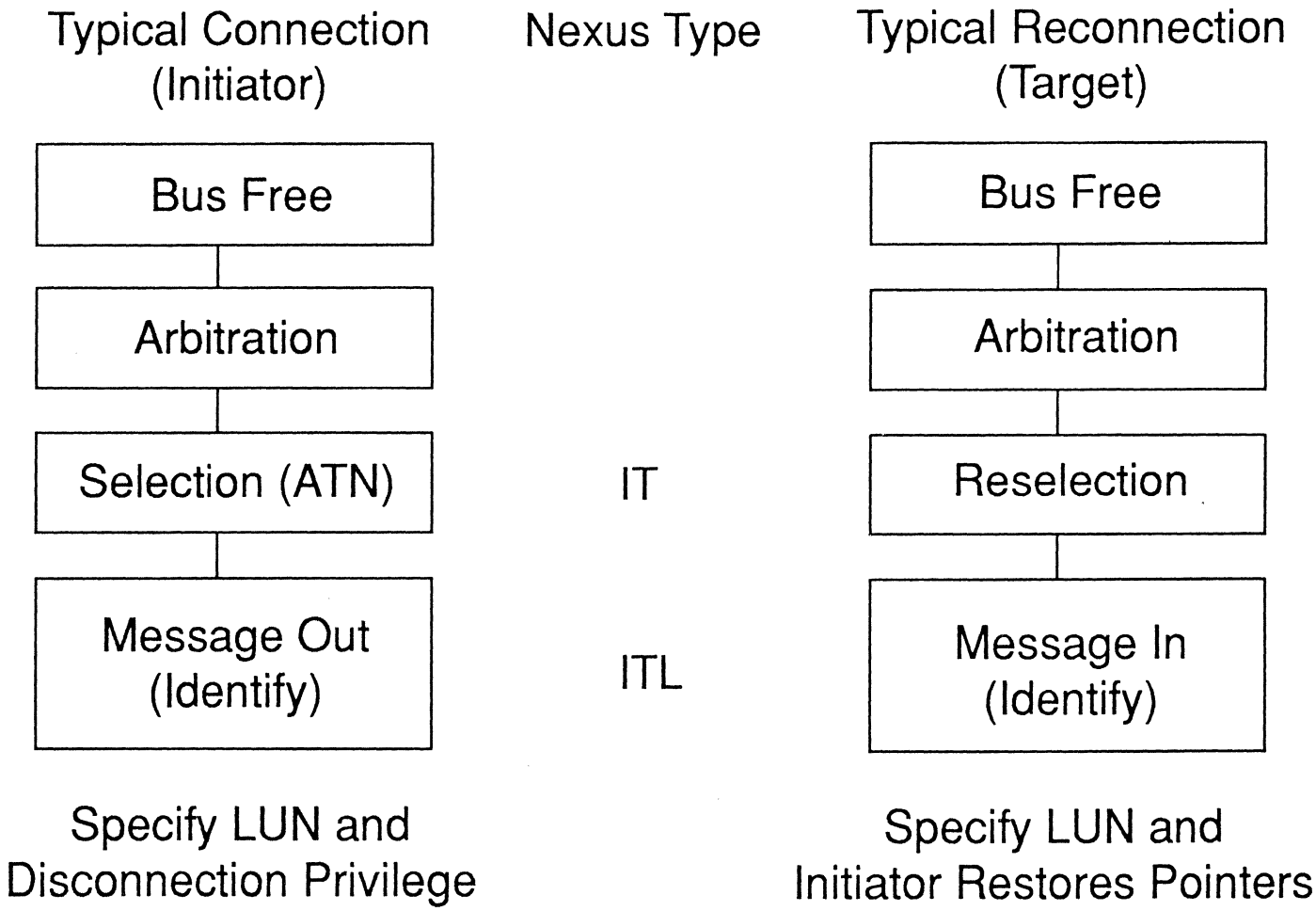
6 DISCONNECT privilege
- 0 no disconnect
- 1 disconnect allowed (invalid with Message In)

5 LUNTAR (SCSI-2), normally 0 (not supported)
- 0 Bits 0-2 specify LUN
  (Command is for Logical Unit)
- 1 Bits 0-2 specify Target Routine
  (Command is for Target Controller)
  For use with Inquiry and Request Sense Only

3-4 RESERVED (SCSI-3: LUN extension)

0-2 LUN or
Target Routine Number (SCSI-2), normally 0 (not supported)

# Identify Message
## (Continued)
## Where Identify Fits



# Identify Message
(Continued)
Examples

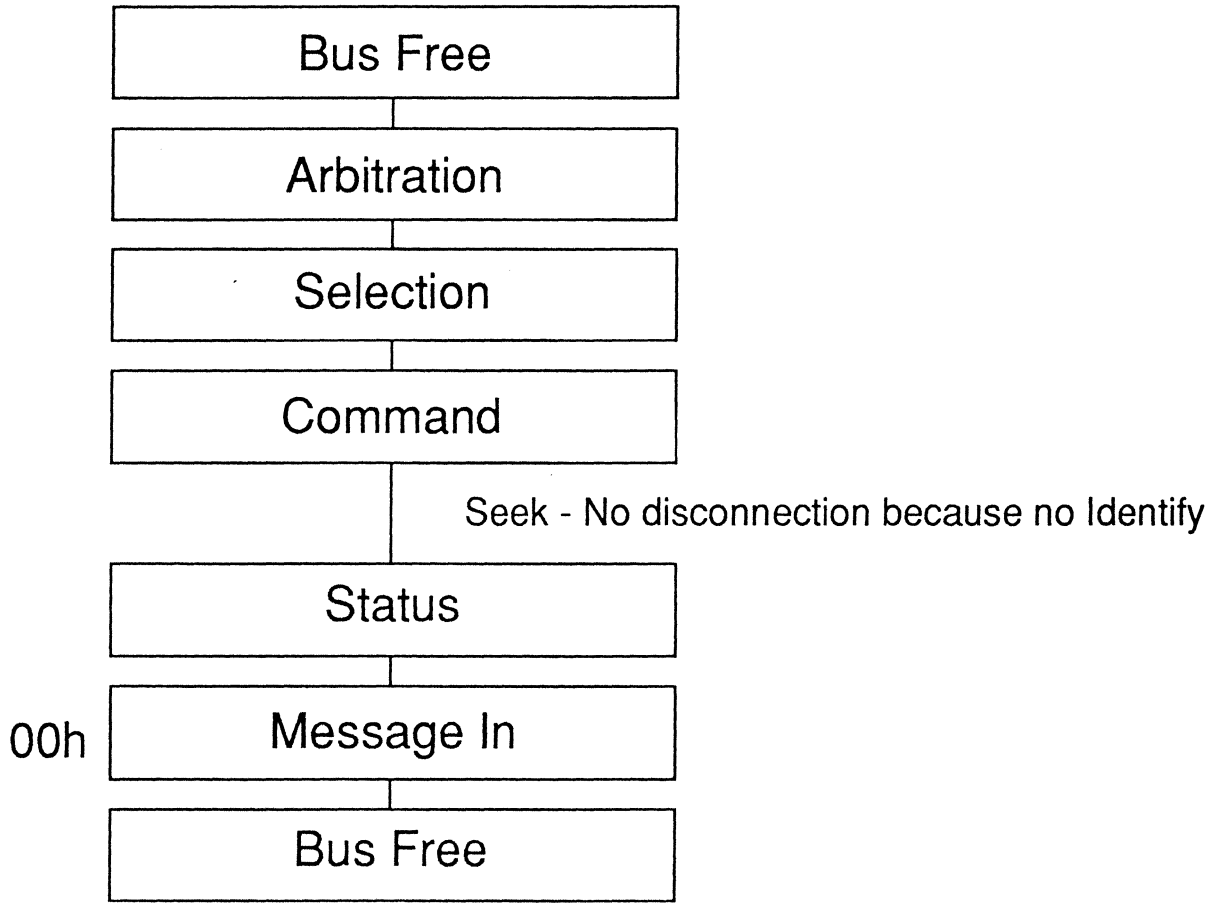
| Message Code | Message Out Meaning | Message In Meaning |
|---|---|---|
| 80h | LUN = 0, No Disconnect | LUN = 0, Restore Pointers |
| 81h | LUN = 1, No Disconnect | LUN = 1, Restore Pointers |
| 83h | LUN = 3, No Disconnect | LUN = 3, Restore Pointers |
| 85h | LUN = 5, No Disconnect | LUN = 5, Restore Pointers |
| 87h | LUN = 7, No Disconnect | LUN = 7, Restore Pointers |
| C0h | LUN = 0, Disconnect | Invalid |
| C6h | LUN = 6, Disconnect | Invalid |
| C7h | LUN = 7, Disconnect | Invalid |

# Identify Message
## (Continued)
## Rules to Remember

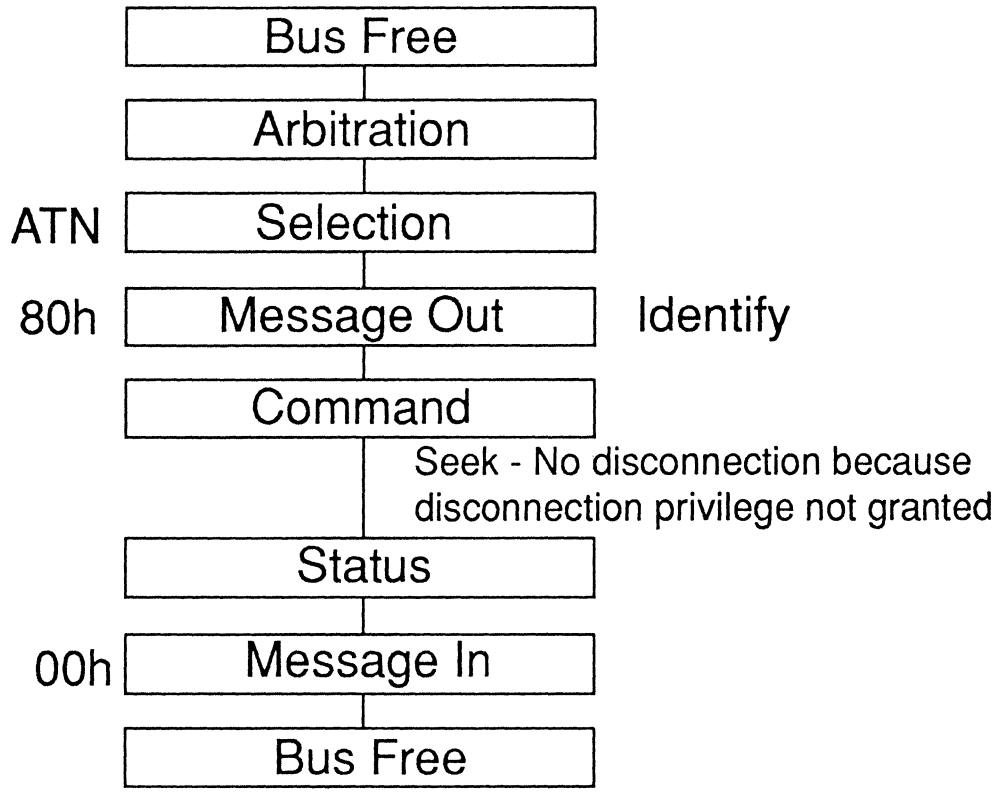
- The first Message Out sent by the initiator after SELECTION shall be:
  - IDENTIFY, ABORT, or BUS DEVICE RESET.
  - Otherwise, the target will go to Bus Free.
- The first Message In sent by the target after RESELECTION is
  - IDENTIFY even if ATTENTION is asserted.
- IDENTIFY Message In implies Restore Pointers operation by initiator.
- Disconnection Privilege is for current I/O process only and not subsequent ones (default is no disconnection if no Identify is sent).

# Identify Message
## (Continued)
## Seek Command Example

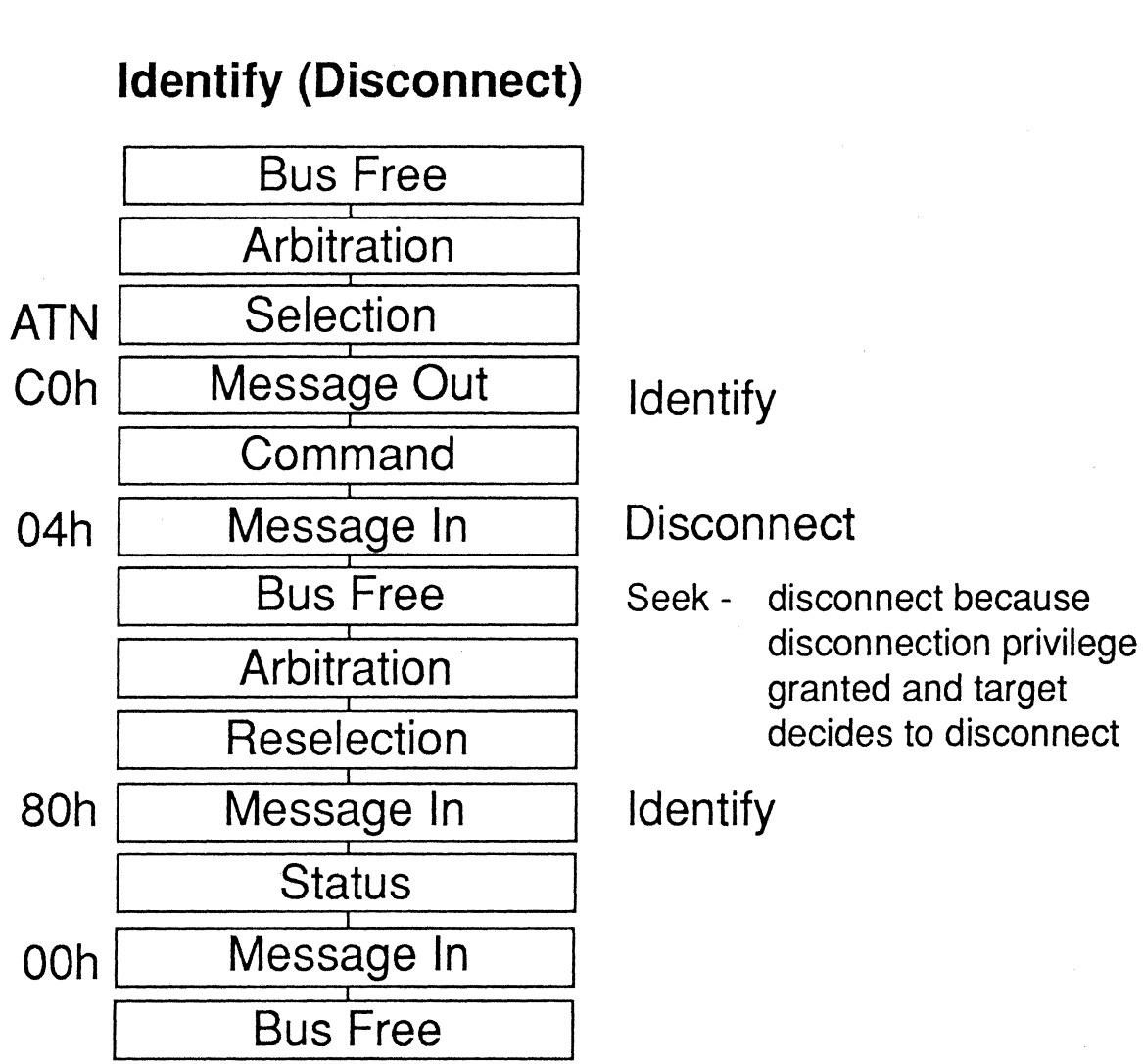
**No Identify (SCSI-1)**



# Identify Message
(Continued)
Seek Command Example



# Identify Message
(Continued)
Seek Command Example



# Expected Bus Free

Expected Bus Free after:

- Power Up
- Reset
- Message In of:
  - Command Complete
  - Disconnect
- Message Out of:
  - Bus Device Reset
  - Clear Queue (SCSI-2)
  - Abort
  - Abort Tag (SCSI-2)
  - Release Recovery (SCSI-2)

# Unexpected Disconnect

- Unexpected Bus Free after Error Conditions that are not handled another way.

- Examples:

    - First Message Out is not Identify, Abort, or Bus Device Reset.
    - Initiator Detected Error Message (described later).

# Linked Commands

- Last CDB Byte (Control Byte):

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| | Vendor Unique | | Reserved | | | | Flag | Link |

- Flag bit is normally not supported (left over from early SCSI days).

# Linked Commands
(Continued)

- Bus Free

- First Linked Command
  - Arbitrate
  - Select - ATN
  - Message Out (IDENTIFY)
  - Command (LINK CDB Bit Set)
  - Data
  - Status (Intermediate)
  - Message In (Linked Command Complete)

# Linked Commands
(Continued)

- Next Linked command(s)
  - Command (LINK CDB Bit Set)
  - Data
  - Status (Intermediate)
  - Message In (Linked Command Complete)

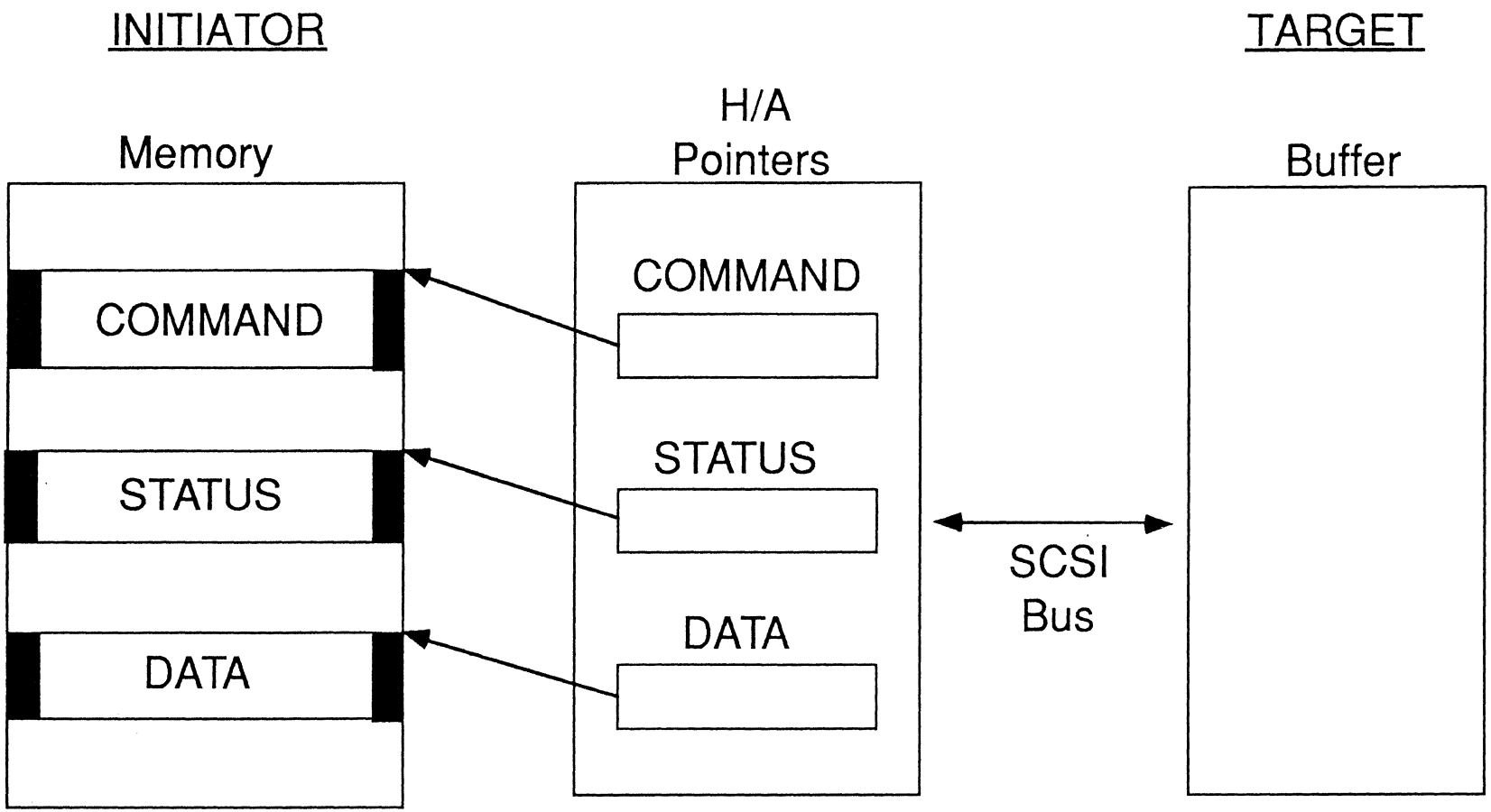
- Last Command
  - Command (LINK CDB Bit Clear)
  - Data
  - Status (Good)
  - Message In (Command Complete)

- Bus Free

# Linked Commands
(Continued)

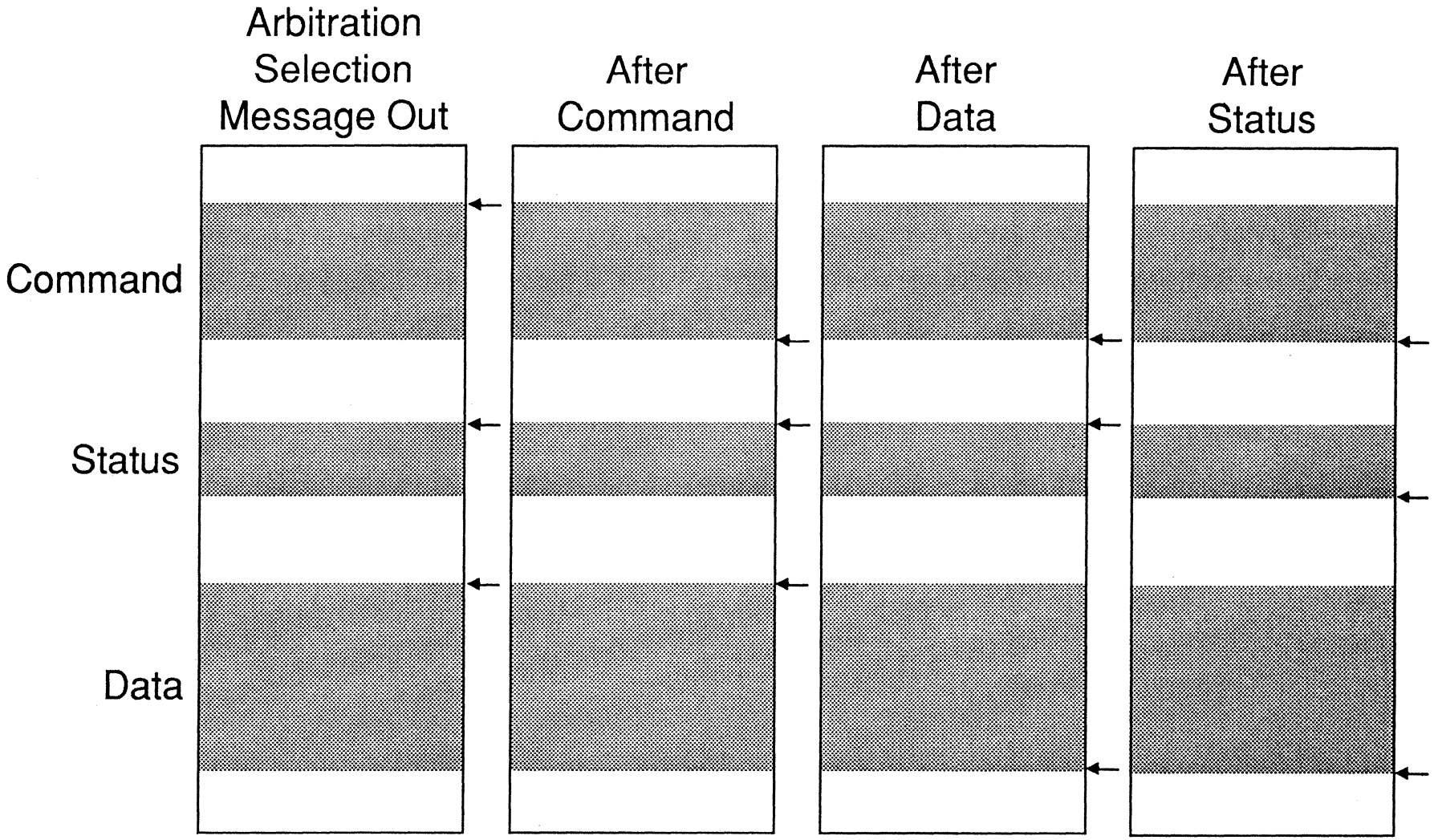
- Optional Feature
- For Sending Multiple Commands Without Freeing the Bus
- No Bus Free, Arbitration, and Selection Between Linked Commands
- Use Link Bit in Last CDB Byte to Link Commands
- Intermediate (10h) Status and Linked Command Complete (0Ah) Message Between Linked Commands
- Other Status Terminates I/O Process

# Host Adapter Pointers

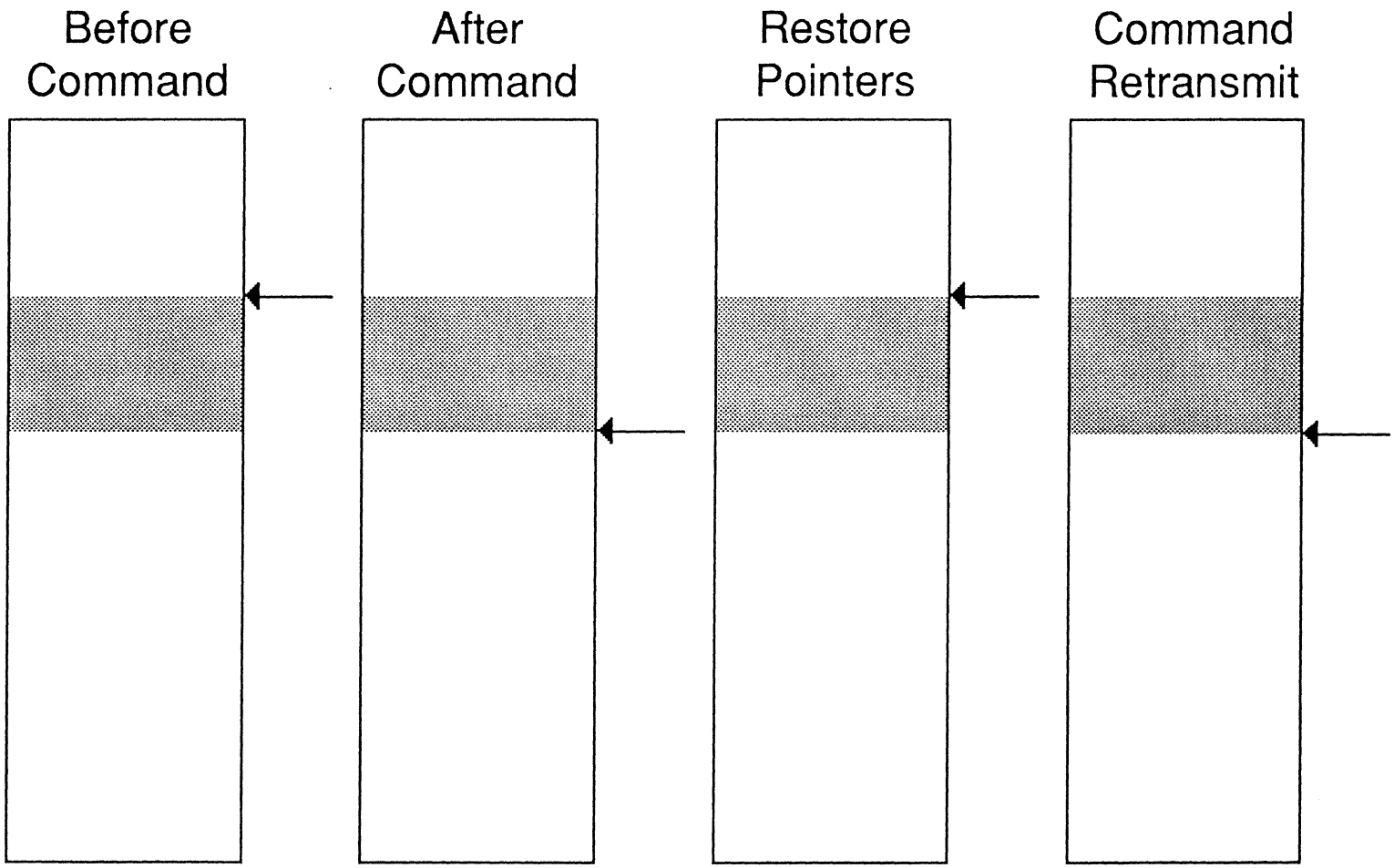



- Pointers are allocated by the host device driver and handed over to the host adapter.
- Pointers move as bytes are transferred during the I/O process.

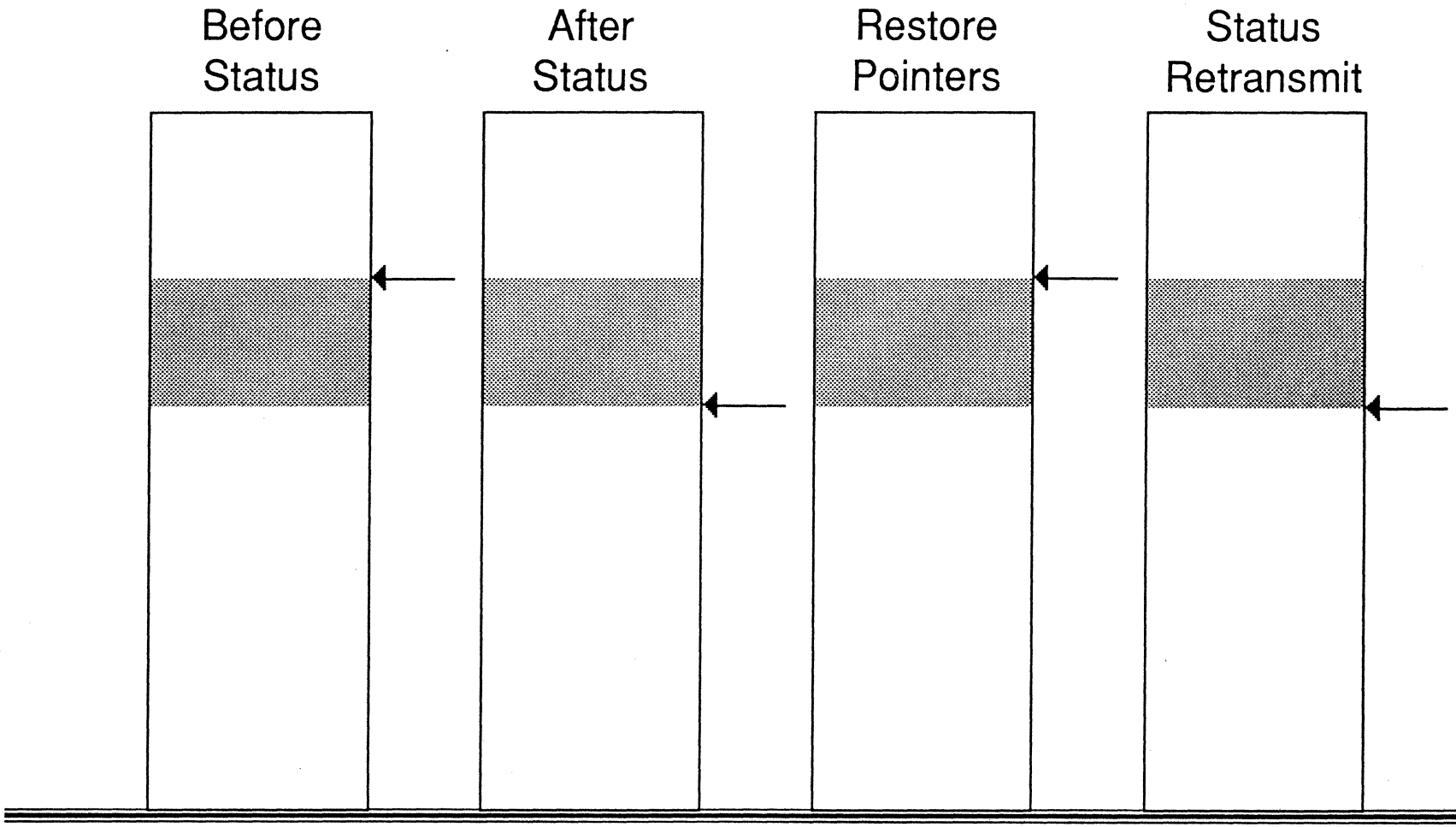
# Host Adapter Pointers
## (Continued)
## Current (Active) Pointers



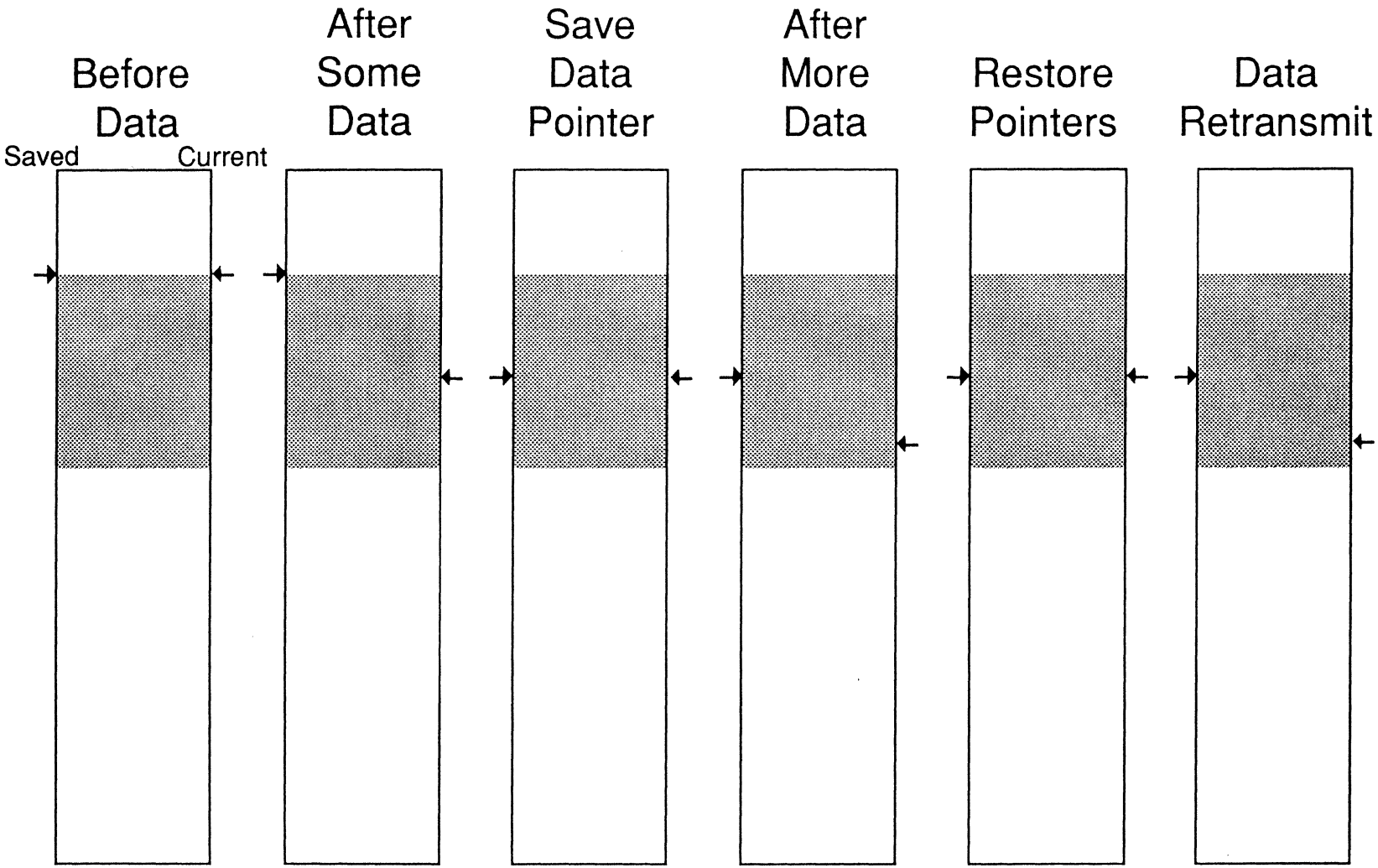
# Host Adapter Pointers
## (Continued)
## Command Pointer



# Host Adapter Pointers
## (Continued)
## Status Pointer



# Host Adapter Pointers
## (Continued)
## Data Pointers



# Host Adapter Pointers
## (Continued)
## Summary

- Pointer Set:
  - Command, Status, and Data

- Save Data Pointer:
  - Saved Data Pointer = Current Data Pointer

- Restore Pointers:
  - Current Data Pointer = Saved Data Pointer
  - Current Command Pointer = Starting Command Pointer
  - Current Status Pointer = Starting Status Pointer

- Sample Pointers in 'C':

```
unsigned char *current_data_ptr;
unsigned char *saved_data_ptr;
unsigned char *command_ptr;
unsigned char *status_ptr;
```

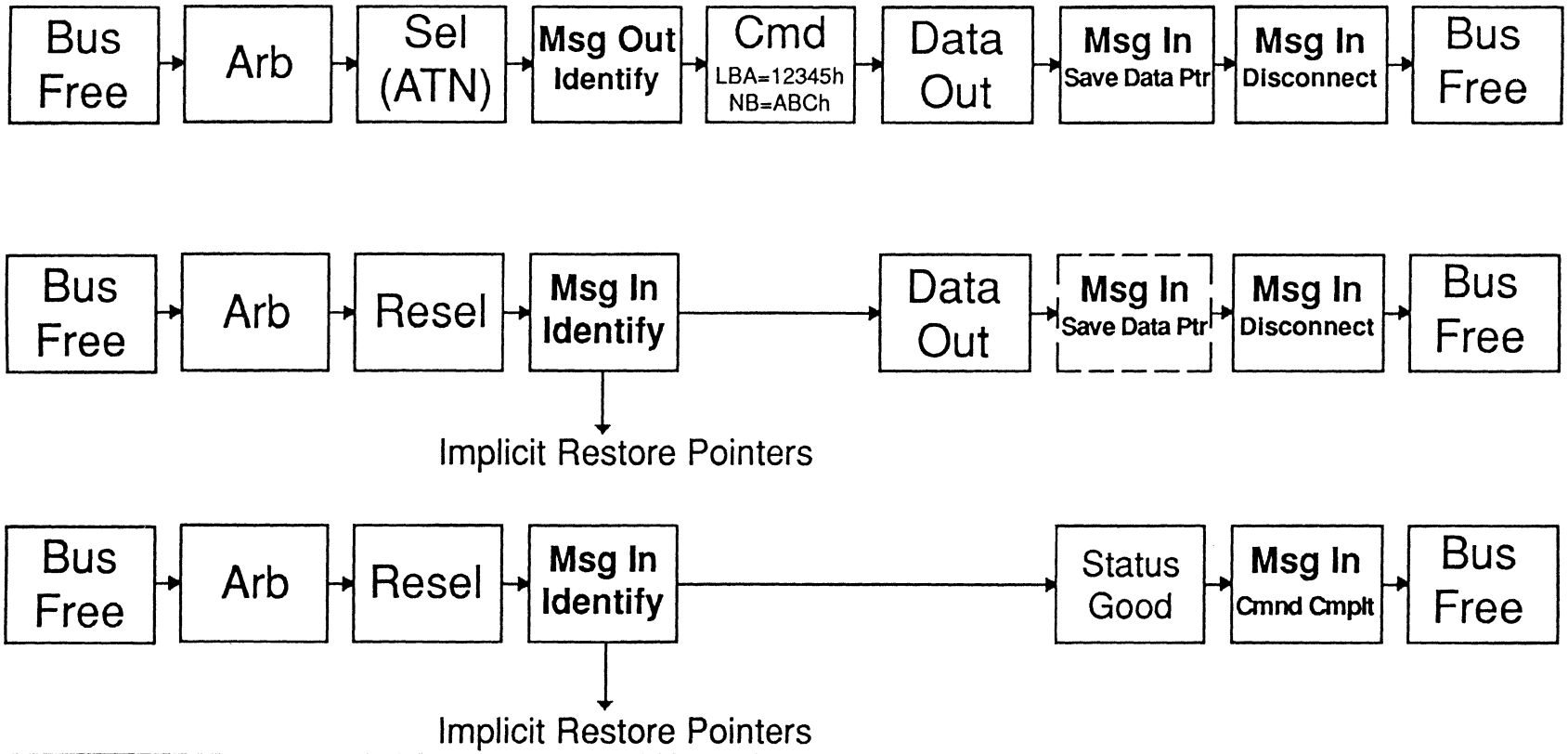
- One set of Pointers per I/O Process.

# Host Adapter Pointers
## (Continued)

| | | |
|---|---|---|
| Bus Free | | |
| | Arbitration | |
| | Selection - ATN | |
| | Message Out - Identify | LUN + Disconnect Allowed |
| | Command | |
| | Data | |
| | Message In - Save Data Ptrs | |
| | - Disconnect | |
| Bus Free | | |
| | Arbitration | |
| | Reselection | |
| | Message In - Identify | LUN + implicit Restore Pointers |
| | Data | |
| | Message In - Save Data Ptrs | |
| | - Disconnect | |
| Bus Free | | |
| | Arbitration | |
| | Reselection | |
| | Message In - Identify | LUN + implicit Restore Pointers |
| | Data | |
| | Status | |
| | Message In - Command Complete | |
| Bus Free | | |

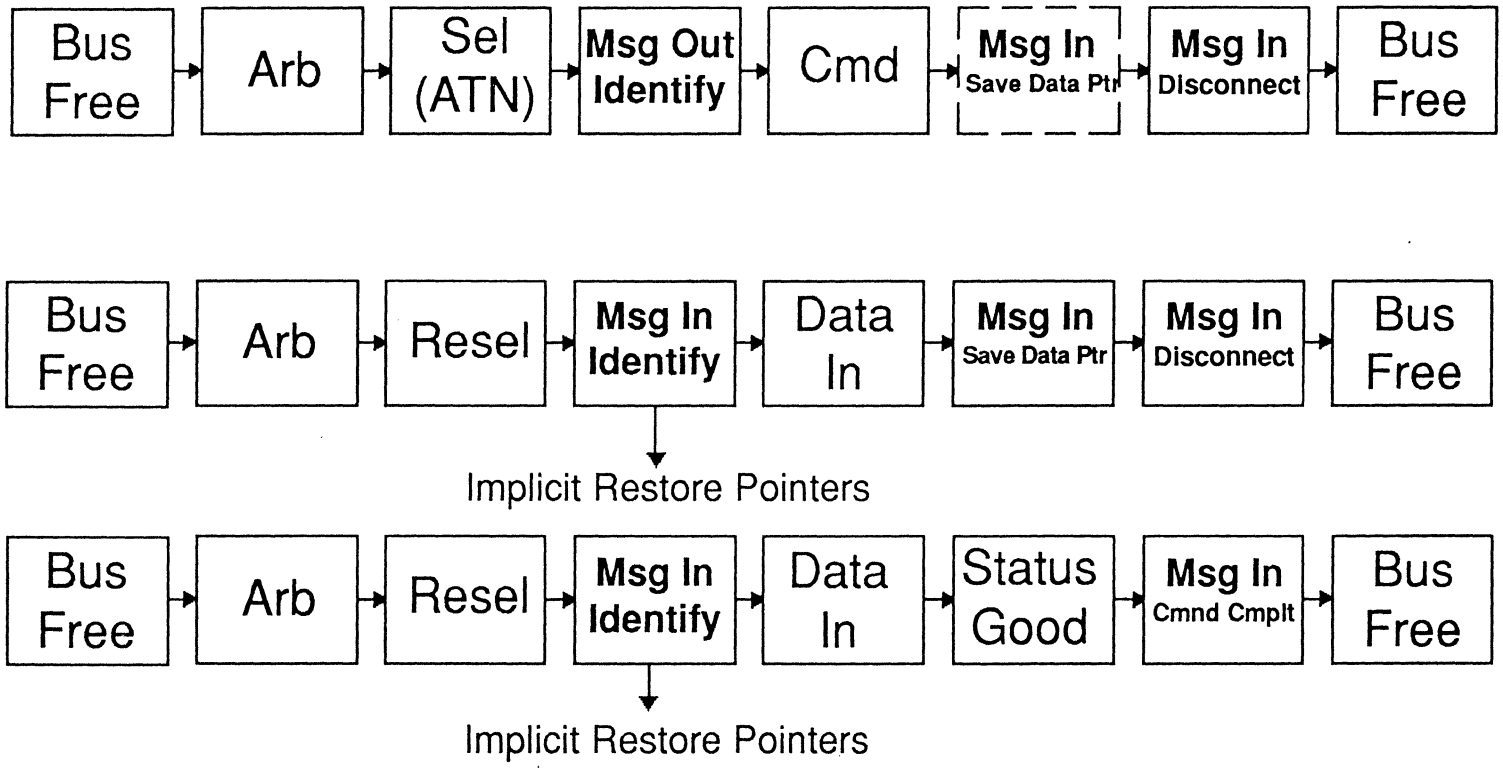
# Host Adapter Pointers
## (Continued)
## Write Example

- Assume iid = 6, tid = 4, LUN = 0, and Disconnection allowed - only initiator is arbitrating durning Connection and only target is arbitrating during Reconnection.
- What are the Data Bus contents in hex in all phases except command and data?



# Host Adapter Pointers
## (Continued)
## Read Example

- Repeat the exercise as in the previous page.



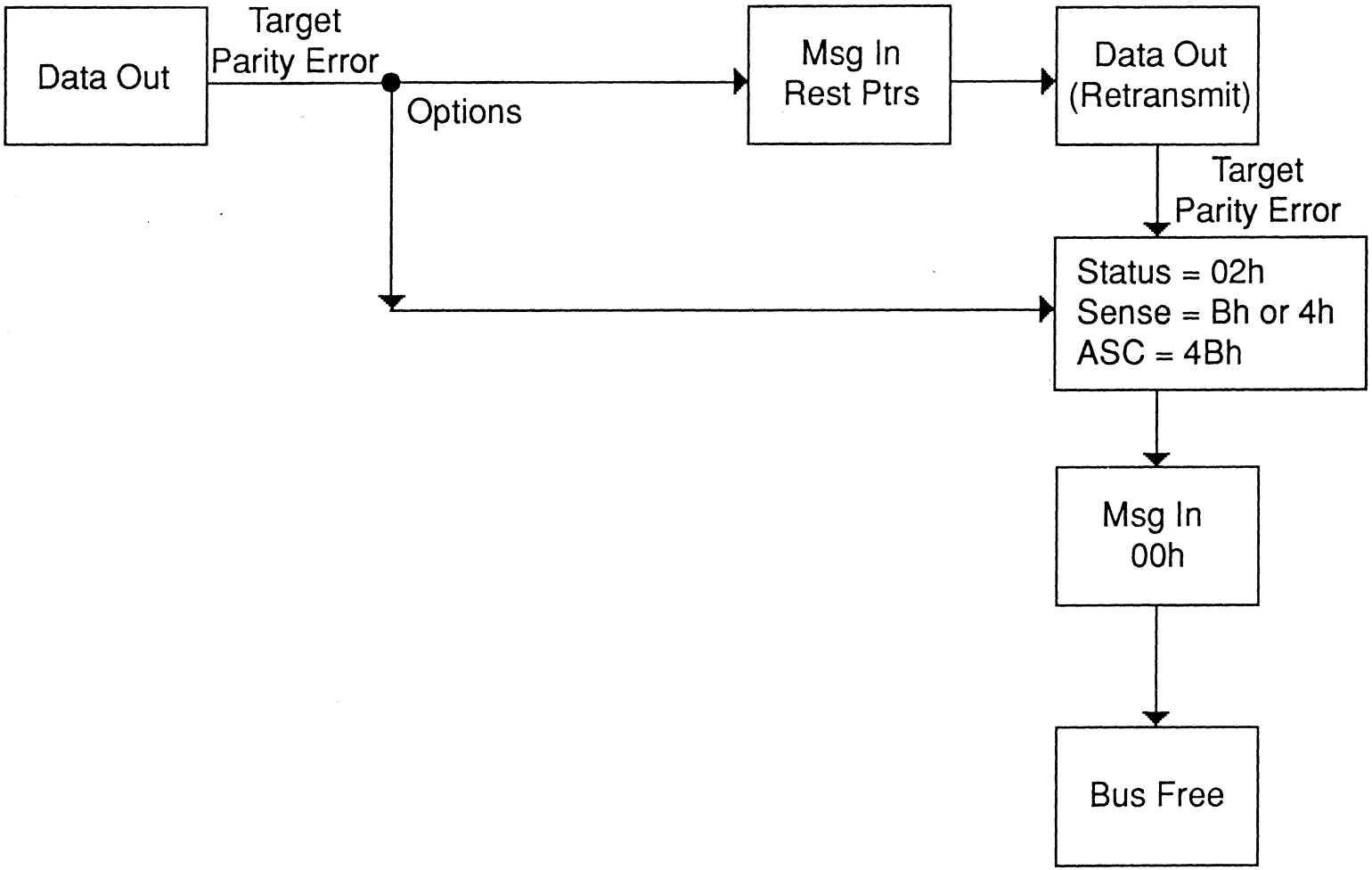
# Parity Error Handling
## SCSI Tools Used

| | | |
|---|---|---|
| • Message In | 03h | Restore Pointers |
| • Message Out | 05h | Initiator Detected Error |
| | 09h | Message Parity Error |
| • Status | 02h | Check Condition |
| • Sense Key | 4h | Hardware Error |
| | Bh | Aborted Command |

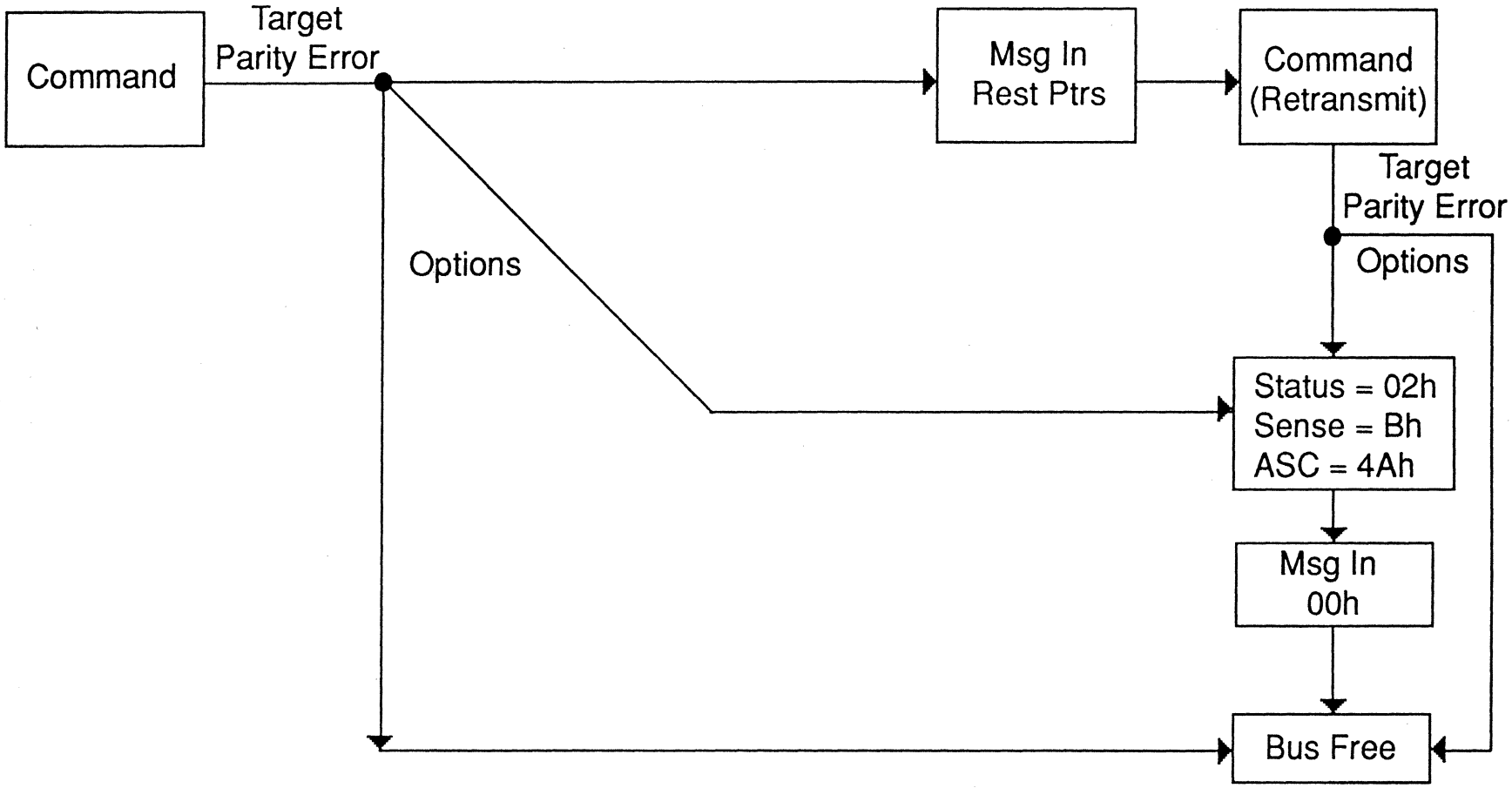
• Additional Sense Code (ASC) - in byte 12 of the sense data

| | |
|---|---|
| 43 h | Message Error |
| 48 h | Initiator Detected Error Message Received |
| 4Ah | Command Phase Error |
| 4Bh | Data Phase Error |

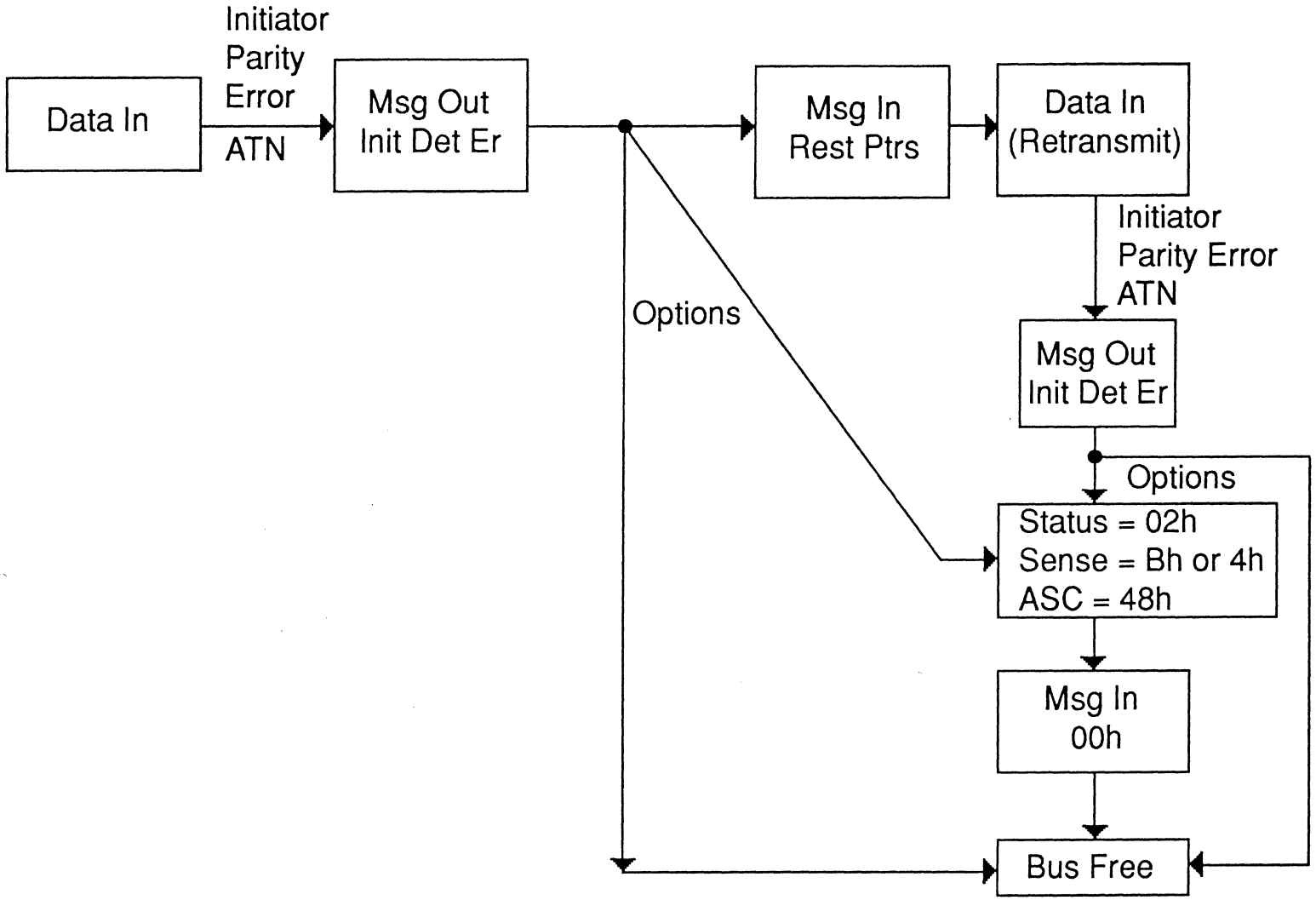
# Parity Error Handling
## (Continued)
## During Data Out Phase



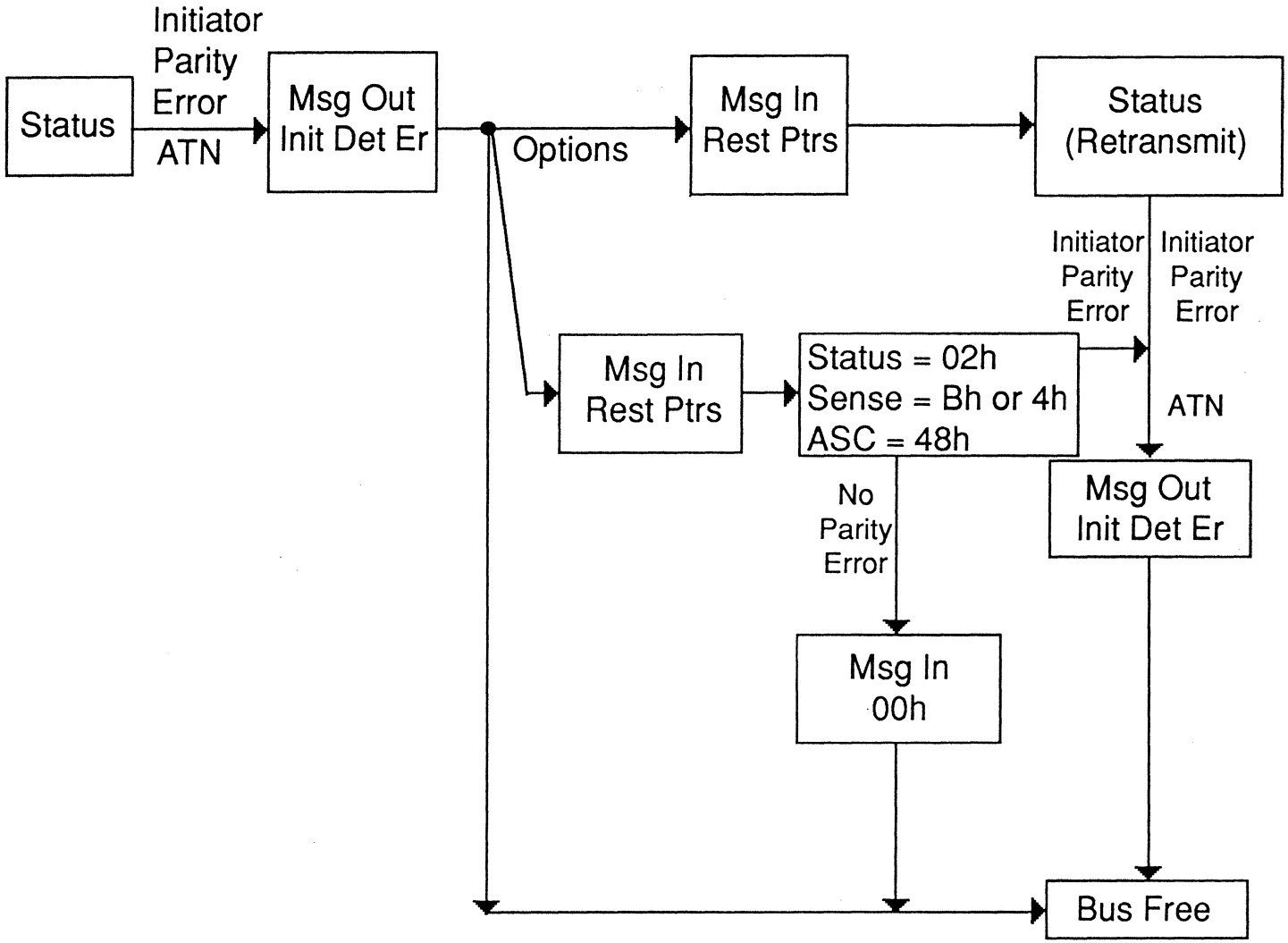
# Parity Error Handling
## (Continued)
## During Command Phase



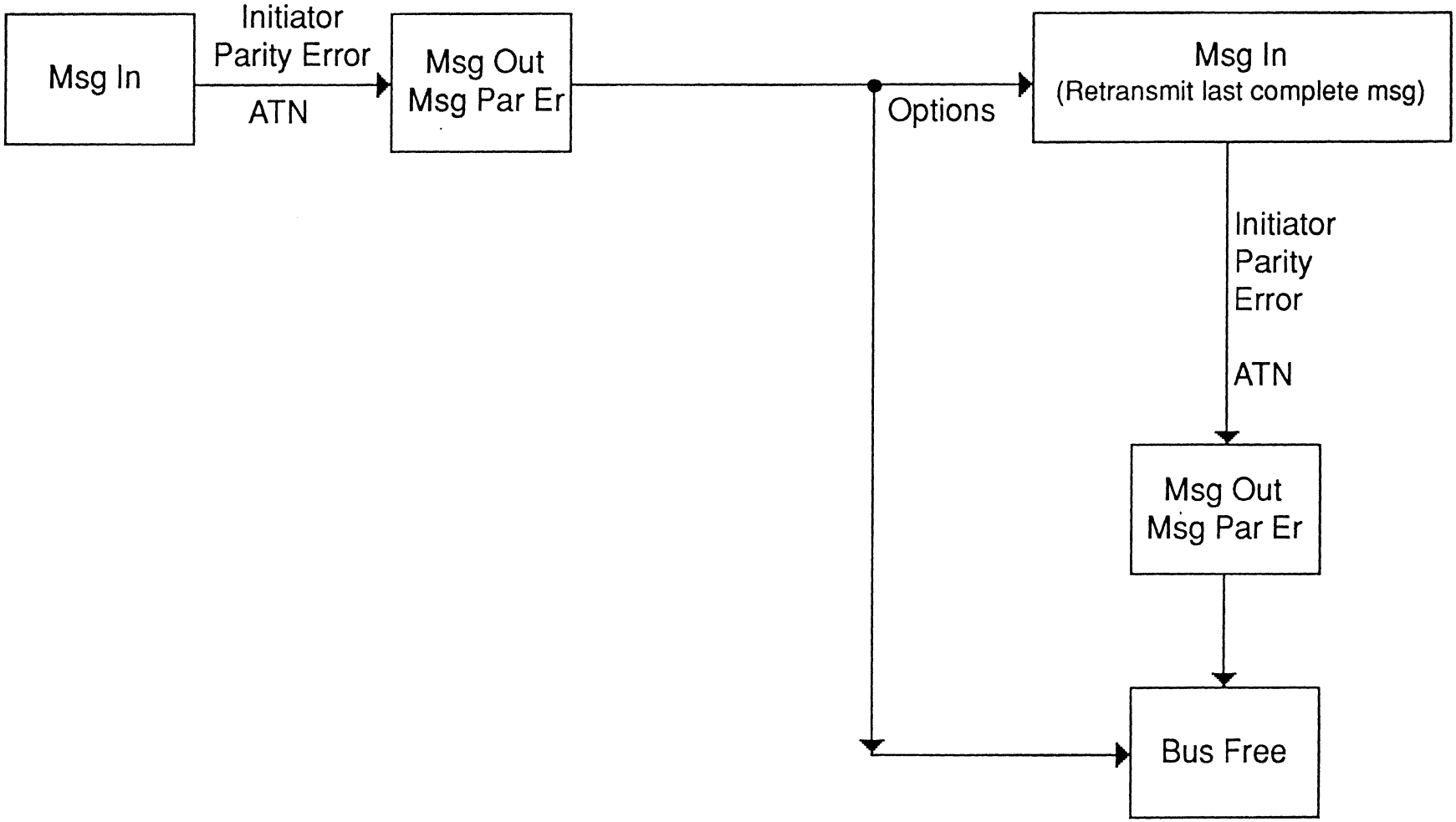
# Parity Error Handling
## (Continued)
## During Data In Phase



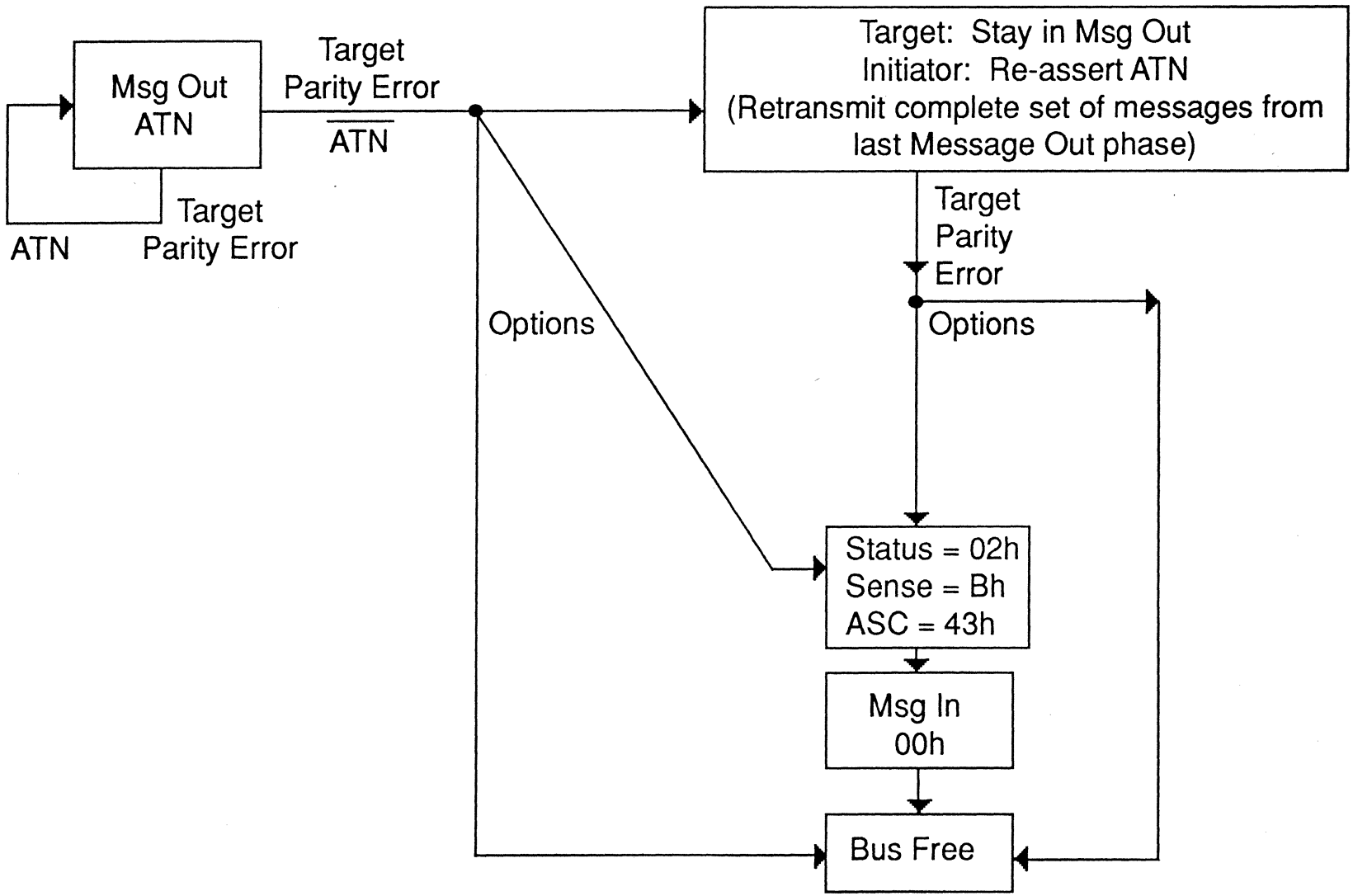
# Parity Error Handling
## (Continued)
## During Status Phase



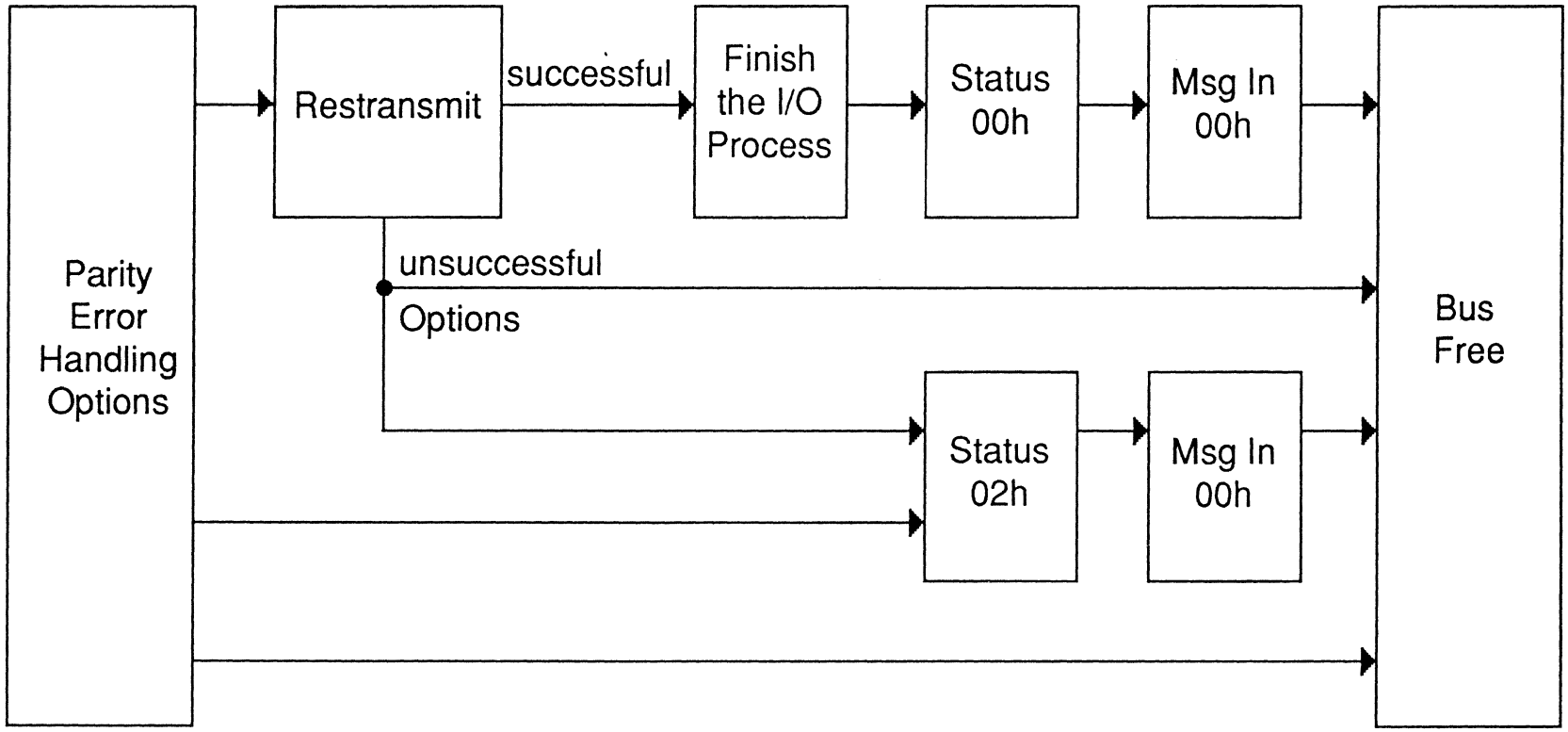
# Parity Error Handling
## (Continued)
## During Message In Phase



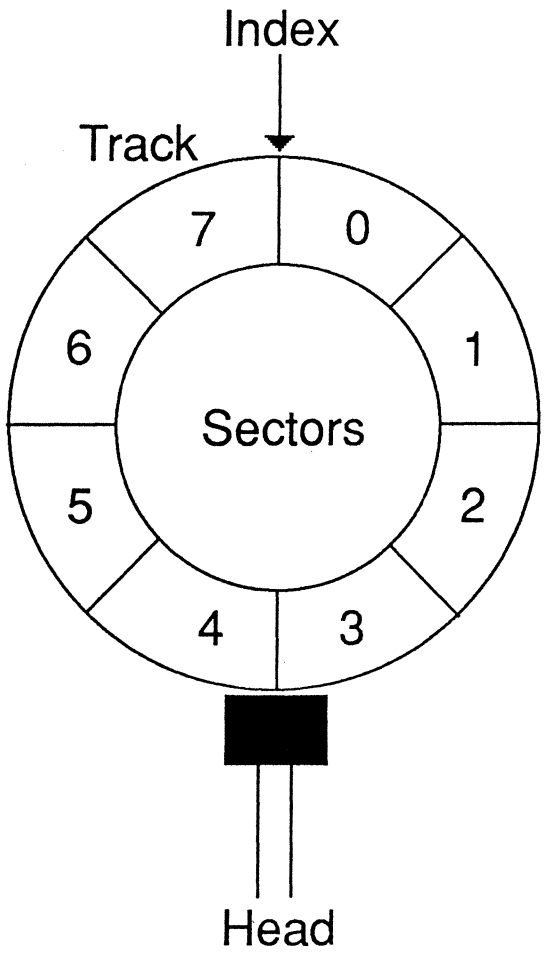
# Parity Error Handling
## (Continued)
## During Message Out Phase

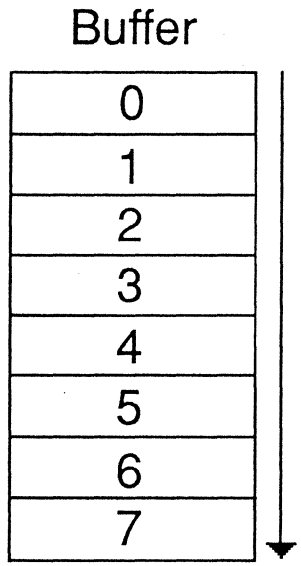


# Parity Error Handling
## (Continued)
## General Summary

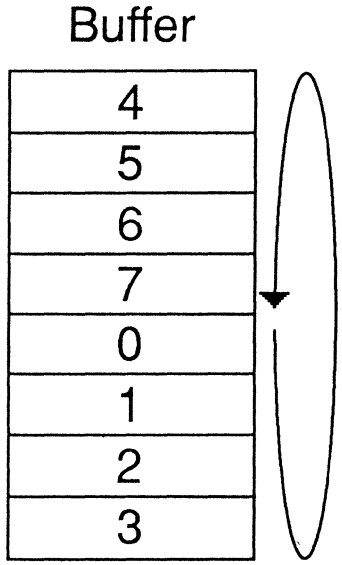


# First Sector Up (Zero Latency)

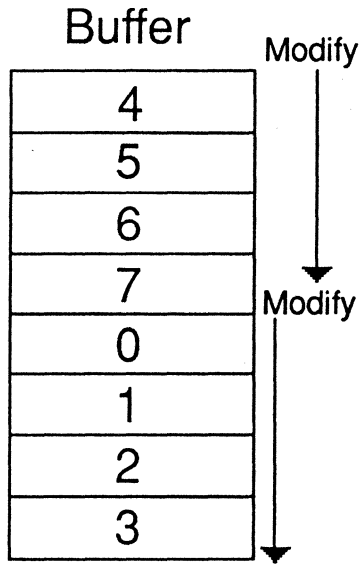



Seek to 0
Read 0-7
Return 0-7




Read 4-7
Read 0-3
Return 0-7




Modify Data Ptrs
Read 4-7
Return 4-7
Modify Data Ptrs
Read 0-3
Return 0-3

# First Sector Up (Zero Latency)
## (Continued)
## Zero Latency Without Modify

Example: Read full track (Blocks 0-N), landing on Block X-1.

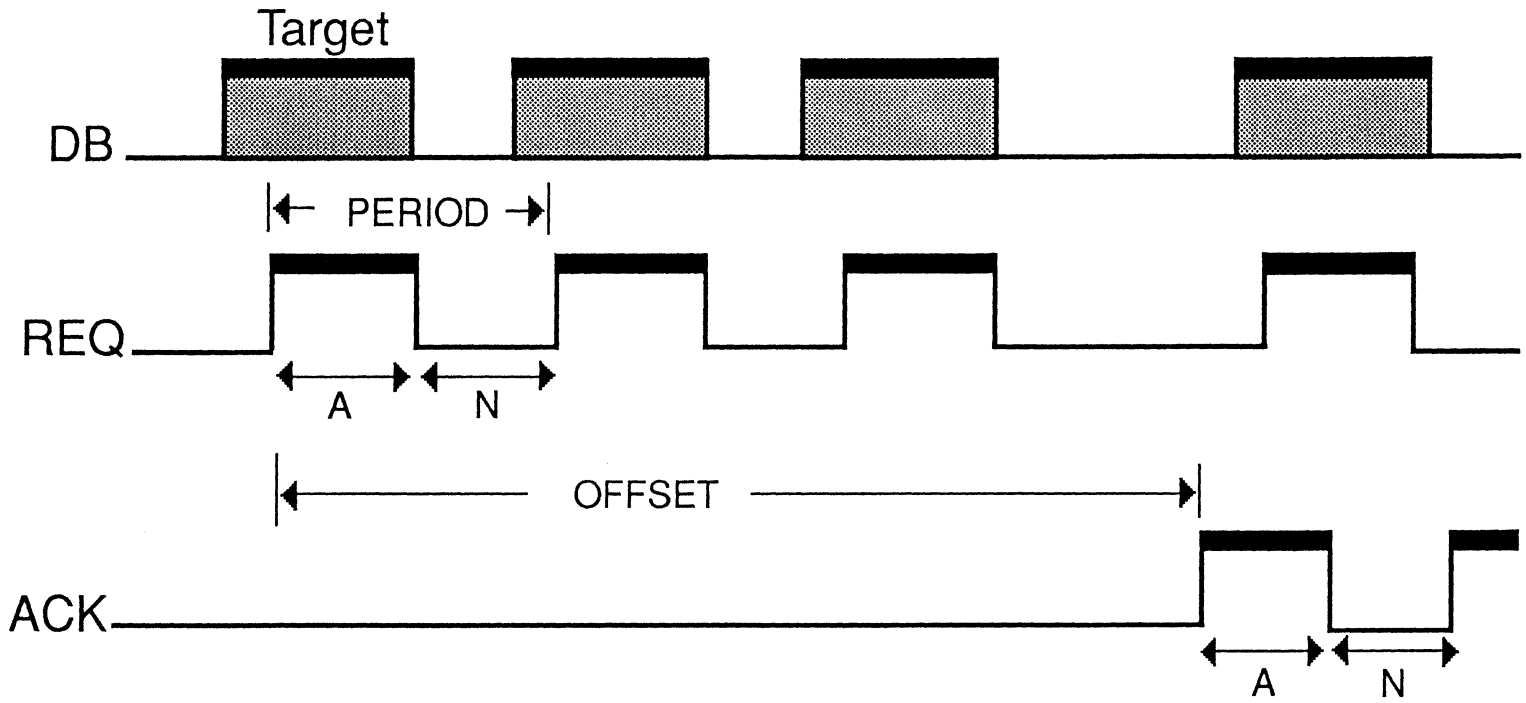
Bus Free
Arbitrate
Select (ATN)
Message Out - Identify
Command
Read Blocks X to N into Buffer
Data (Blocks 0-N) Read Blocks 0 to X-1
Status
Message In
Bus Free

# First Sector Up (Zero Latency)
(Continued)
Modify Data Pointers

Example: Read Full Track (Blocks 0-N), landing on Block X-1.

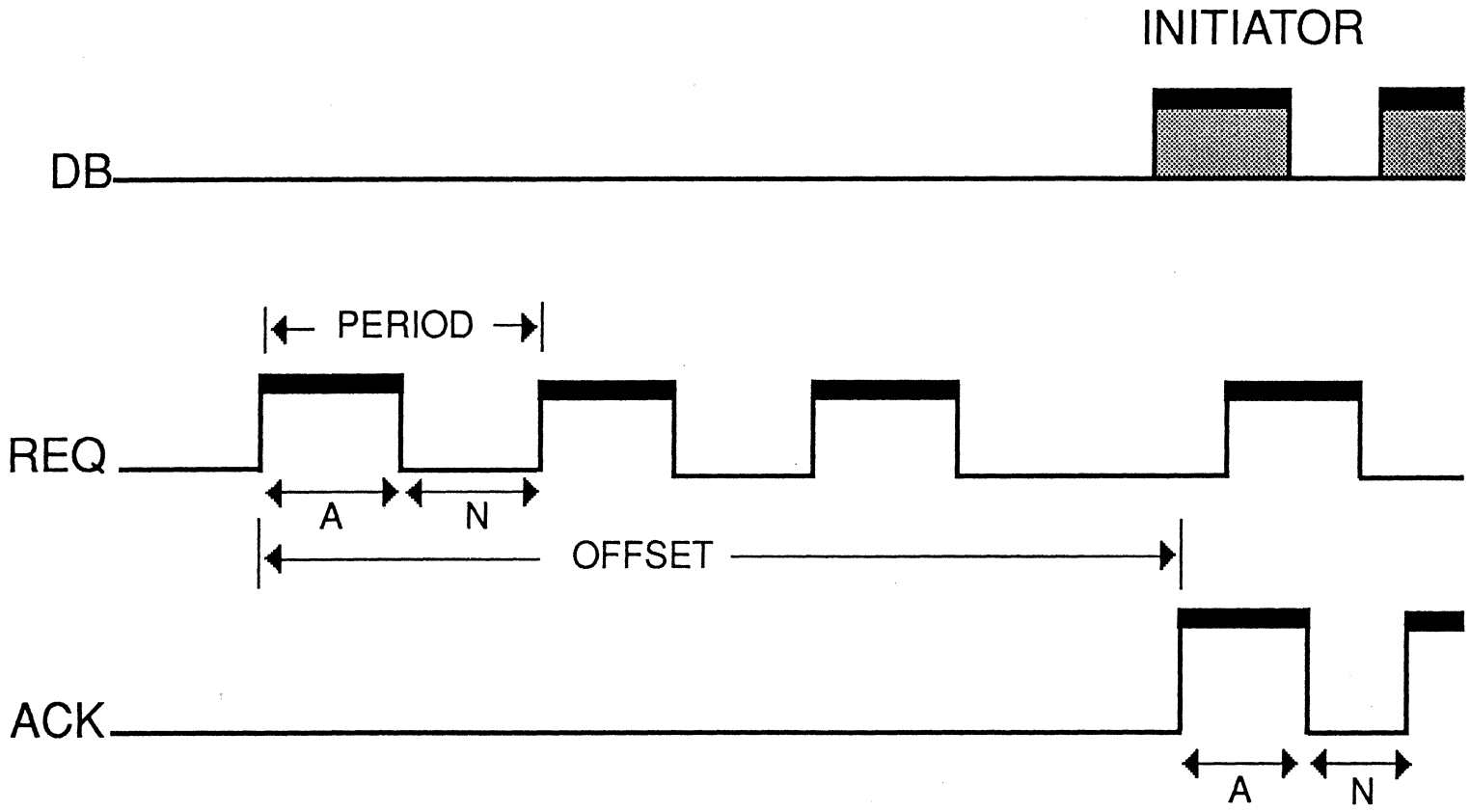
| | |
|---|---|
| Bus Free | |
| Arbitrate | |
| Select (ATN) | |
| Message Out | Identify |
| Command | |
| Message In | Modify Data Pointers |
| Data | (Blocks X to N) |
| Message In | Modify Data Pointers |
| Data | (Blocks 0 to X-1) |
| Status | |
| Message In | |
| Bus Free | |

# Synchronous REQ/ACK Handshake
## Data In

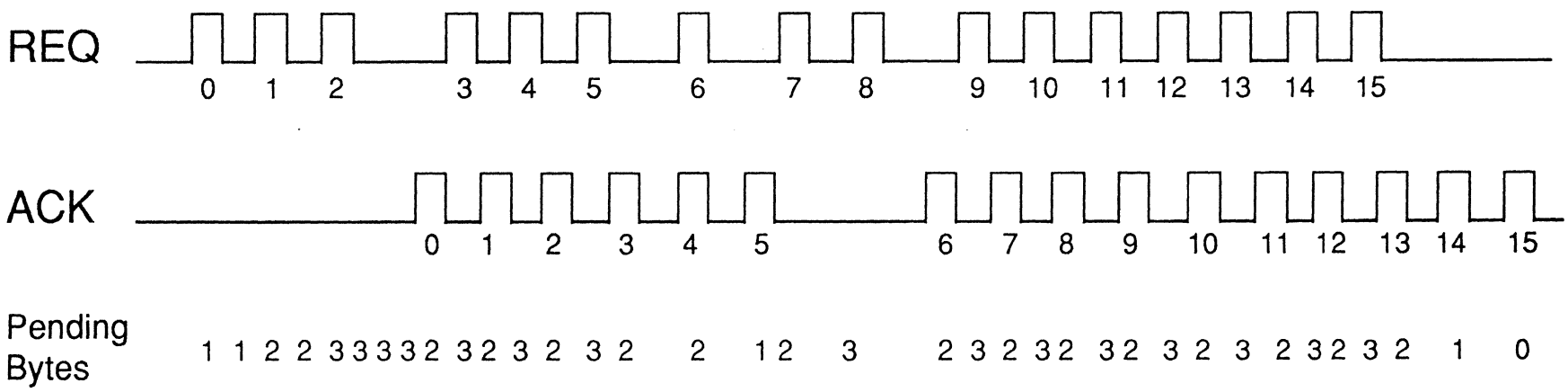



- A = Assertion Period (90 ns min), N = Negation Period (90 ns min)
- DB valid for Skew (10 ns) + Deskew (45 ns) Delay before REQ
- DB valid for Skew (10 ns) + Deskew (45 ns) + Hold Time (45 ns) after REQ
- Min period = 200 ns
- Transfer Rate = 1/period, 5 MBPS max

# Synchronous REQ/ACK Handshake
## (Continued)
## Data Out



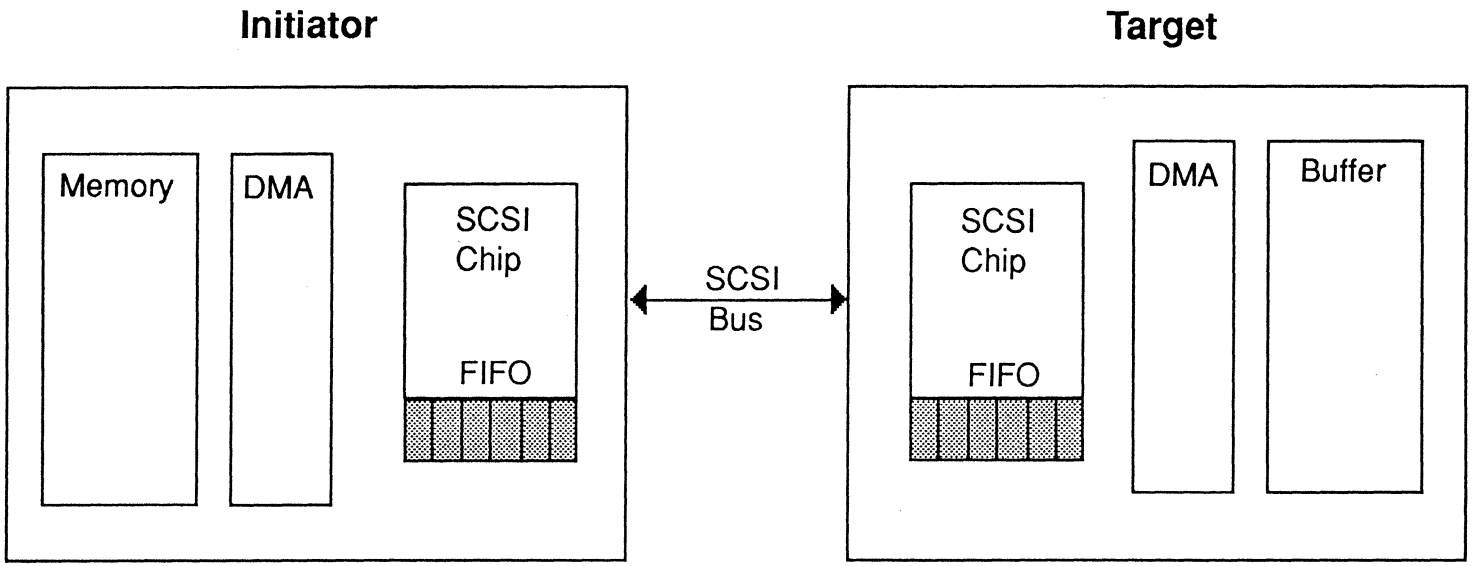
# Synchronous REQ/ACK Handshake
## (Continued)
## Example with Offset 3




Basic Rules:

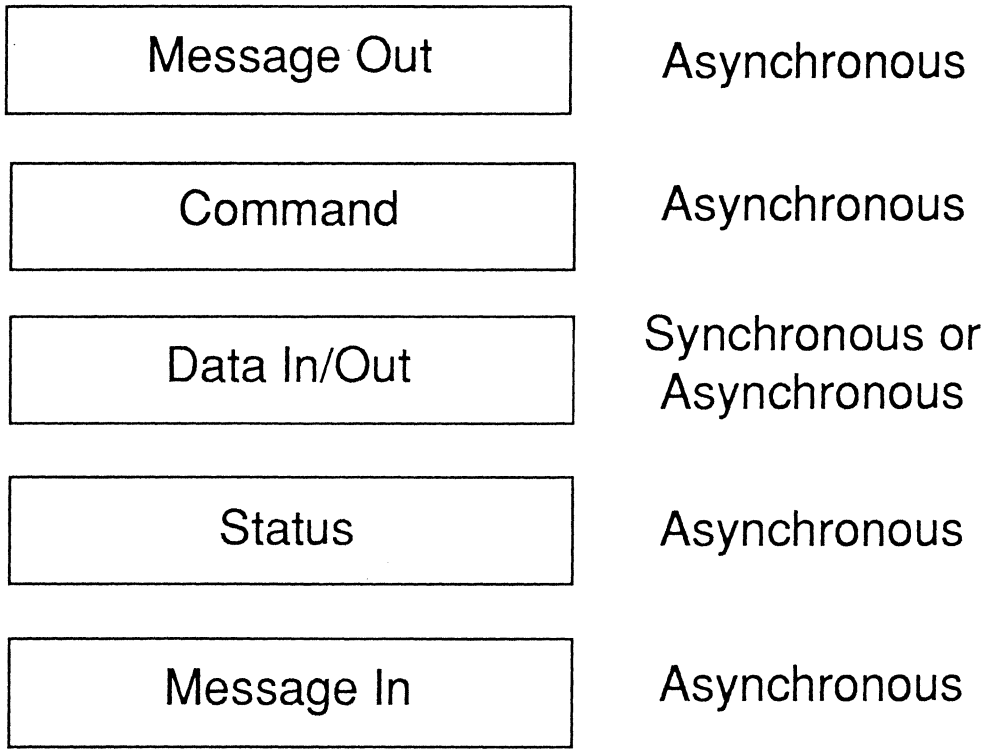
- REQ is never ahead of ACK by more than the offset
- ACK is never ahead of REQ
- Number of REQ and ACK pulses must be equal at end of phase
- Target doesn't change phase until all ACK pulses received

# Synchronous SCSI
## Hardware Implementation

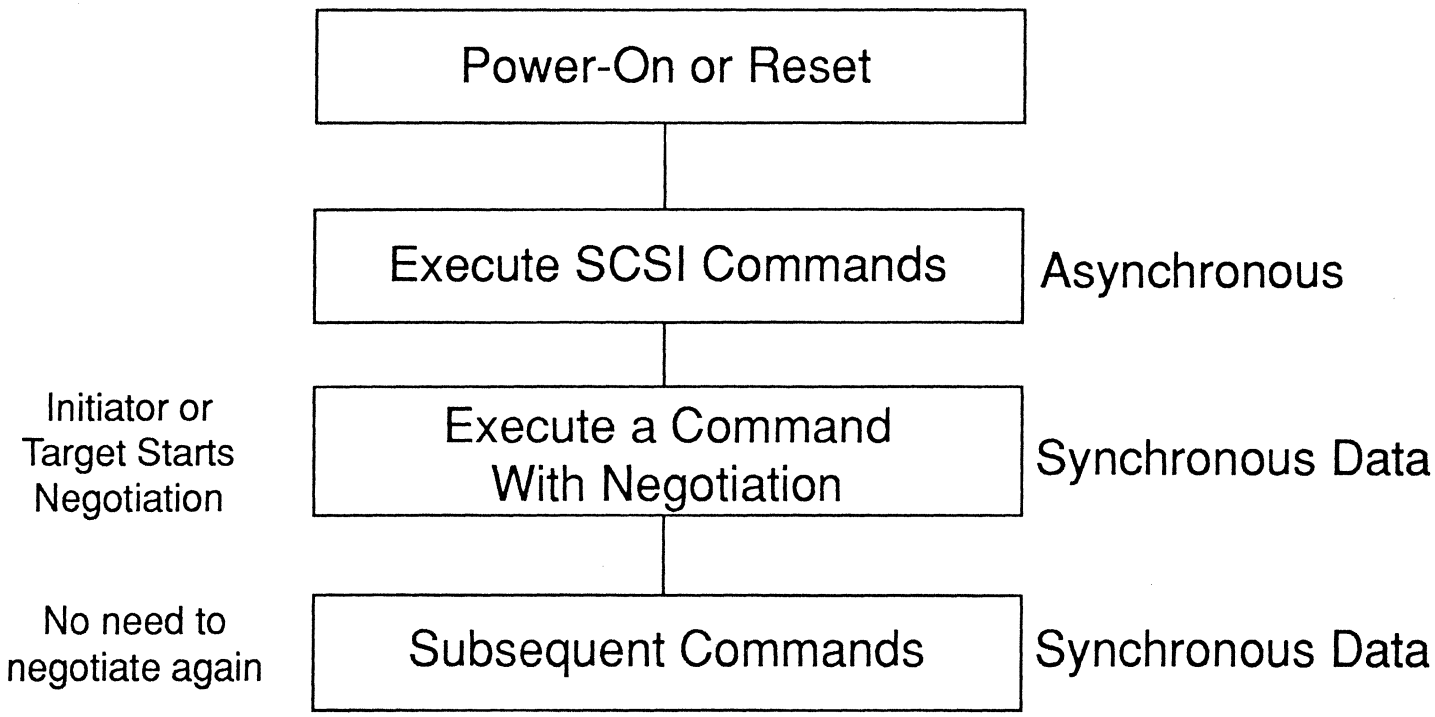



Offset =< FIFO Size

# Synchronous SCSI
## (Continued)
## How Bytes are Transferred



# Synchronous SCSI
## (Continued)
## How to get into Synchronous



# Synchronous SCSI
## (Continued)
## Summary

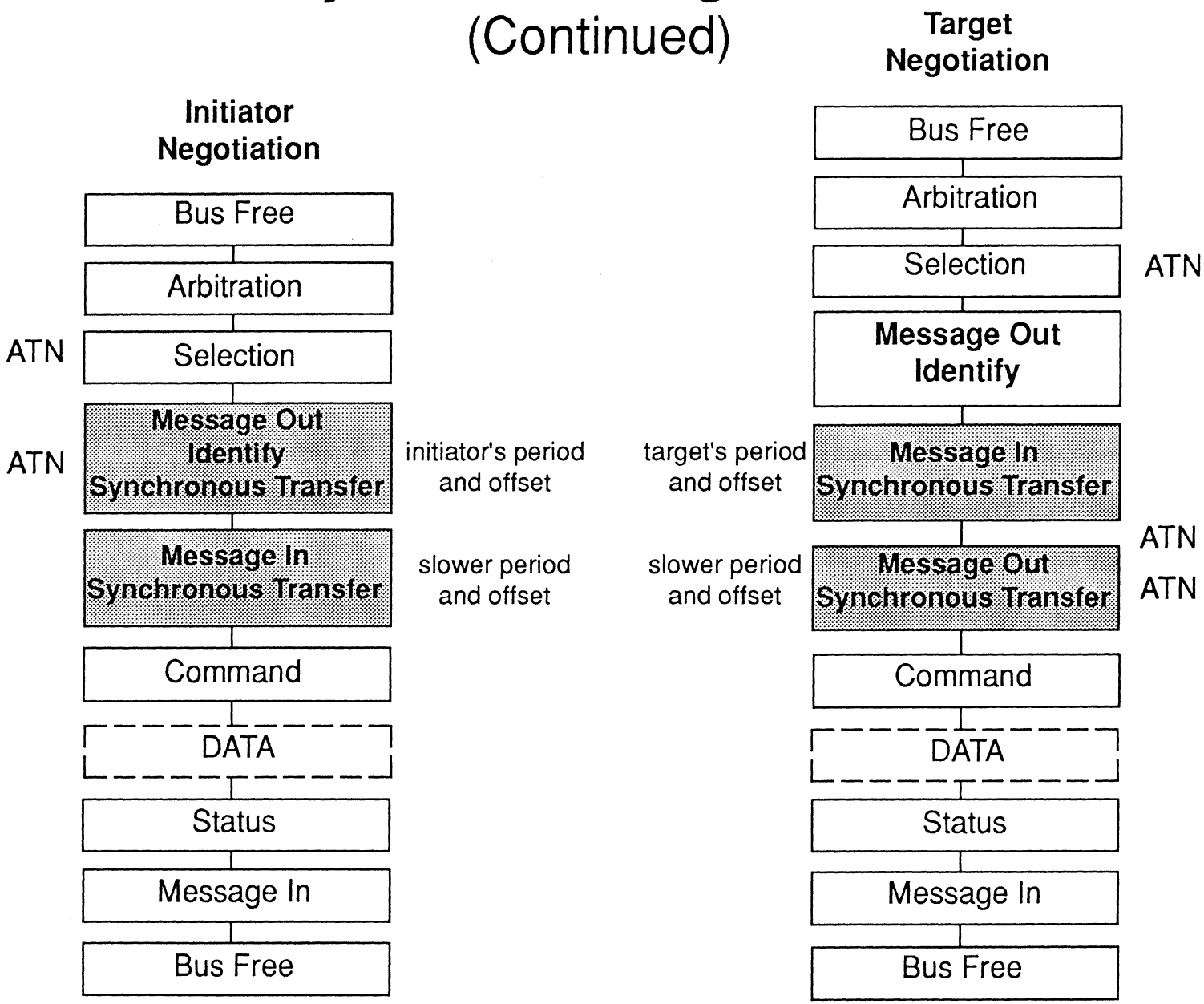
- Synchronous is optional, default is asynchronous
- Command, status, and messages are transferred asynchronously
- Data In/Out May be Synchronous (Optional) or Asynchronous (Mandatory)
- Typical Asynchronous Data Rate = 3-4 MByte/Sec
- Max Synchronous Data Rate = 5 MByte/Sec
- Typical offset 8-16
- Negotiation is needed to use synchronous
- Negotiation:
  - Exchange Extended Messages
  - Agree On Period (Data Rate) and Offset
  - Invalidated by Power Recycle or Reset

# Synchronous Negotiation

## Multi-Initiator Multi-Target Negotiation Example

| | Initiator<br><br>Asynchronous | Initiator<br>Synchronous<br>(offset, period)<br>(7, 250ns) |
|---|---|---|
| Target<br>8, 200ns | Asynchronous | (7, 250ns) |
| Target<br>Asynchronous | Asynchronous | Asynchronous |
| Target<br>(6, 300ns) | Asynchronous | (6, 300ns) |
| Target<br>(5, 200ns) | Asynchronous | (5, 250ns) |

# Synchronous Negotiation
## (Continued)



# Synchronous Negotiation
## (Continued)
## Synchronous Negotiation Message

| Byte | Value | Description |
|---|---|---|
| 0 | 01h | Extended Message |
| 1 | 03h | Extended Message Length |
| 2 | 01h | Synchronous Data Transfer Request Code |
| 3 | m | Period/4 nanoseconds |
| 4 | x | Offset |

# Synchronous Negotiation
## (Continued)
## A Few Reminders

- Offset 00h = Asynchronous
  FFh = Infinite (memory is fast enough to keep up with synchronous)
- Message Reject reply results in Asynchronous
- Negotiation agreements are invalidated by power cycle and hard reset
- Negotiation with every Inquiry and Request Sense Command is Recommended. This protects against cases where the target reverts to asynchronous after Reset or power cycle, while the initiator is synchronous based on previous negotiation with that target.

# Synchronous Negotiation
(Continued)
Example

| | Device A | Device B |
|---|---|---|
| Supported Periods | 200, 300, 400 | 250, 350, 450 |
| Agreement | 250 | 250 |
| Transmit at | 300 | 250 |
| Can Receive at up to | 200 | 250 |

# Fast Bus

- Synchronous Transfer with Periods of 100-196ns.
- Assertion and Negation Periods of 30ns.
- Up to 10 MBPS Over 8-Bit Bus.
- Synchronous Transfer Negotiation Needed.
- Single-ended Implementation Recommendations:
  - max cable length of 3 meters.
  - active negation drivers for REQ, ACK, and DB.
  - active terminators.

# Sample Phase Sequences

Test Unit Ready After Reset

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free-RST | | Bus Reset |
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 02 | Check Condition |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Request Sense

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Command | 03 00 00 00 FF 00 | Request Sense |
| Data In | 70 00 06 00 00 00 00 0A | Unit Attention |
| | 00 00 00 00 29 00 00 00 | Power On or Reset |
| | 00 00 | |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Request Sense

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Command | 03 00 00 00 FF 00 | Request Sense |
| Data In | 70 00 00 00 00 00 00 0A | No Sense |
| | 00 00 00 00 00 00 00 00 | |
| | 00 00 | |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Test Unit Ready

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Inquiry (Pending Unit Attention)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 12 00 00 00 08 00 | Inquiry |
| Data In | 00 00 01 01 7D 00 00 00 | Inquiry Data |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Test Unit Ready (Pending Unit Attention)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 02 | Check Condition |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Request Sense

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 03 00 00 00 06 00 | Request Sense |
| Data In | 70 00 06 00 00 00 | Unit Attention |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Test Unit Ready

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Test Unit Ready (With Identify)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

## Seek

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 0B 00 00 00 00 00 | Seek |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Write (No Disconnect)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 0A 00 00 00 01 00 | Write |
| Data Out | xx xx xx . . . . | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)

Write (With Disconnect)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 0A 00 00 00 01 00 | Write |
| Data Out | xx xx xx . . . . | Data Bytes |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Write (With Disconnects)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 0A 00 00 00 64 00 | Write |
| Data Out | xx xx xx . . . | Data Bytes |
| Message In | 02 | Save Data Ptrs |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data Out | xx xx xx . . . | Data Bytes |
| Message In | 02 | Optional Save Data Ptrs |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Read (Without Disconnect)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 08 00 00 00 01 00 | Read |
| Data In | xx xx xx . . . . | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Read (With Disconnect)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 08 00 00 00 01 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx xx . . . . | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Read (With Disconnects)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 08 00 00 00 64 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx xx . . . | Data Bytes |
| Message In | 02 | Save Data Ptrs |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx xx . . . | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Read (With Multiple Initiators)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 30 | iid 5, iid 4 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 08 00 00 00 20 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Status | 08 | Busy |
| Message In | 00 | Command Complete |
| Bus Free | | |
| Arbitration | 50 | iid 4, tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx . . . | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)

Write (Data Out Parity Error)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | 0A 00 00 00 01 00 | Write |
| Data Out | xx xx xx... | Data Bytes |
| | | Target Detects Parity Error |
| Message In | 03 | Restore Pointers |
| Data Out | xx xx xx... | Data Bytes Again |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Read (Data In Parity Error)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 08 00 00 00 01 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx xx... | Data Bytes |
| ATN | | Initiator Detects Parity Error |
| Message Out | 05 | Initiator Detected Error |
| Message In | 03 | Restore Pointers |
| Data In | xx xx xx... | Data Bytes again |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Vendor Unique Command (With Parity Errors)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out | 80 | Identify |
| Command | E0 00 00 01 01 00 74 80 | Vendor Unique CDB |
| | | Target Detects Parity Error |
| Message In | 03 | Restore Pointers |
| Command | E0 00 00 01 01 00 74 80 | Re-transmit CDB |
| Data Out | xx xx xx... | Data Bytes, Target Detects Parity error |
| Message In | 03 | Restore Pointers |
| Data Out | xx xx xx... | Data Bytes again |
| Data In | xx xx xx... | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)

Test Unit Ready (Synchronous Negotiation)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection-ATN | 60 | iid 5, tid 6 |
| Message Out-ATN | 80 | Identify |
| Message Out-ATN | 01 03 01 32 07 | Period = 200ns, offset = 7 |
| Message In | 01 03 01 3E 06 | Period = 250ns, offset = 6 |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
(Continued)

Test Unit Ready (Target-initiated Synchronous Negotiation)

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection-ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Message In | 01 03 01 3E 06 | Period = 250ns, offset = 6 |
| Message Out-ATN | 01 03 01 3E 06 | Period = 250ns, offset = 6 |
| Command | 00 00 00 00 00 00 | Test Unit Ready |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Copy Command

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection - ATN | 60 | iid 5, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 18 00 xx xx xx 00 | Copy |
| Data Out | xx xx... | Data Bytes |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | iid 6 |
| Selection - ATN | 42 | iid 6, tid 1 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 28 00 xx xx xx xx 00 xx xx 00 | Read (or 2a - write) |
| Data In | xx xx... | Data Bytes (or Data Out) |
| | | Possible disconnect/reconnect |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 80 | Identify |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Linked Commands

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection - ATN | 50 | iid 4, tid 6 |
| Message Out | 80 | Identify |
| Command | 00 00 00 00 00 01 | Test Unit Ready, Linked |
| Status | 10 | Intermediate |
| Message In | 0A | Linked Command Complete |
| Command | 12 00 00 00 01 01 | Inquiry, Linked |
| Data In | 00 | Inquiry Data |
| Status | 10 | Intermediate |
| Message In | 0A | Linked Command Complete |
| Command | 00 00 00 00 00 00 | Test Unit Ready, not Linked |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Abort Message

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection - ATN | 50 | iid 4, tid 6 |
| Message Out | 06 | Abort |
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection - ATN | 50 | iid 4, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 08 00 00 00 01 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection - ATN | 50 | iid 4, tid 6 |
| Message In - ATN | 80 | Identify |
| Message Out | 06 | Abort |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Multi-Threading/Untagged Queueing

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection - ATN | 50 | iid 4, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed - LUN 0 |
| Command | 0B 00 00 00 00 00 | Seek |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 20 | iid 5 |
| Selection - ATN | 60 | iid 5, tid 6 |
| Message Out | C1 | Identify - Disconnect allowed - LUN 1 |
| Command | 0B 01 00 00 00 00 | Seek |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 60 | iid 5, tid 6 |
| Message In | 81 | Identify - LUN 1 |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 50 | iid 4, tid 6 |
| Message In | 80 | Identify - LUN 0 |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# Sample Phase Sequences
## (Continued)
### Multiple Identify Messages

| Phase | Data Bus (hex) | Notes |
|---|---|---|
| Bus Free | | |
| Arbitration | 10 | iid 4 |
| Selection - ATN | 50 | iid 4, tid 6 |
| Message Out | C0 | Identify - Disconnect allowed |
| Command | 28 00 00 00 00 00 00 FF FF 00 | Read |
| Message In | 04 | Disconnect |
| Bus Free | | |
| Arbitration | 40 | tid 6 |
| Reselection | 50 | iid 4, tid 6 |
| Message In | 80 | Identify |
| Data In | xx xx ... | Data Bytes |
| Message In - ATN | 02 | Save Data Ptrs |
| Message Out | 80 | Identify - No Disconnect |
| Data In | xx xx ... | Data Bytes |
| Status | 00 | Good |
| Message In | 00 | Command Complete |
| Bus Free | | |

# SCSI-2 Features

# SCSI-2 Highlights

- Mainly SCSI-1 and CCS Compatible
- Minor Hardware Changes
- Optional Fast Bus
- Optional Wide Bus
- Some SCSI-1 Options are Mandatory in SCSI-2
- More Device Types
- More Commands
- More Messages
- More Status Bytes
- More Optional Features, e.g., Command Queueing

# Document Changes

- Commands, Messages, and Pages Listed Alphabetically (By Code in SCSI-1)
- More Details and Clarifications
- More Implementors Notes

# Hardware Changes

- High-Density Non-Shielded Connector
- Arbitration is Mandatory
- Parity is Mandatory
- Optional Fast Bus
- Optional Wide Bus
- Initiators Supply Terminator Power (Optional in SCSI-1)
- New Single-Ended Terminator Alternative
- Arbitration Delay = 2.4 us (2.2 in SCSI-1)
- New Bus Timings:
  - Disconnection Delay
  - Power-on to Selection Time
  - Reset to Selection Time
  - Fast Bus Timings
- Pins 23, 24, 27, and 28 Reserved (GROUND in SCSI-1)
- Or-Tied SEL

# Wide Bus
## Summary

| Standard | Byte Width | Bit Width | Cable Name | Pin Count | Max Transfer Rate MByte/sec | Max SCSI Devices | Description |
|---|---|---|---|---|---|---|---|
| SCSI-1 | 1 | 8 | A | 50 | 5 | 8 | synchronous |
| SCSI-2 | 1 | 8 | A | 50 | 10 | 8 | fast |
| SCSI-2 | 2 | 16 | A+B | 50+68 | 20 | 8 | fast & wide with 2 cables |
| SCSI-2 | 4 | 32 | A+B | 50+68 | 40 | 8 | fast & wide with 2 cables |
| SCSI-3 | 1 | 8 | A | 50 | 10 | 8 | fast |
| SCSI-3 | 2 | 16 | P | 68 | 20 | 16 | fast & wide with 1 cable |
| SCSI-3 | 4 | 32 | P+Q | 68+68 | 40 | 32 | fast & wide with 2 cables |

- A is most commonly used.
- P is getting popular.
- A+B is currently not popular due to cost and space issues.

# Wide Bus
## (Continued)
## Two-Byte Wide SCSI-3 Implementation

- Single Cable (P-Cable) with 68 Lines

- Signals:

| | | |
|---|---|---|
| Control | = | BSY SEL ATN RST REQ ACK C/D I/O MSG |
| Data | = | DB0-7, P |
| | | DB8-15, P1 |

- Narrow (1-byte) is mandatory, wide is optional, default is narrow

- Wide bus negotiation using extended messages needed to use wide

- Agreements invalidated with power cycle and hard reset

- Only data phases may use wide, other information transfer phases use narrow only

- Ignore Wide Residue message is used when data transfers do not fit on wide boundary

# Wide Bus
## (Continued)
## Single-Ended P-Cable

| Signal Name | Cable Conductor Number | | Signal Name |
|---|---|---|---|
| GROUND | 1 | 2 | -DB(12) |
| GROUND | 3 | 4 | -DB(13) |
| GROUND | 5 | 6 | -DB(14) |
| GROUND | 7 | 8 | -DB(15) |
| GROUND | 9 | 10 | -DB(P1) |
| GROUND | 11 | 12 | -DB(0) |
| GROUND | 13 | 14 | -DB(1) |
| GROUND | 15 | 16 | -DB(2) |
| GROUND | 17 | 18 | -DB(3) |
| GROUND | 19 | 20 | -DB(4) |
| GROUND | 21 | 22 | -DB(5) |
| GROUND | 23 | 24 | -DB(6) |
| GROUND | 25 | 26 | -DB(7) |
| GROUND | 27 | 28 | -DB(P) |
| GROUND | 29 | 30 | GROUND |
| GROUND | 31 | 32 | GROUND |
| TERMPWR | 33 | 34 | TERMPWR |

# Wide Bus
## (Continued)
## Single-Ended P-Cable

| Signal Name | Cable Conductor Number | | Signal Name |
|---|---|---|---|
| TERMPWR | 35 | 36 | TERMPWR |
| RESERVED | 37 | 38 | RESERVED |
| GROUND | 39 | 40 | GROUND |
| GROUND | 41 | 42 | -ATN |
| GROUND | 43 | 44 | GROUND |
| GROUND | 45 | 46 | -BSY |
| GROUND | 47 | 48 | -ACK |
| GROUND | 49 | 50 | -RST |
| GROUND | 51 | 52 | -MSG |
| GROUND | 53 | 54 | -SEL |
| GROUND | 55 | 56 | -C/D |
| GROUND | 57 | 58 | -REQ |
| GROUND | 59 | 60 | -I/O |
| GROUND | 61 | 62 | -DB(8) |
| GROUND | 63 | 64 | -DB(9) |
| GROUND | 65 | 66 | -DB(10) |
| GROUND | 67 | 68 | -DB(11) |

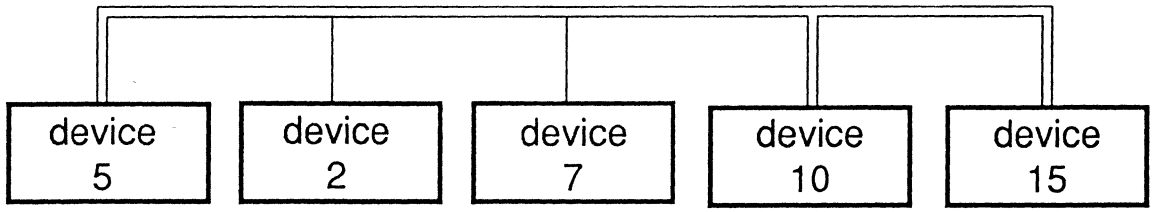
# Wide Bus
## (Continued)
## SCSI Devices With SCSI-3 P-Cable

- P-Cable allows up to 16 devices on bus

- Arbitration priorities:

  Highest 7 6 5 4 3 2 1 0 15 14 13 12 11 10 9 8 Lowest

- Example




  - 2, 5, and 7 can connect, disconnect, and reconnect with one another
  - 5, 10, and, 15 can connect, disconnect, and reconnect with one another
  - 10 and 15 can connect to 2 and 7 with SASI selection without disconnect
  - 2 and 7 cannot connect or reconnect to 10 and 15

# Wide Bus
## (Continued)
## Four-Byte Wide SCSI-3 Implementation

- Two Cables: P-Cable and Q-Cable

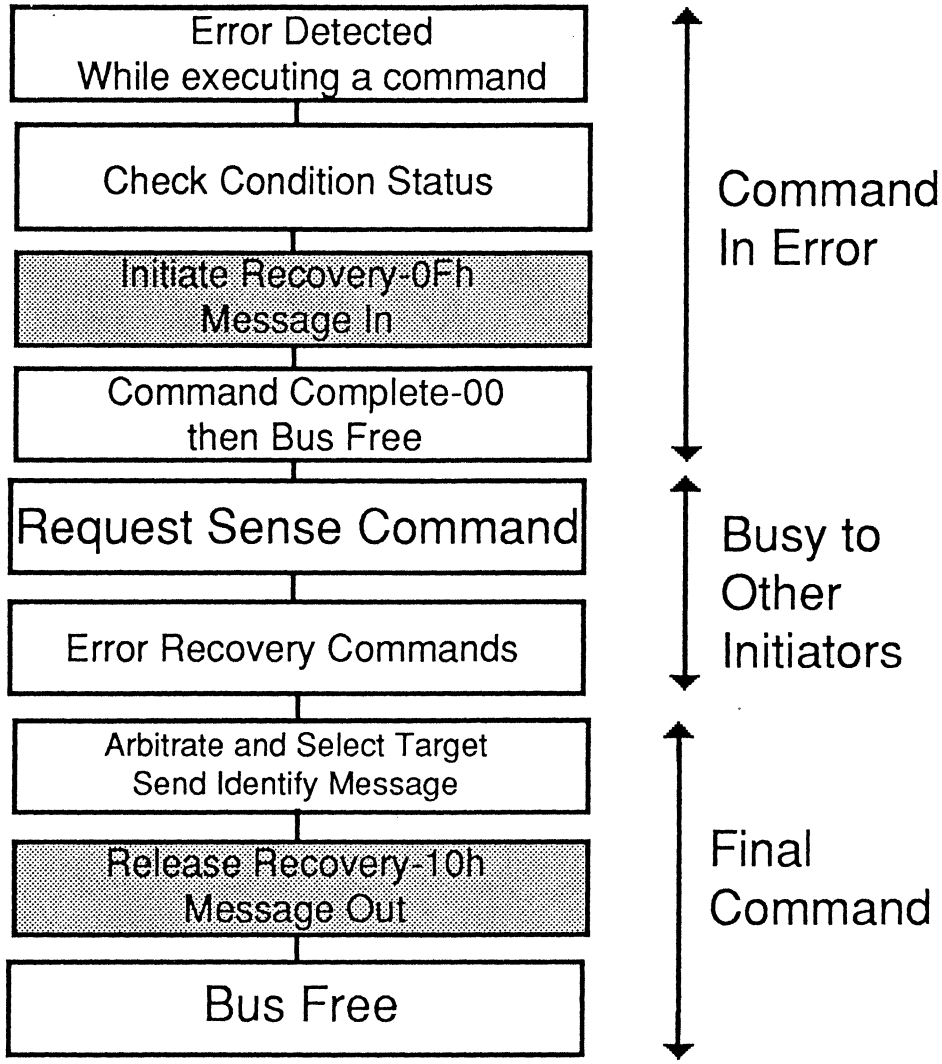
- Q-Cable:
  - 68 pins
  - Signals: DB16-31, P2-3, and REQQ/ACKQ

- Allows 32 devices on bus

- Maximum Data Byte Burst Rate:

| Frequency MHZ | 1-Byte Bus | 2-Byte Wide | 4-Byte Wide |
|---|---|---|---|
| 5 | 5 MB/s | 10 MB/s | 20 MB/s |
| 10 | 10 MB/s | 20 MB/s | 40 MB/s |

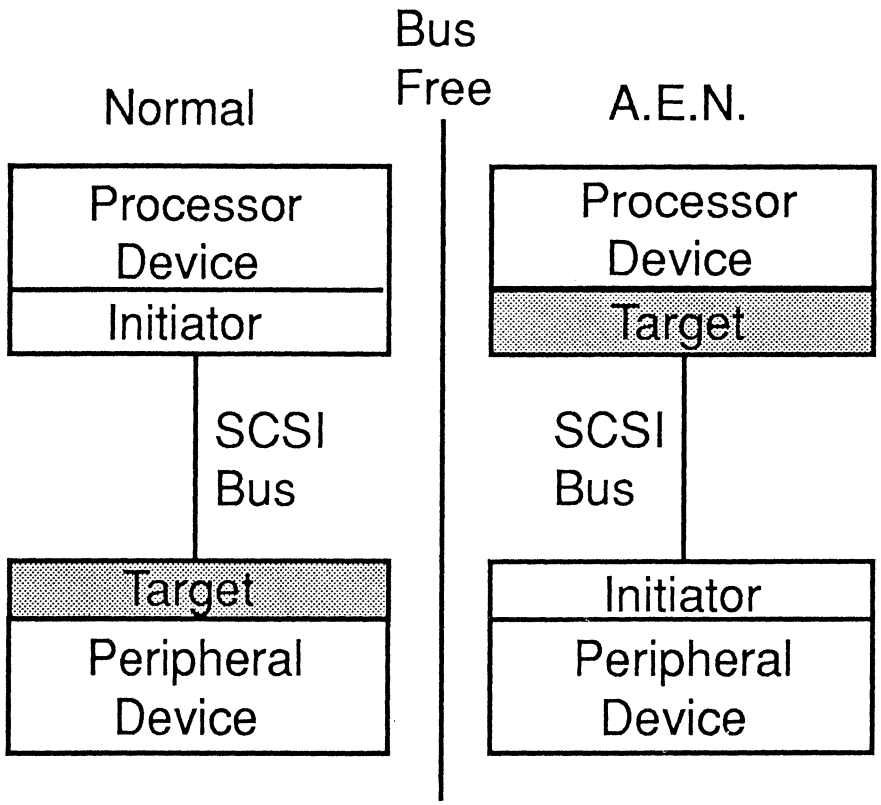
# Extended Contingent Allegiance



# Extended Contingent Allegiance
(Continued)

- Optional Feature
- For Error Condition Preservation and Tying Data to Initiator
- For Devices that Buffer Data (e.g., tape)
- Device Blocks Out Other Initiators, so the Affected Initiator can Take Action
- When a CHECK CONDITION is Detected, the Target is "Reserved" to the Calling Initiator and returns Busy to other Initiators
- Used When Error Recovery Requires Multiple Commands

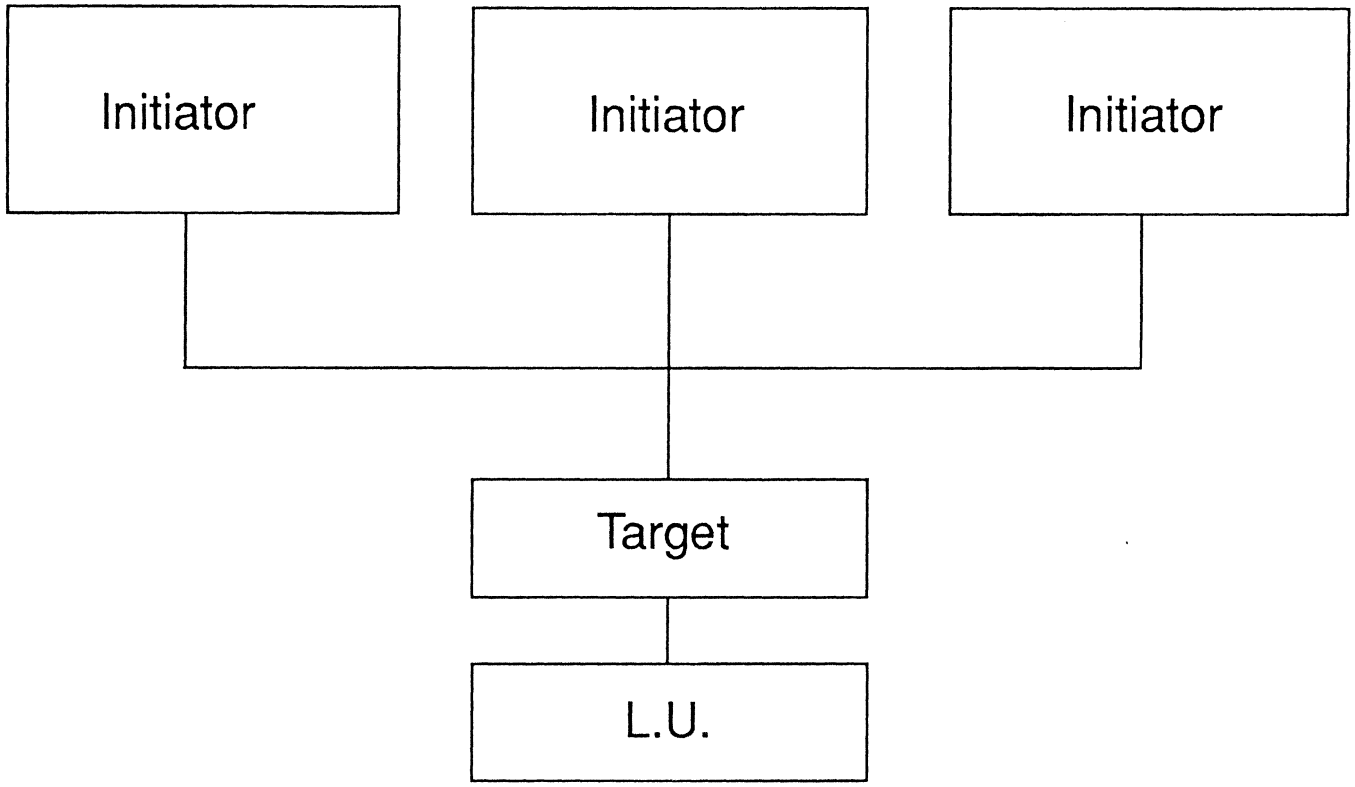
# Asynchronous Event Notification



# Asynchronous Event Notification
(Continued)

- Optional Feature.
- Used for Reporting:
  - device initialization completion.
  - unit attention.
  - errors.
- Starts From Bus Free.
- Target Becomes Initiator and Transfers a "SEND" Processor Command with AEN Bit Set. Sense Data is Transferred During Data Phase.
- Reported to Processor Devices that Support AEN Only.
- Peripheral Device Scans the Bus, using Inquiry, to Find Processor Devices that Support AEN.

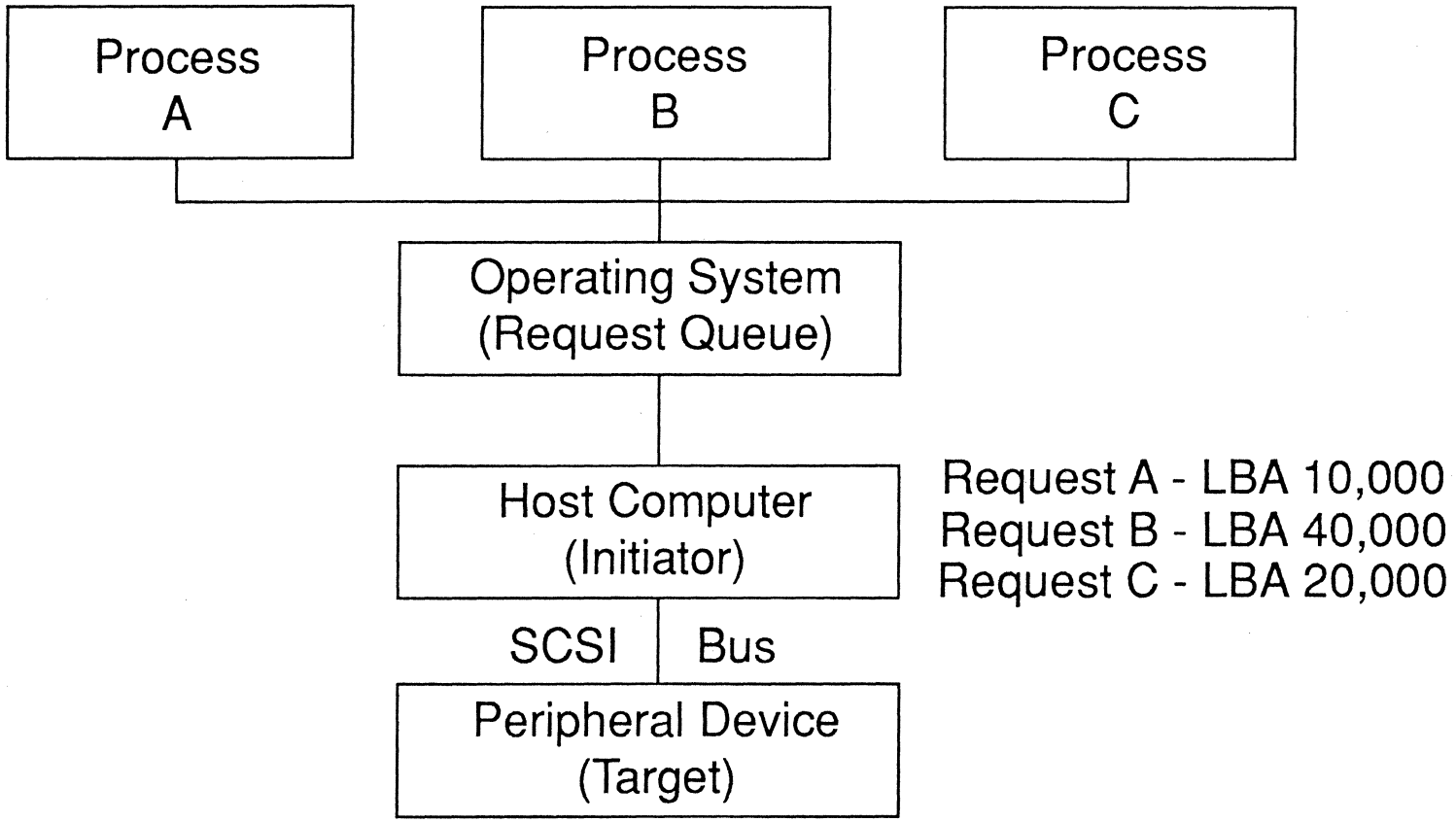
# Untagged Queueing



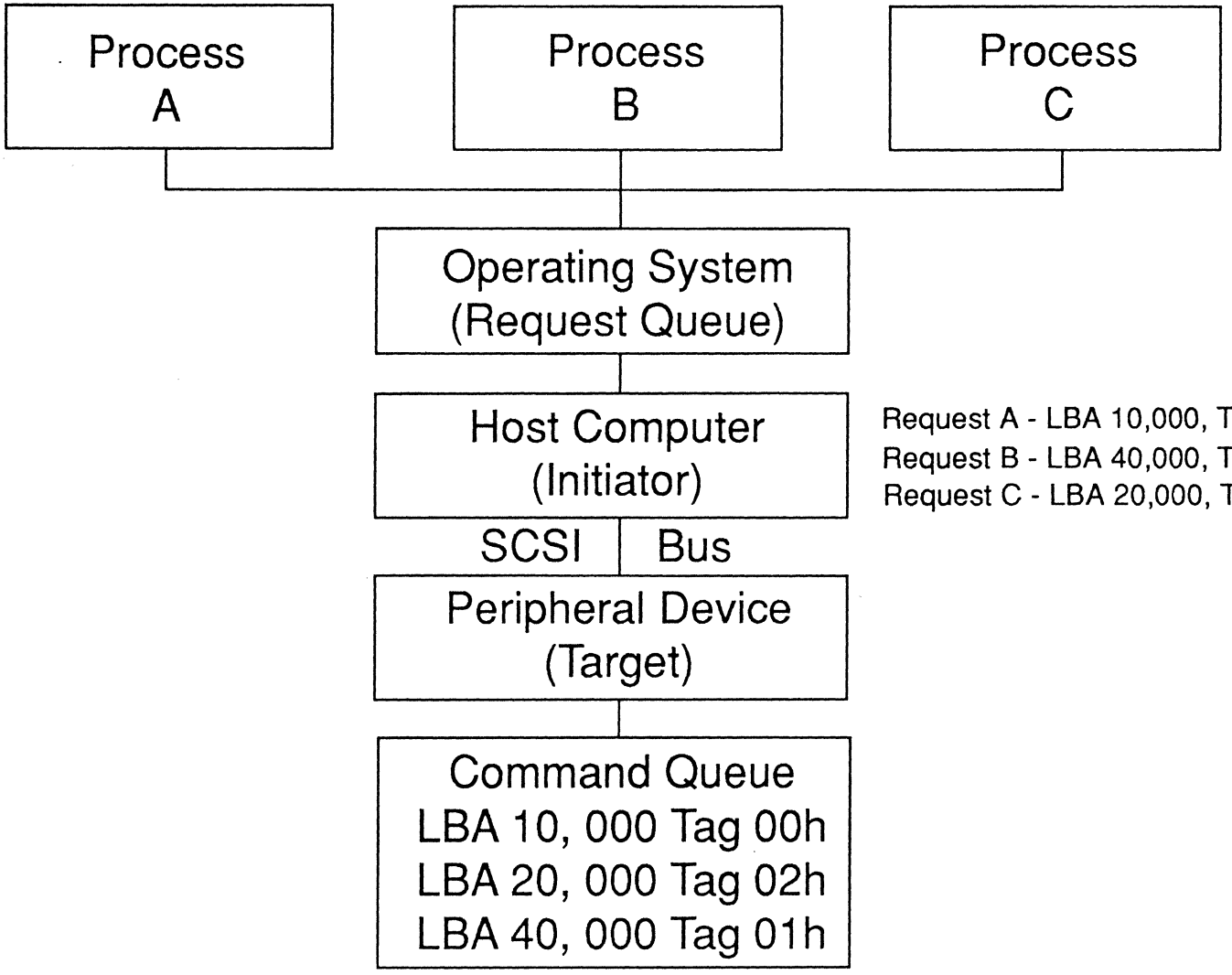

- Multiple Initiators Send One Command Each, to the Same Target/L.U.
- Optional feature in SCSI-1 and SCSI-2.

# Tagged Queueing

## The Problem



# Tagged Queueing
## (Continued)
## The Solution



# Tagged Queueing
## (Continued)

- Types of Queueing:

| | |
|---|---|
| Simple | Target decides order (e.g., elevator seek) |
| Head of Queue | Last In First Out |
| Ordered | Initiator decides order (First In First Out) |

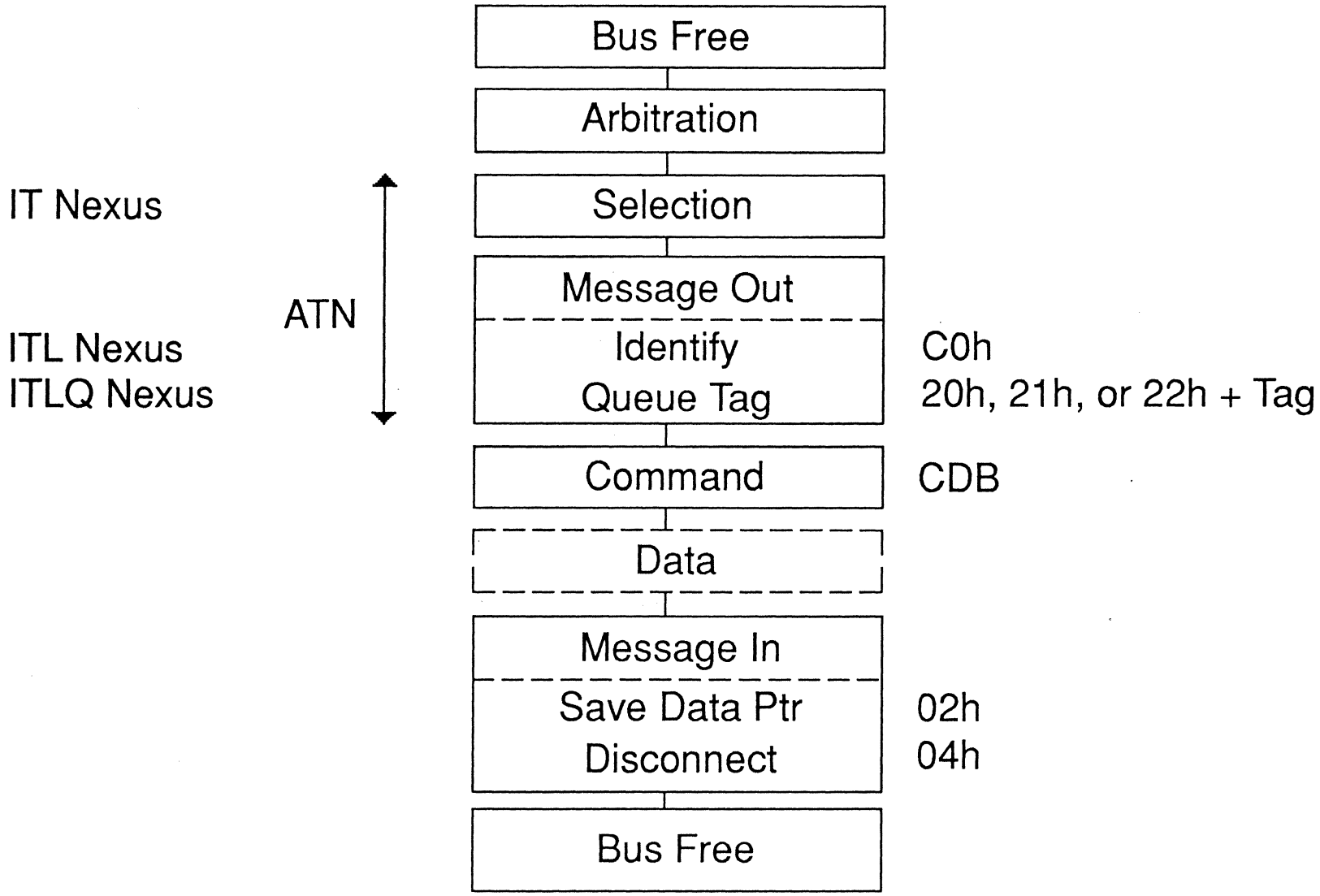
- Example: Requests for LBA 10,000 40,000 20,000 - Drive is at LBA 0

| | | | |
|---|---|---|---|
| Simple | 10,000 | 20,000 | 40,000 |
| Head of Queue | 20,000 | 40,000 | 10,000 |
| Ordered | 10,000 | 40,000 | 20,000 |

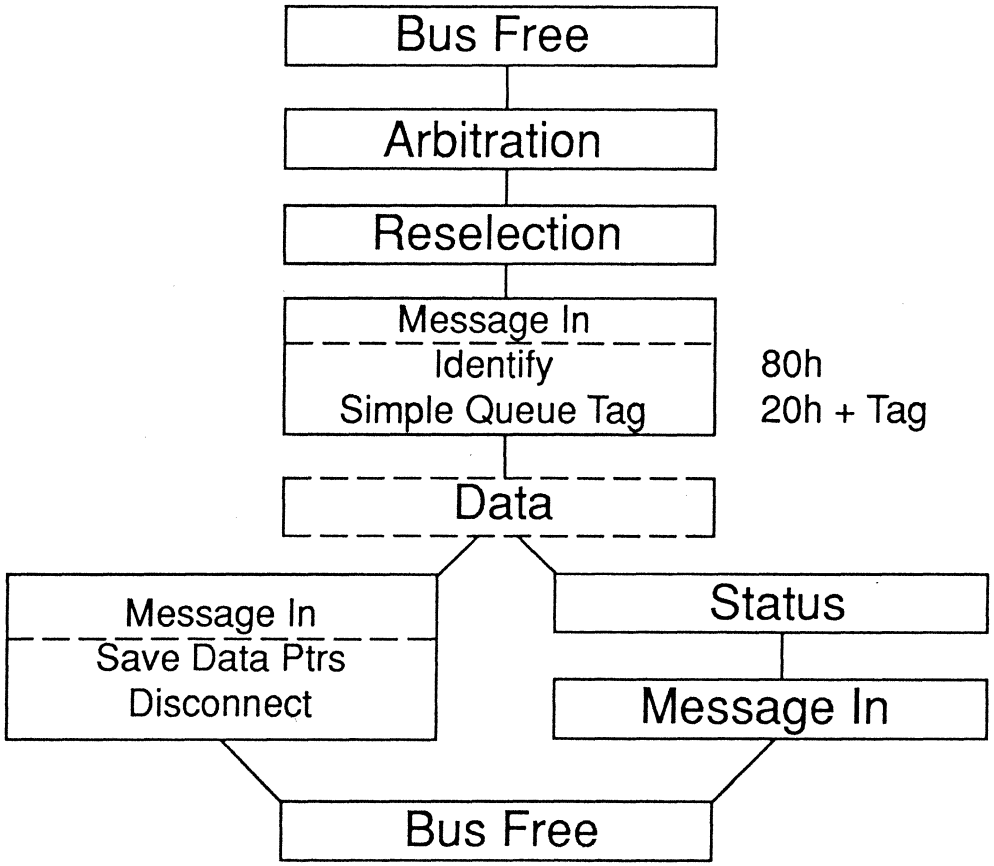
- Messages:

| Code | | Name | Direction |
|---|---|---|---|
| 20h | Tag | Simple Queue | Out/In |
| 21h | Tag | Head of Queue | Out |
| 22h | Tag | Ordered Queue | Out |

# Tagged Queueing
## (Continued)
## Connection



# Tagged Queueing
## (Continued)
## Reconnection



# Tagged Queueing
(Continued)
Rules

- Optional Feature
- Maximum of 256 Queued Commands (I/O processes) per ITL, each with Unique Tag
- Tags are assigned by the Initiator.
- When Queue is Full, QUEUE FULL status is Returned to Tagged Commands and BUSY to Untagged Ones.
- When Queued Commands are Pending Without Contingent Allegiance, Commands Without Disconnect Privilege Result In BUSY Status, and Untagged Commands from the Same Initiator Result in CHECK CONDITION Status (Aborted Command Sense Key).

# Tagged Queueing
## (Continued)
## More Rules

- Ordered Commands are Executed in the Order Received (Initiator Order).
- Simple Commands are Executed in the Order Determined by the Target (Target Order).
- If a Set of Simple Commands is Received Before a Set of Ordered Ones, the Simple Commands are Executed First, and Vice Versa.
- Linked Commands Use One Queue Tag, i.e., They are Considered a Single I/O Process.

# I/O Process Termination Messages

| | | |
|---|---|---|
| Bus Device Reset | 0Ch | Clear All Commands from All Initiators<br>Perform Reset Function<br>Report Unit Attention |
| Clear Queue | 0Eh | Clear All Commands from All Initiators<br>Report Unit Attention |
| Abort | 06h | Clear All Commands from this Initiator<br>No Sense Data |
| Abort Tag | 0Dh | Clear Current command from this Initiator<br>No Sense Data |
| Terminate I/O Process | 11h | Finish Command if possible<br>Return COMMAND TERMINATED status<br>Prepare Sense Data<br>(Sense Key = Aborted Command) |

# PRACTICAL ASPECTS

# SCSI Testing

- Types of Testers:
  - Bus Monitors
  - Logic Analyzers
  - Initiator Emulators
  - Target Emulators
  - Multiport Test Systems

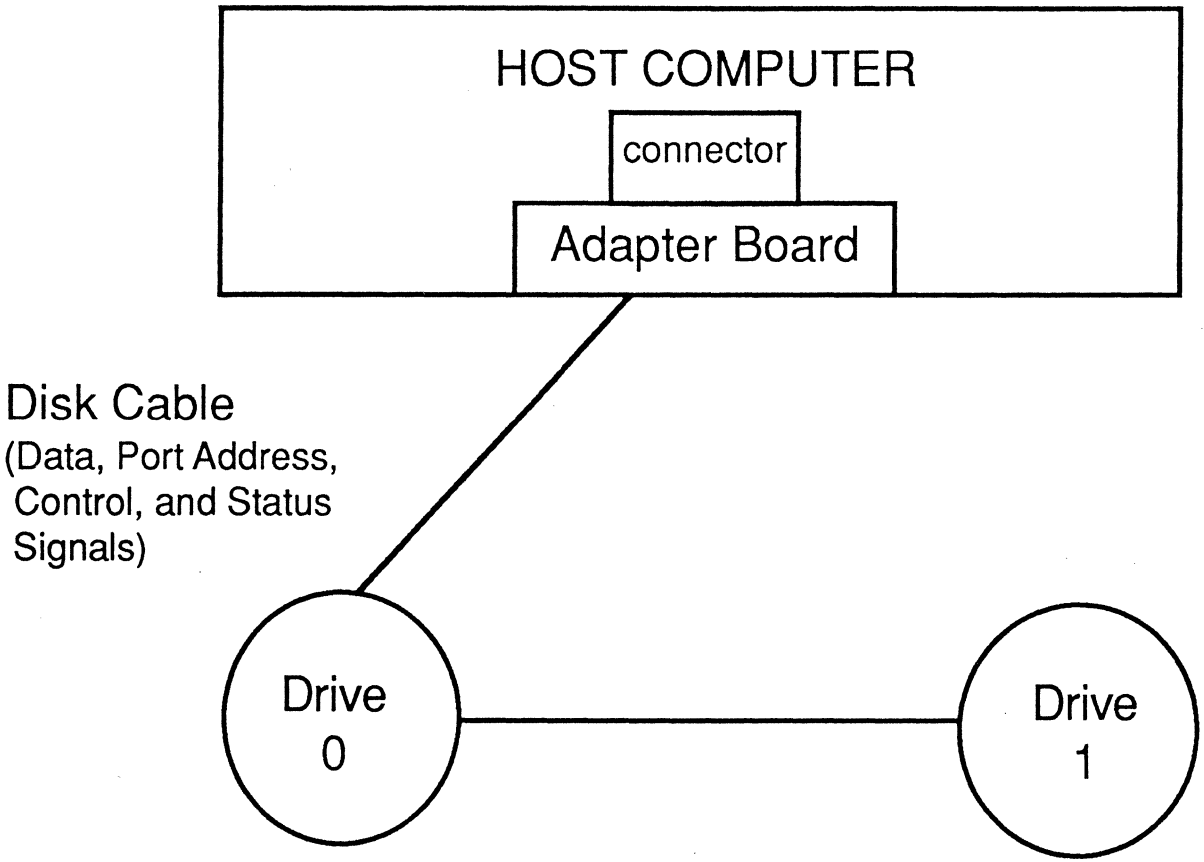
- Types of Testing
  - SCSI Protocol Compliance under legal and illegal conditions:
    commands, messages, etc.
  - Device Hardware Operation:
    read, write, seek, etc.
  - Traditional analog testing through SCSI cable not possible

# SCSI Testing
(Continued)
Self-Test

- Download Test Firmware Using Write Buffer or Vendor-Unique Command
- Start Test Using Send Diagnostic or Vendor-Unique Command
- Upload Results Using Receive Diagnostic or Vendor-Unique Command
- Types of Testing:
  - Seek
  - Write/Read
  - Media Scan
- SCSI Interface Still Needs Testing

# ATA Bus

(PC AT is a registered trademark of IBM)



# ATA Bus
(Continued)

- ATA - Advanced Technology (AT) Attachment
  IDE - Integrated Drive Electronics

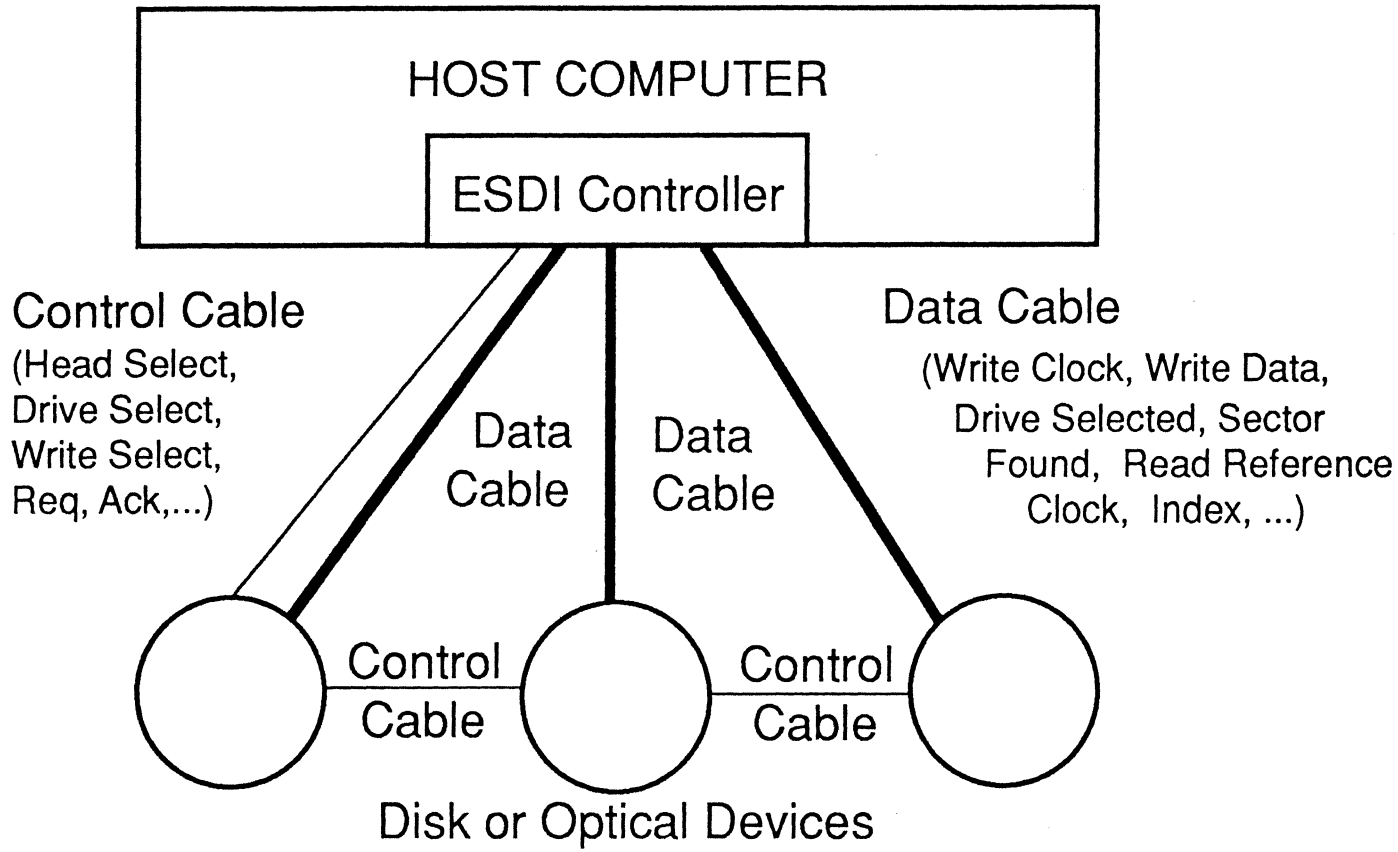
- Mandatory Commands:

  Recalibrate
  Seek
  Read
  Write
  Read Long
  Write Long
  Format Track
  Read Verify
  Execute Drive Diagnostics
  Initialize Parameters (heads and sectors per track)

# ATA Bus
## (Continued)

- Cylinder, Head, Sector Addressing.
- For in-cabinet Application (18" cable).
- 512 Bytes Per Sector.
- Host Driven (Target Follows Host).
- Disk Task File Interface - 8 Registers (ports):
  - Data
  - Error (bits) or Write Precomp
  - Sector Count (Decremented During Transfer)
  - Sector Number (Incremented During Transfer)
  - Low Cylinder
  - High Cylinder
  - Drive/Head
  - Command or Status

# ESDI Bus

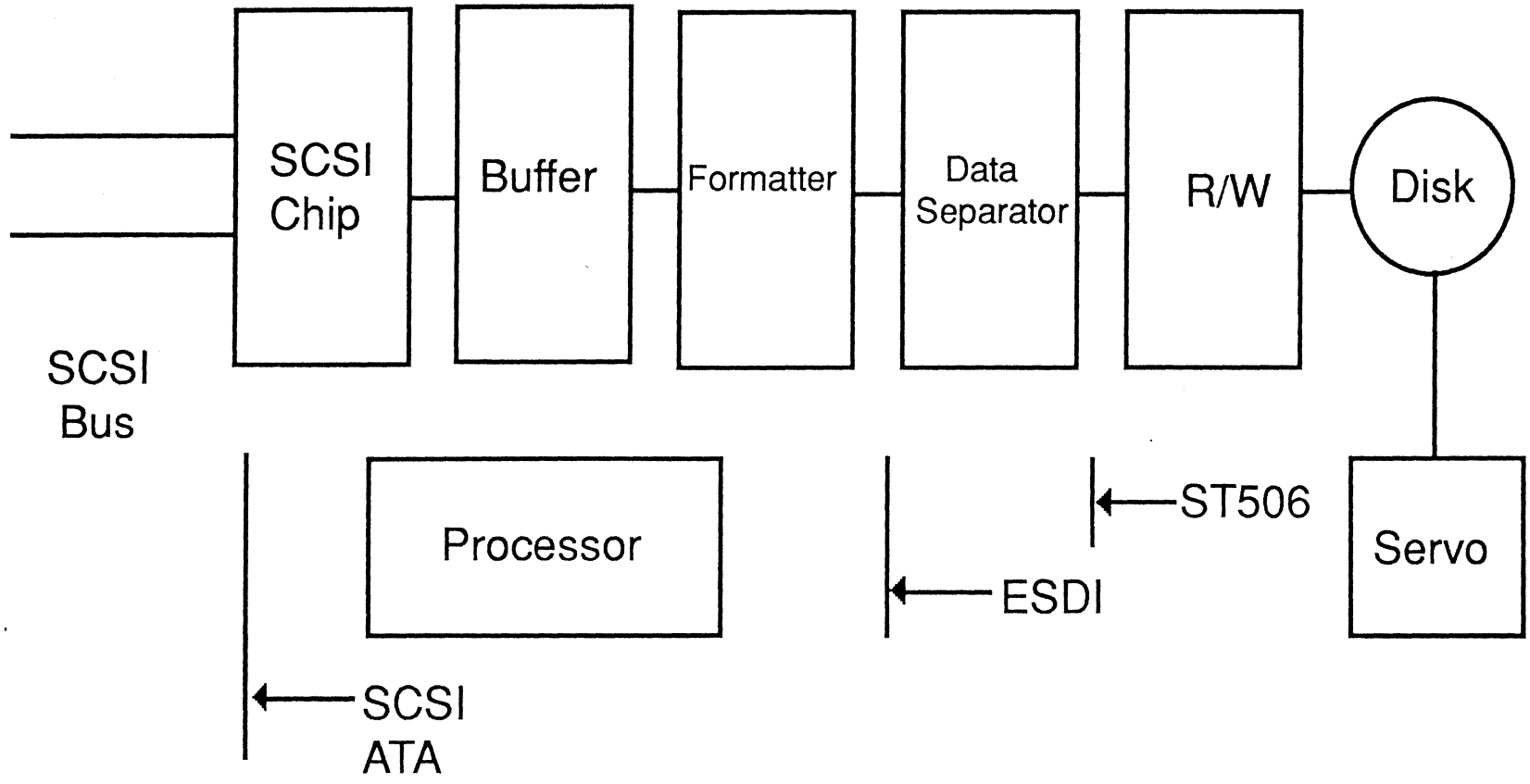

HOST COMPUTER
ESDI Controller
Control Cable
(Head Select,
Drive Select,
Write Select,
Req, Ack,...)
Data Cable
Data Cable
Data Cable
(Write Clock, Write Data,
Drive Selected, Sector
Found, Read Reference
Clock, Index, ...)
Control
Cable
Control
Cable
Disk or Optical Devices

# ESDI Bus
## (Continued)

- Enhanced Small Device Interface.
- Magnetic and Optical Disk.
- One to Seven Devices Per Controller.
- Up to 24 Mbits/second.
- Disk Commands (16 bits plus parity):

| | |
|---|---|
| Seek | Data Strobe Offset |
| Recalibrate | Track Offset |
| Request Status | Initiate Diagnostics |
| Request Configuration | Set Unformatted Bytes/Sector |
| Select Head Group | Set High Order Value |
| Control (reset, start,...) | Set Configuration |

# Interface Function Comparison



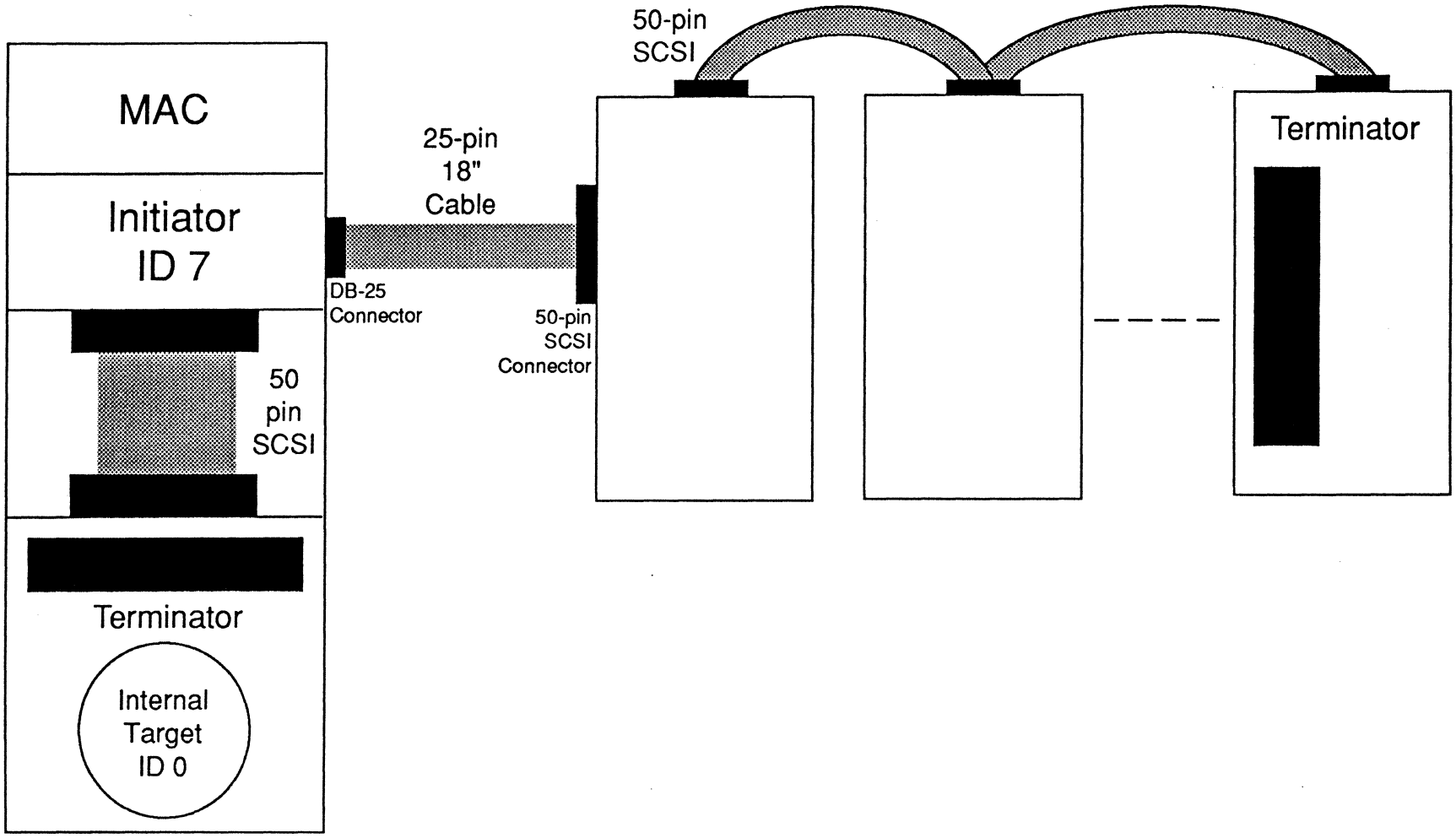
# Apple SCSI

*(Apple and Macintosh are registered trademarks of Apple Computer, Inc.)*

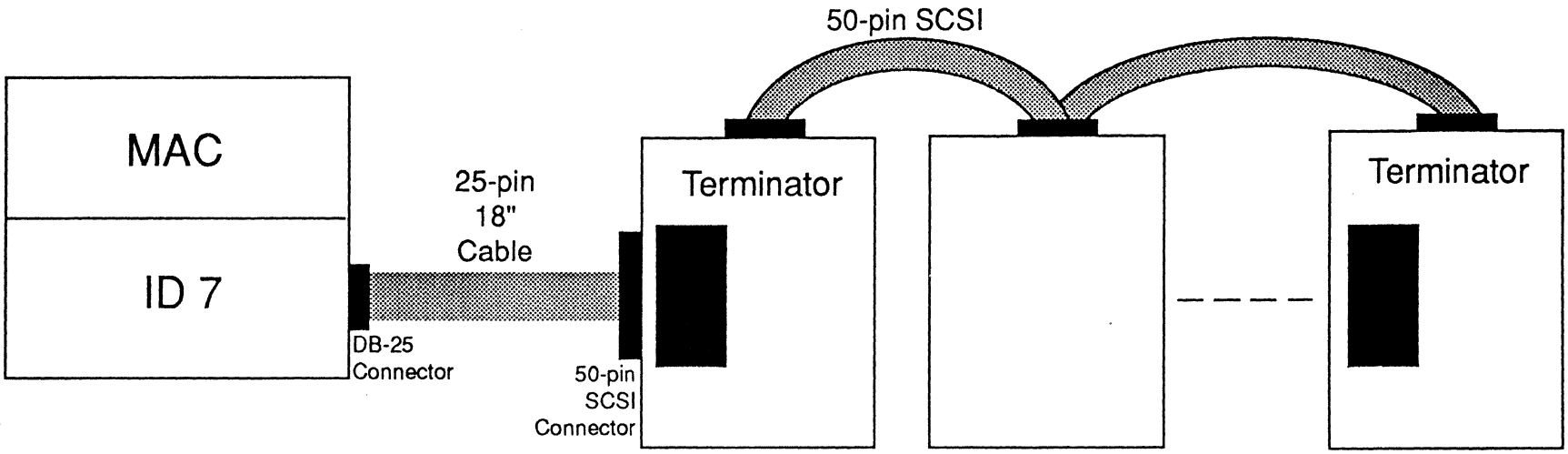
## Hardware

- Single-ended
- Asynchronous
- External 25-pin Apple SCSI connector (DB-25):
  - 18 Lines for Standard SCSI Control, Data, and Parity Signals
  - TERMPWR on pin 25
- Terminator power may or may not be supplied by Mac (model-dependent)
- Internal termination may or may not be installed on host

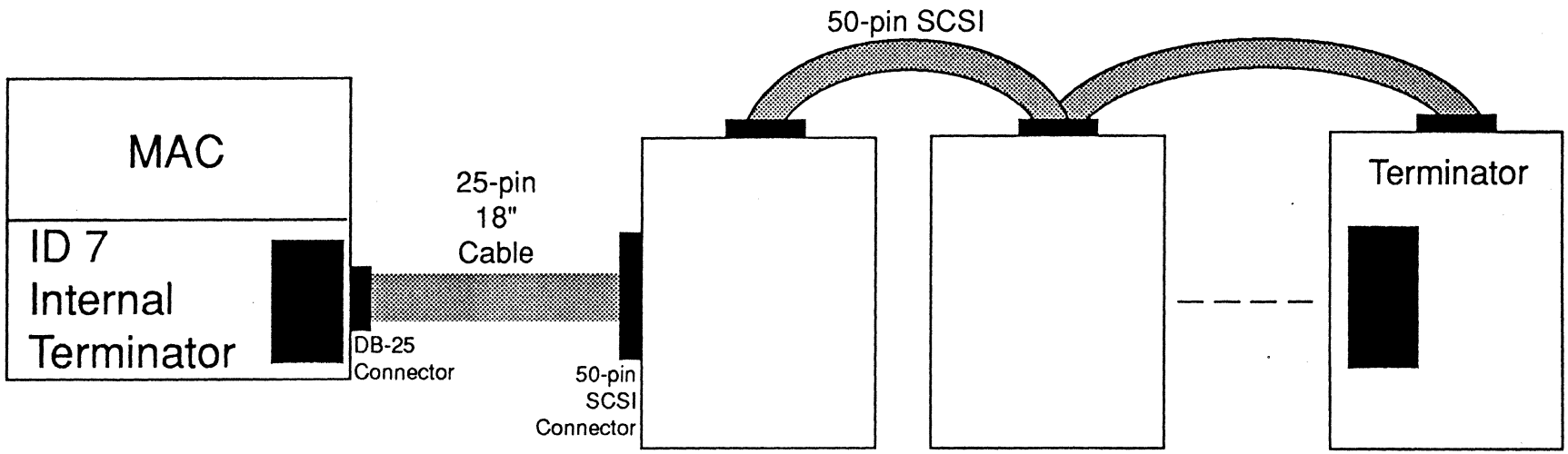
# Apple SCSI
## (Continued)
### Optional Internal Drive Configuration
(e.g., Mac-SE and Mac-II)



# Apple SCSI
## (Continued)
### External Drive Configuration - No Internal Termination
(e.g., Mac-Plus)



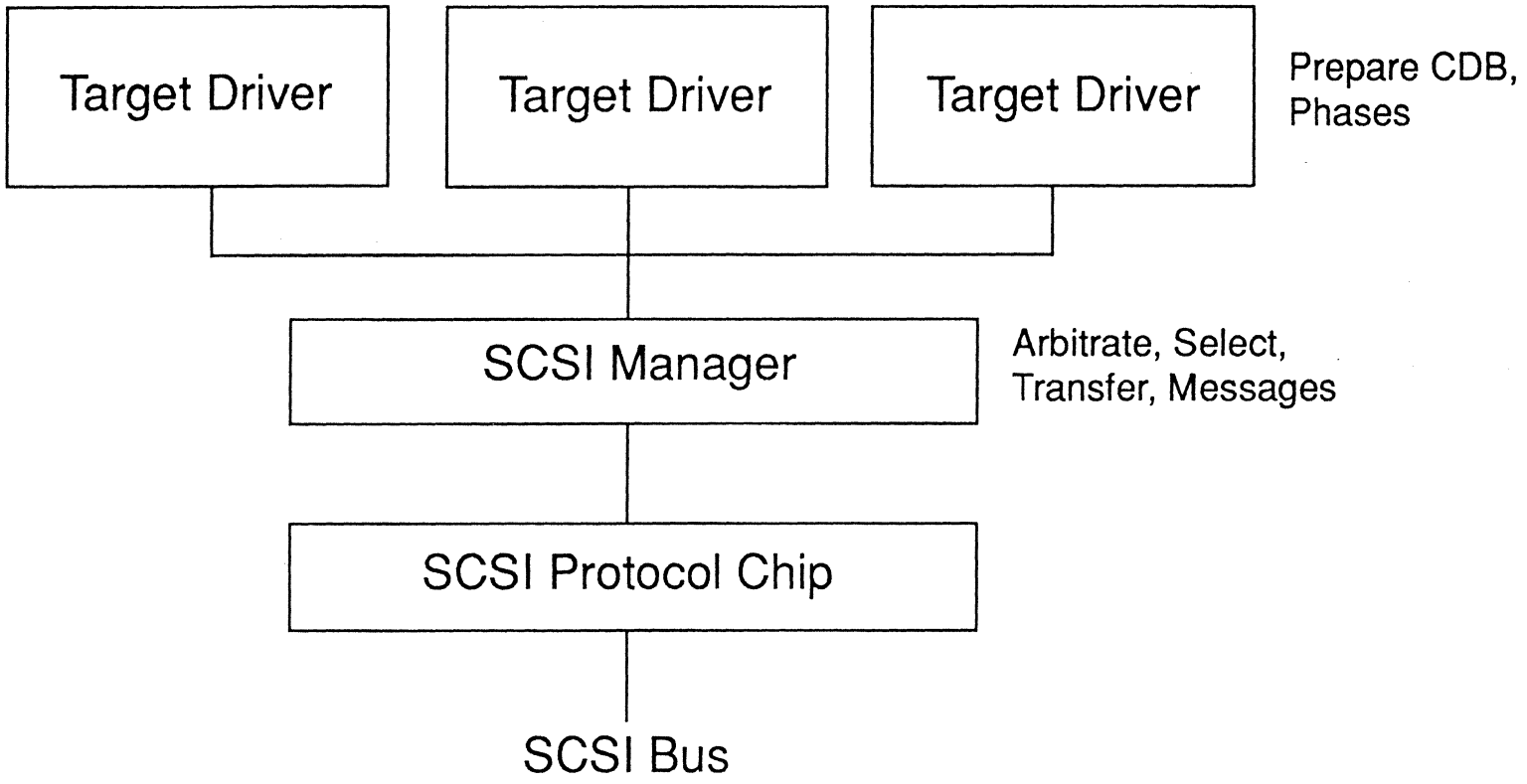
# Apple SCSI
## (Continued)
### External Drive Configuration-With Internal Termination
(e.g., Mac-FX)



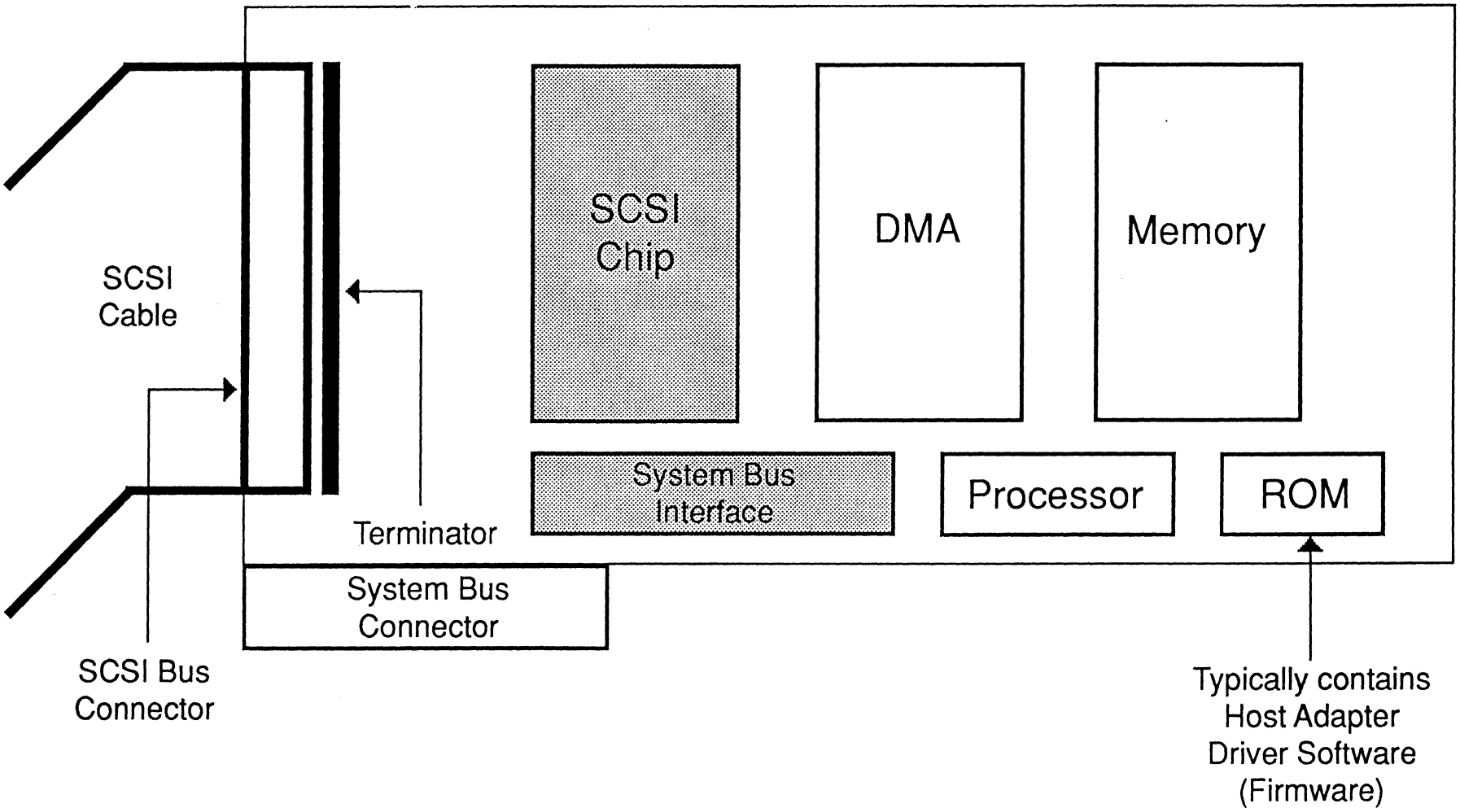
# Apple SCSI
## (Continued)
### Software

- CCS Based
- Selection without Attention
- Identify message not sent
- Disconnect/Reconnect not supported
- Unit Attention not allowed in some models (Mac-Plus)

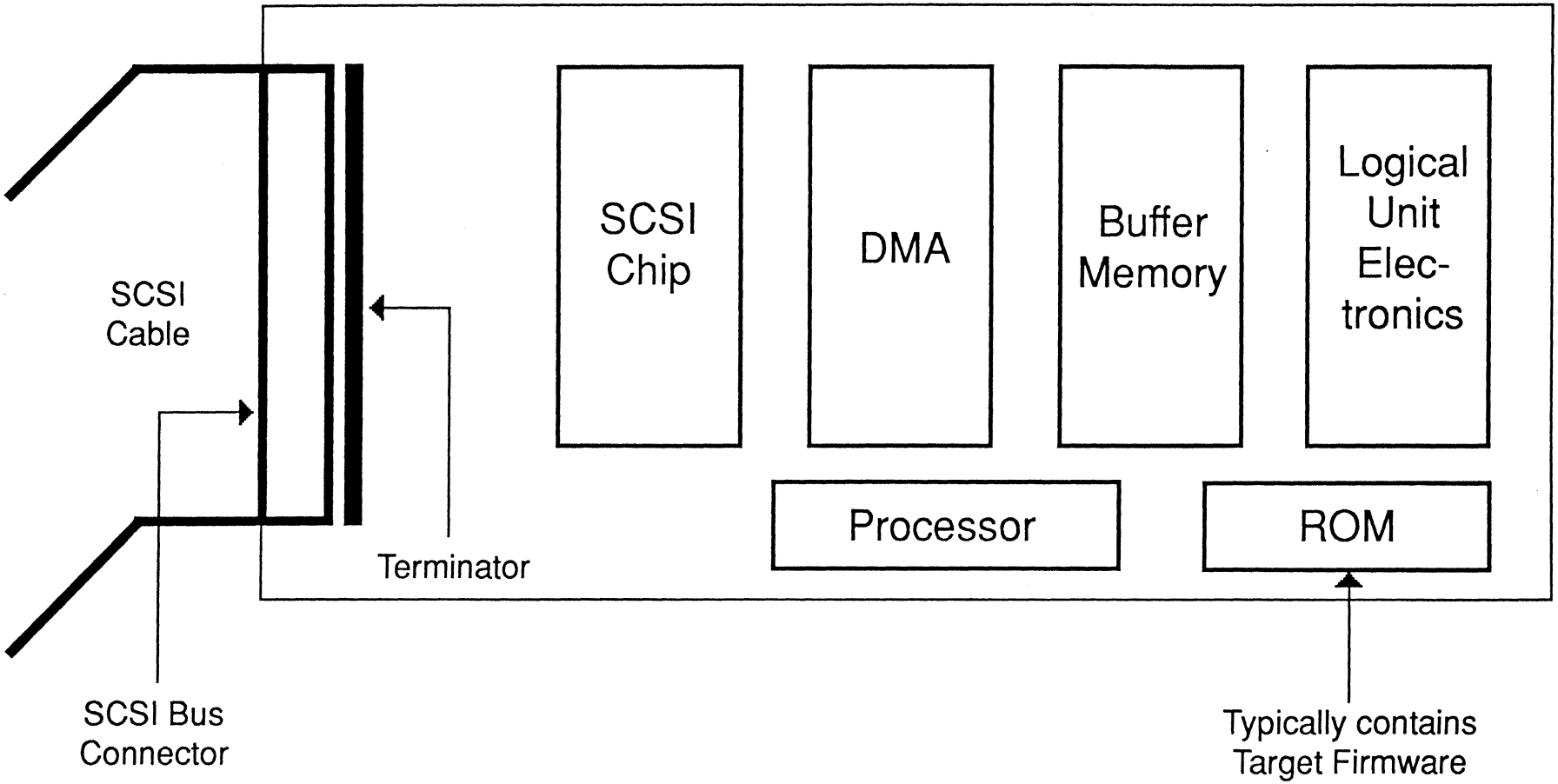
# Apple SCSI
## (Continued)
### Software Architecture



# Host Adapters



# Target Controllers



# Target Firmware
## Initialization

Initialize Hardware

Read Configuration Jumpers

Initialize Device - Spin Up, Rewind, etc.

Read Saved or Default Mode Parameters

Setup Unit Attention Condition

# Target Firmware
## (Continued)
### Common Execution Loop

Chip Command

- Wait for Selection
- Check ATN
- Receive Message Out
- Receive First CDB Byte:
  - Determine CDB Length
- Receive Remaining CDB Bytes
- Check CDB Validity
- Check Reservation Conflict
- Check Contingent Allegiance
- Execute Command:
  - Transfer Data
  - Disconnect/Reconnect

Chip Command

- Send Status Byte
- Send Message In Byte
- Free Bus

# SCSI Chips
## Functions Provided by Chips

- Bus Timings
- Bus Phases
- Parity generation and checking
- SCSI ID
- REQ/ACK handshake
- Synchronous FIFO
- DMA interface
- Microprocessor interface
- Single-ended Chips usually include Drivers and Receivers

# SCSI Chips
## (Continued)

- Chips normally support initiator and target modes

- Initiator Mode Functions:
  - Arbitrate and Select
  - Set ATN
  - Get Phase
  - Wait for Reselection and respond to it

- Target Mode Functions:
  - Arbitrate and Reselect
  - Wait for Selection and respond to it
  - Set Phase

- Transfer Methods:
  - DMA - Direct Memory Access
    (Multiple bytes at hardware speed)
  - PIO - Programmed I/O
    (Single byte at a time)

# SCSI Chips
(Continued)

- Interrupts:
  - Reset
  - Parity Error
  - Chip Command Done
  - Selected/Reselected
  - Bus Free (Initiator Mode)
  - Phase Change (Initiator Mode)
  - ATN (Target Mode)

- Chip Generations:
  - First Generation: Asynchronous, Many Interrupts
  - Second Generation: Synchronous, Less Interrupts
  - Third Generation: Built-in Sequencer, Less Interrupts, Handles Basic Sequences Except Error Conditions
  - Fourth Generation: Built-in RISC Processor, No Interrupts, Can Handle Everything Based on User Code

# SCSI Chips
## (Continued)
### Hypothetical Chip Register Set
### (All registers are read/write)

MODE PORT
bit description
0 initiator/target
1 selection watch
2 reselection watch
3 parity
4 interrupt
5 auto ATN on error

COMMAND PORT
val description
0 initialize chip
1 arbitrate/select
2 arbitrate/reselect
3 transfer
4 arb/sel/transfer
5 arb/resel/transfer
6 abort

INTERRUPT PORT
bit description
0 reset detected
1 chip command done
2 selected
3 reselected
4 bus free (initiator)
5 phase change (initiator)
6 ATN detected (target)
7 parity error
8 time out

SCSI SIGNALS PORT
bit description
0 BSY (target)
1 C/D (target)
2 I/O (target)
3 MSG (target)
4 REQ (target)
5 ACK (initiator)
6 ATN (initiator)
7 RST

SOURCE ID PORT

DESTINATION ID PORT

OFFSET PORT

PERIOD PORT

TIMEOUT PORT

DATA BUS PORT

CMD PTR PORT
auto increments

STATUS PTR PORT
auto increments

DATA PTR PORT
auto increments

MSG PTR PORT
auto increments

CMD LENGTH PORT
auto decrements

STATUS LENGTH PORT
auto decrements

DATA LENGTH PORT
auto decrements

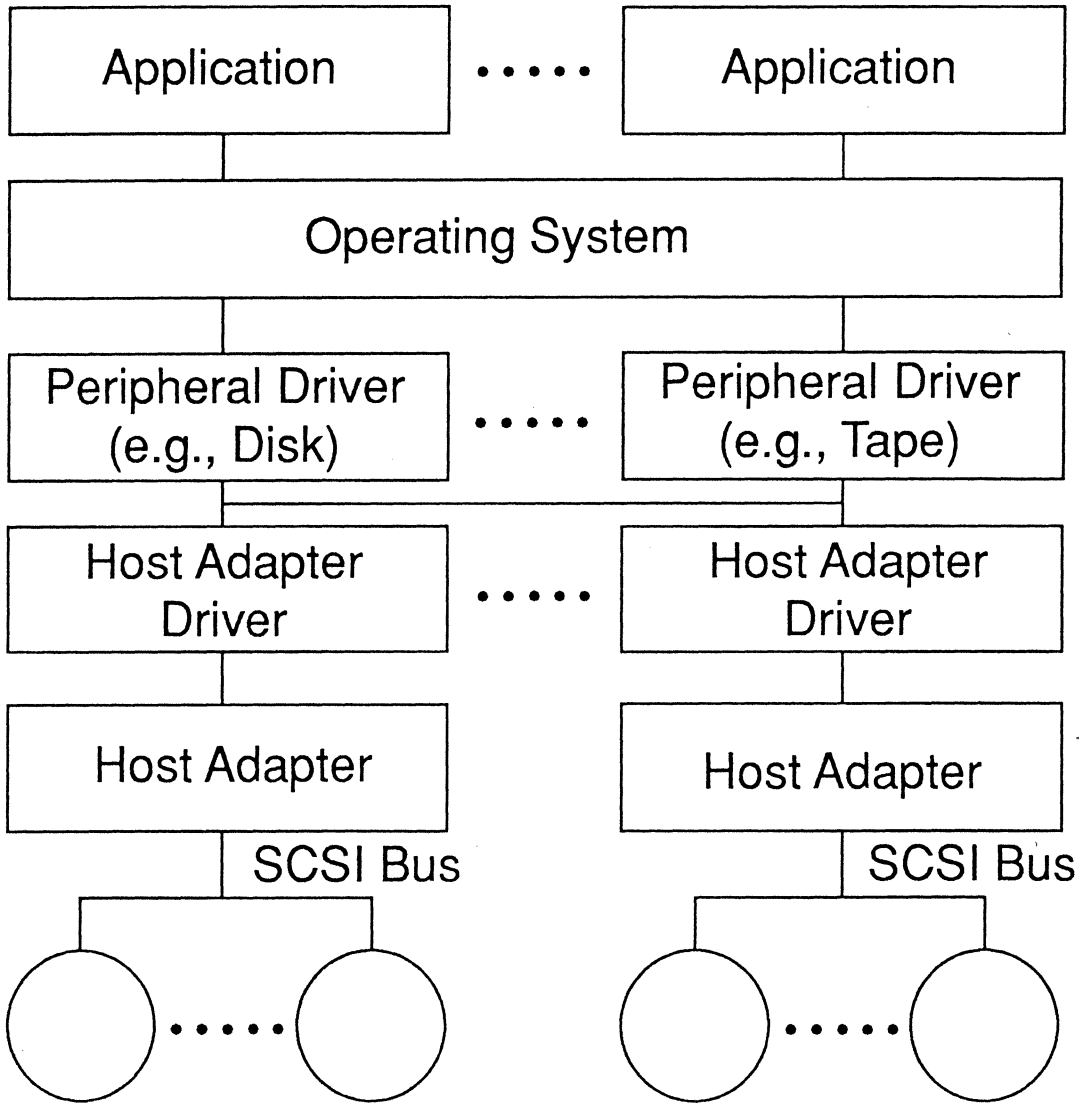
MSG LENGTH PORT
auto decrements

# Host Device Drivers
## Initialization

Single-Initiator System

- Initialize hardware and SCSI chip
- If not Bus Free, Reset Bus
- Scan the Bus (Determine Present Devices):
  - For All SCSI Addresses Except Mine:
    - Send Inquiry Command
    - Negotiate for Synchronous Transfer
    - If Selection Time out, Device not Present
- Initialize Present Devices:
  - Clear Unit Attention
  - Start Stopped Drives
  - Mode Select (If required)
- Find Device Characteristics:
  - Device Type, Compliance, Vendor,...
  - Capacity
  - Mode Sense Parameters

# Host Device Drivers
(Continued)



# Host Device Drivers
(Continued)

- Host Adapter Driver
  - Host Adapter Specific
  - Arbitrates, selects, then follows the target phases
  - Does Not Interpret Commands
  - Handles Data Pointers
  - Handles Messages
  - May Handle CHECK CONDITION

- Peripheral Driver
  - Operating System and Device Specific
  - Prepares CDBs
  - Calls the Host Adapter Driver to execute the command
  - Handles Some Status Errors

# Host Device Drivers
## (Continued)
## SCSI Driver Error Handling

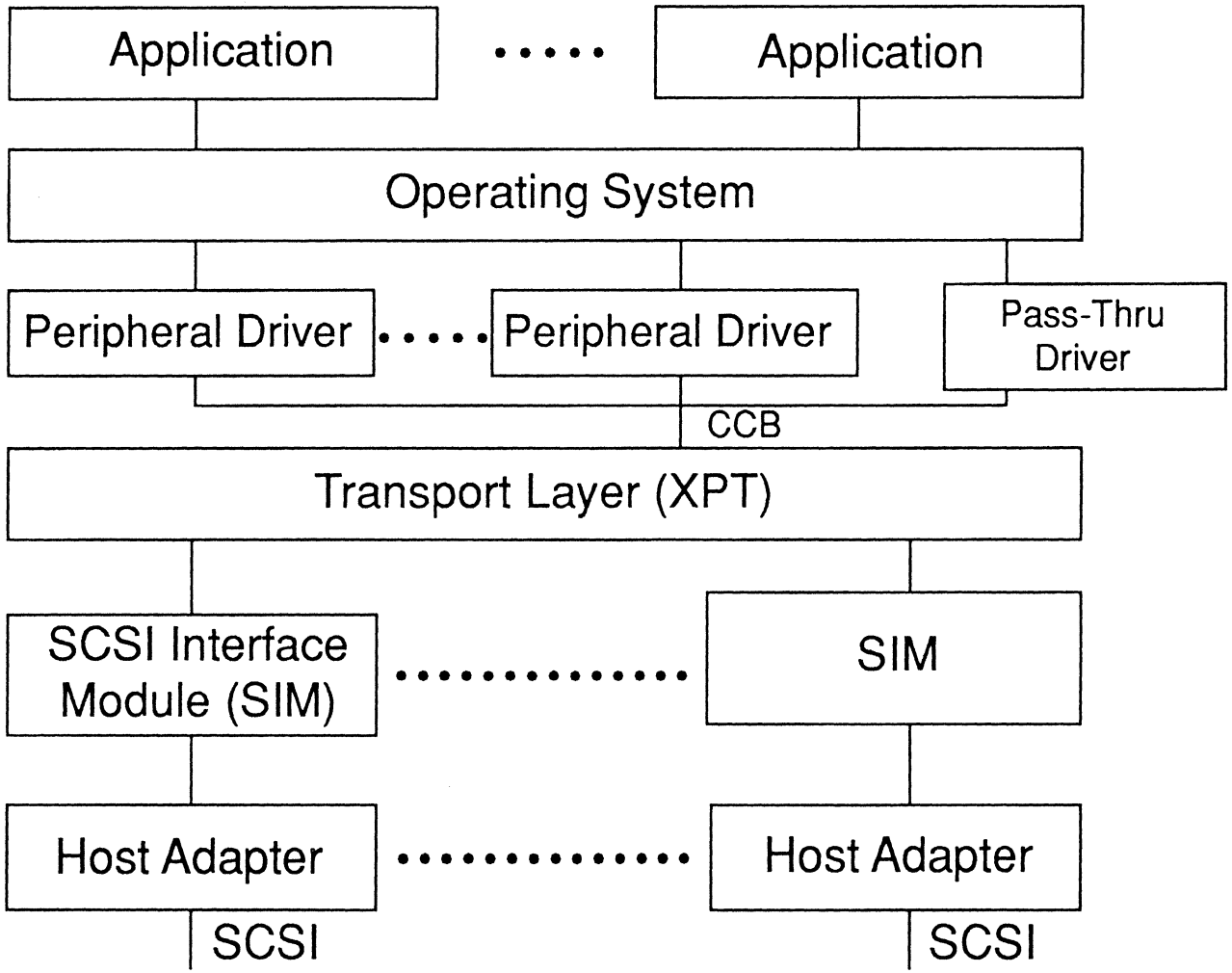
Error Types:

- Errors Reported by Target:
  - Status
  - Check Condition/Sense
  - Unexpected Disconnect
- Errors Detected by Driver:
  - Arbitration Loss
  - Selection Timeout
  - Command Timeout
  - Data Underrun
  - Data Overrun
  - Reset Detected
  - Invalid Bus Phase
  - etc.

Error Handling:

- Analyze
- Retry
- Reassign Block (Repeatable Recovered and Write Medium Errors)
- Bus Device Reset Message
- Bus Reset
- Report Error Details to Operating System
- Keep Statistics

# Common Access Method (CAM)




• See next page for details.

# Common Access Method (CAM)
(Continued)

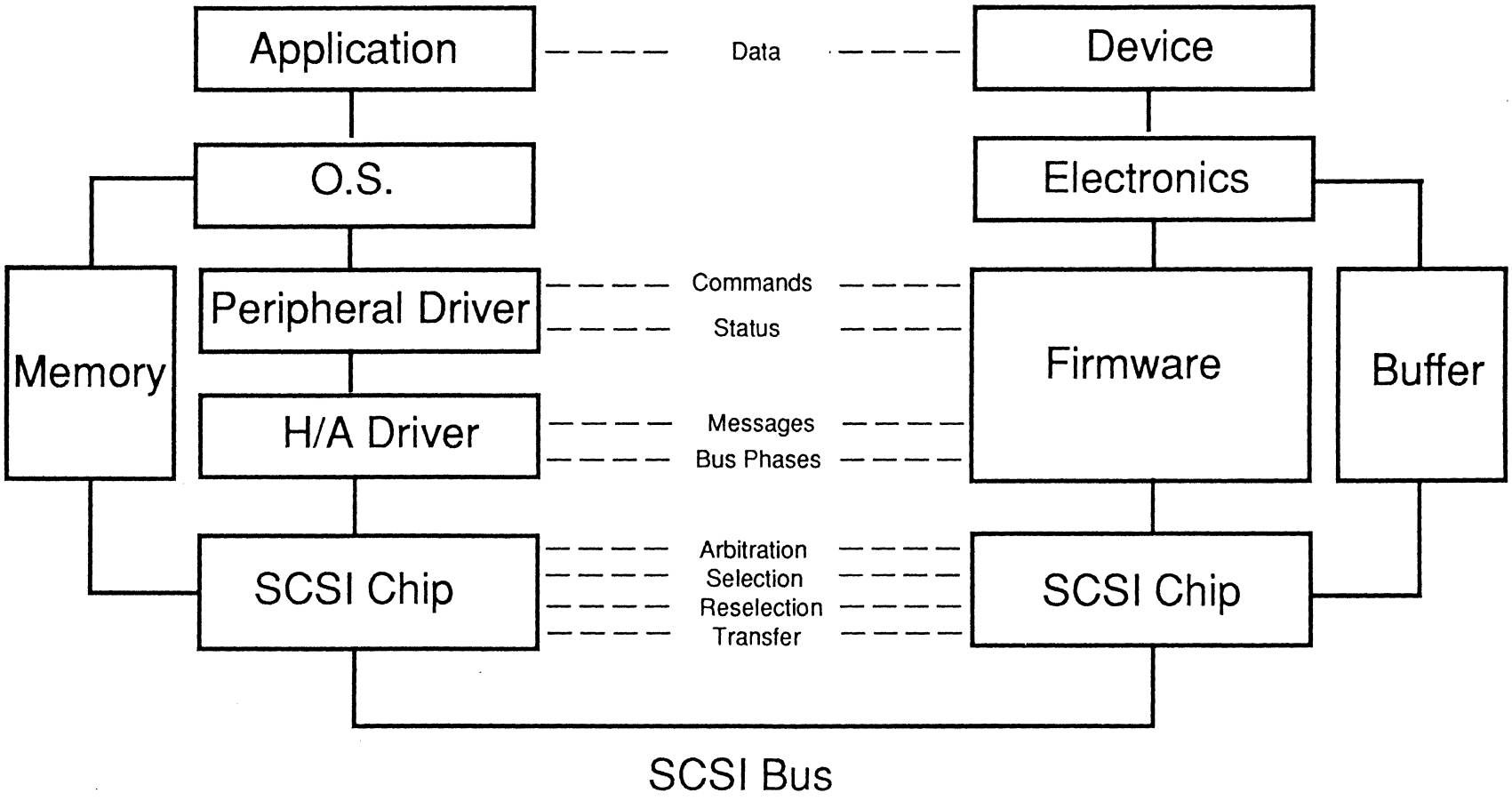
- Pass-through Driver:
  - for diagnostics

- Transport Layer (XPT) responsibilities:
  - system initialization, including bus scan
  - routing of requests from Peripheral Drivers to the proper SIM

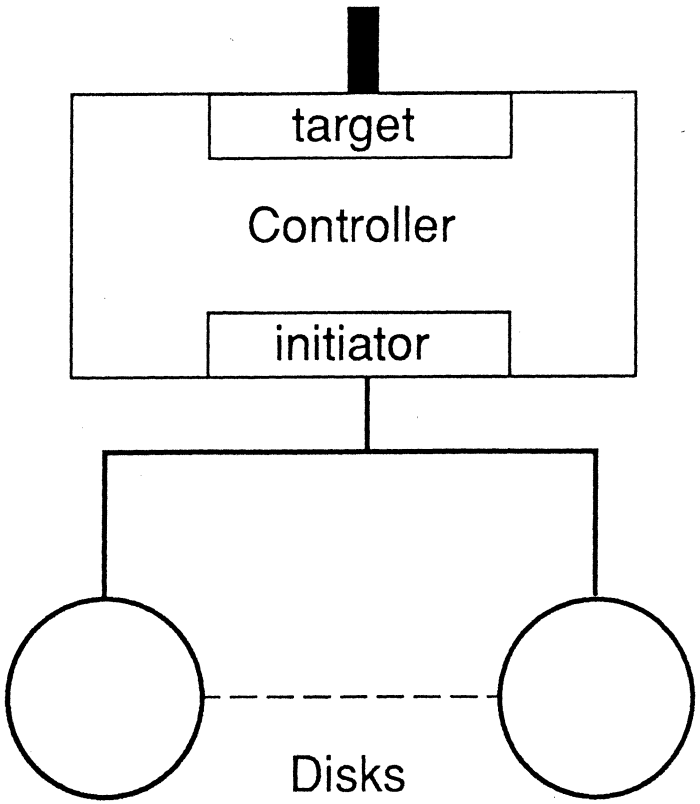
- SCSI Interface Module (SIM):
  - host adapter driver

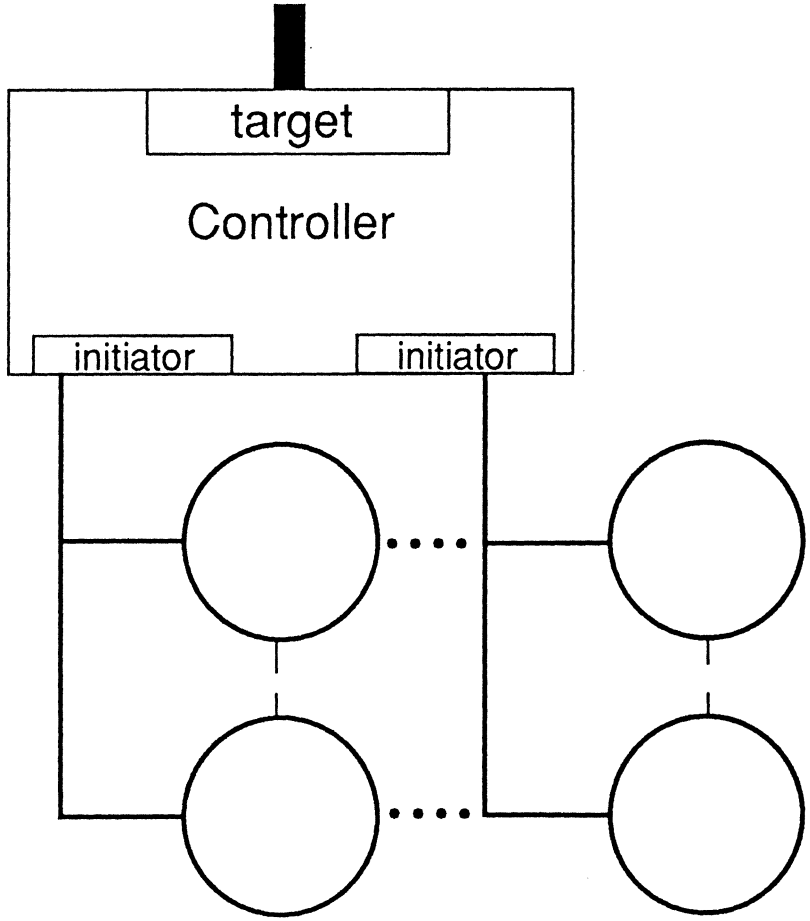
- CAM Control Block (CCB):
  - a block of bytes prepared by the Peripheral Driver and sent to the XPT, which may route it to the proper SIM
  - may contain description of the SCSI command to execute, such as target ID, LUN, CDB, data pointers, and timeout.

# System Interactions



# Disk Arrays


target
Controller
initiator
Disks


target
Controller
initiator
initiator

# Disk Arrays
(Continued)

**Advantages:**

- Increased capacity
- Data redundancy: mirroring and down-time minimization
- Performance: parallel execution

**RAID - Redundant Array of Inexpensive Disks**

- Different methods (called levels) for connecting drives to the controller

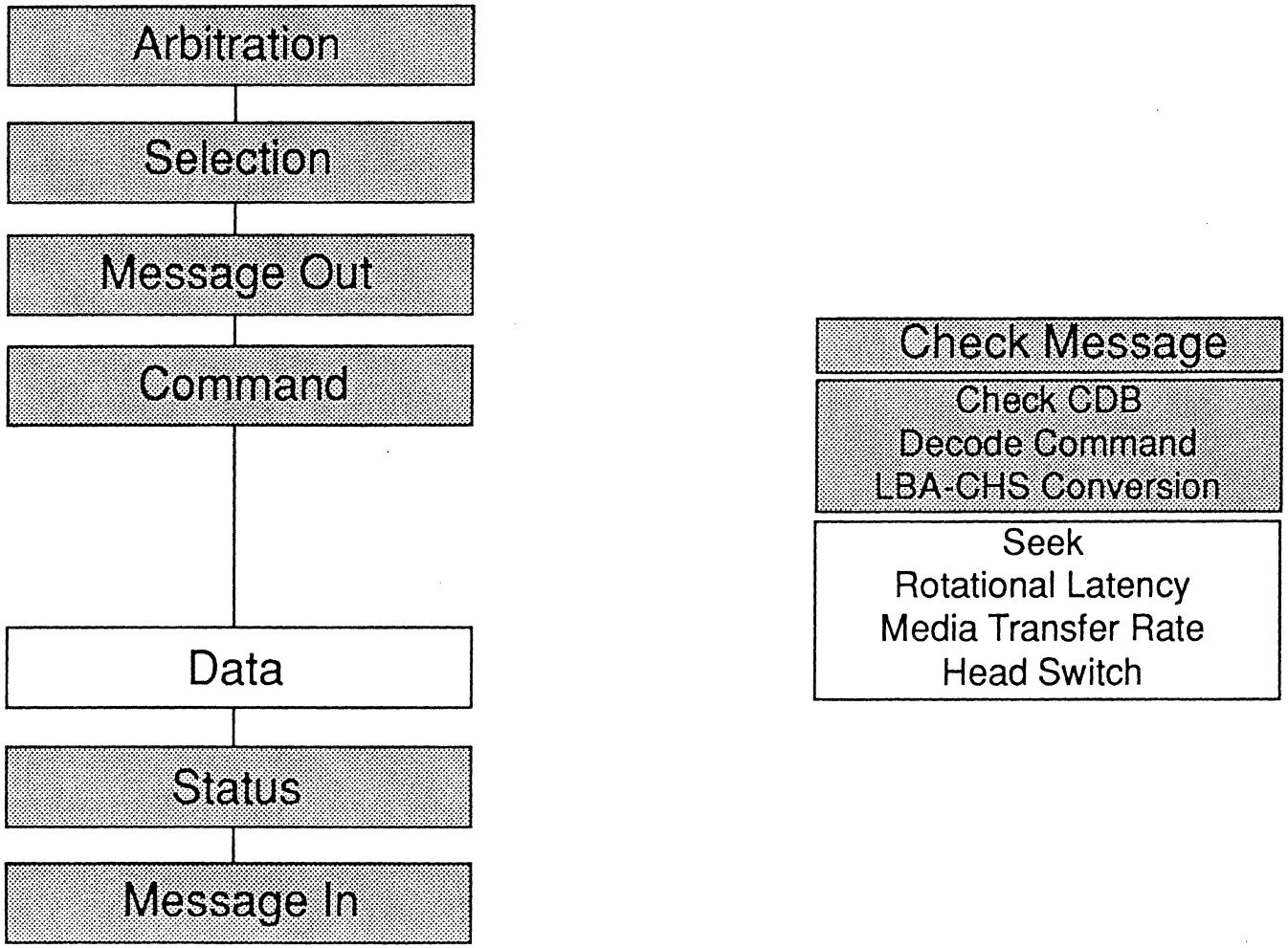
# Cache

- Write Cache:
  - Target report Good status when all Write data is received in its buffer, and writes the data to the media in the background later.

- Read Cache:
  - After Read commands, target prefetches next blocks into its buffer in the background.

- Mode Select Page 8 has cache parameters such as:
  - cache enable/disable
  - maximum prefetch: number of blocks to prefetch under normal conditions.
  - minimum prefetch: number of blocks to prefetch when new command is received while prefetching.

# SCSI Command Overhead



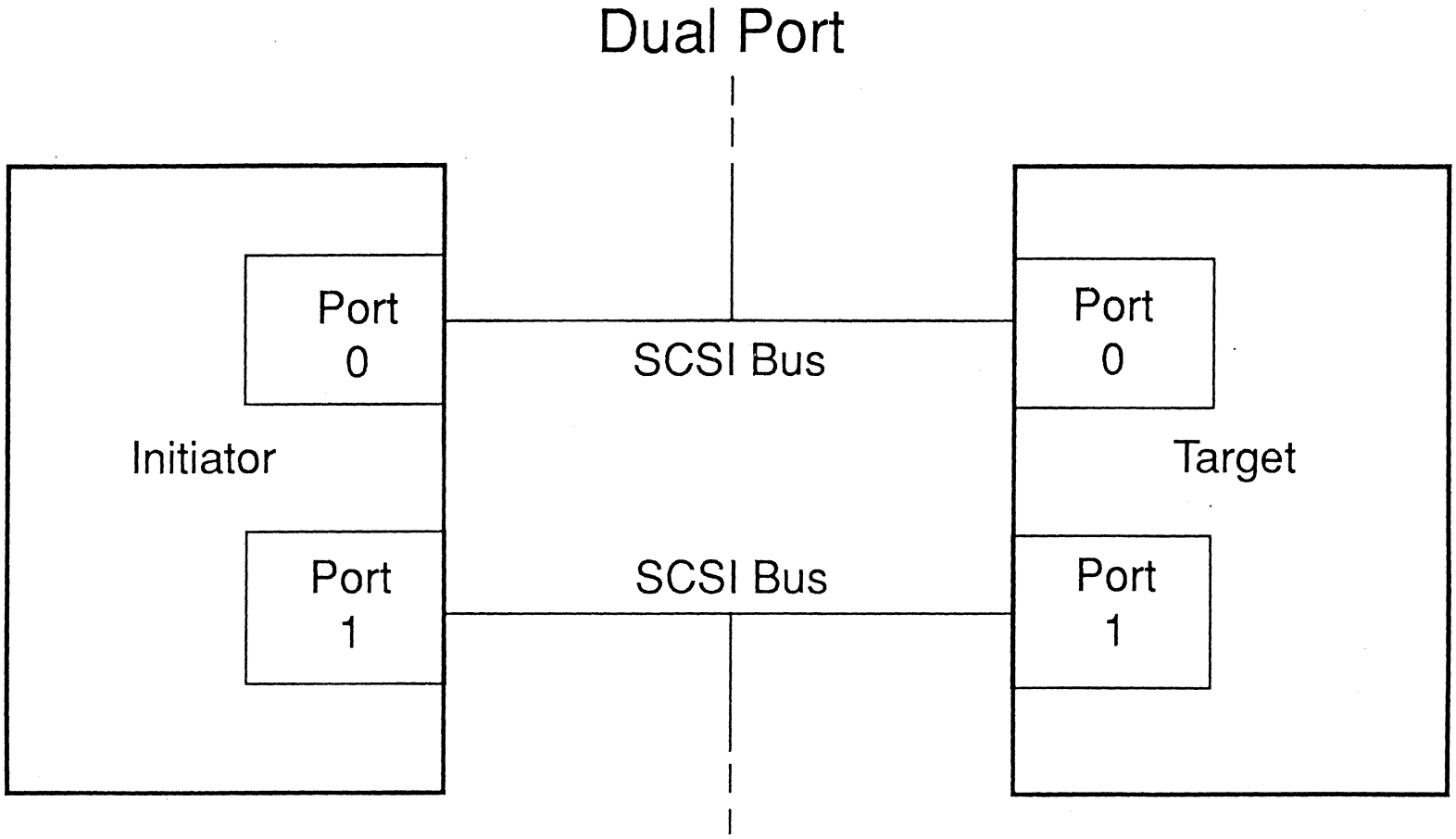
# Advantages of SCSI

- Interface with different device types done through the same cable
  - easy integration
  - expansive
  - multi-media applications
- Peripheral devices of the same type have similar characteristics
  - easy to replace drives with new ones
- Peripheral devices are intelligent and independent
  - frees up the computer to do other work
- I/O is independent of system bus
  - peripheral devices can work with different computer types
  - preserves computer hardware investment
- Fast hardware
  - 10 MB/sec on 8 bit bus, 20 MB/sec on 16 bit bus
- Fast software
  - multi-threaded using disconnect/reconnect and queueing

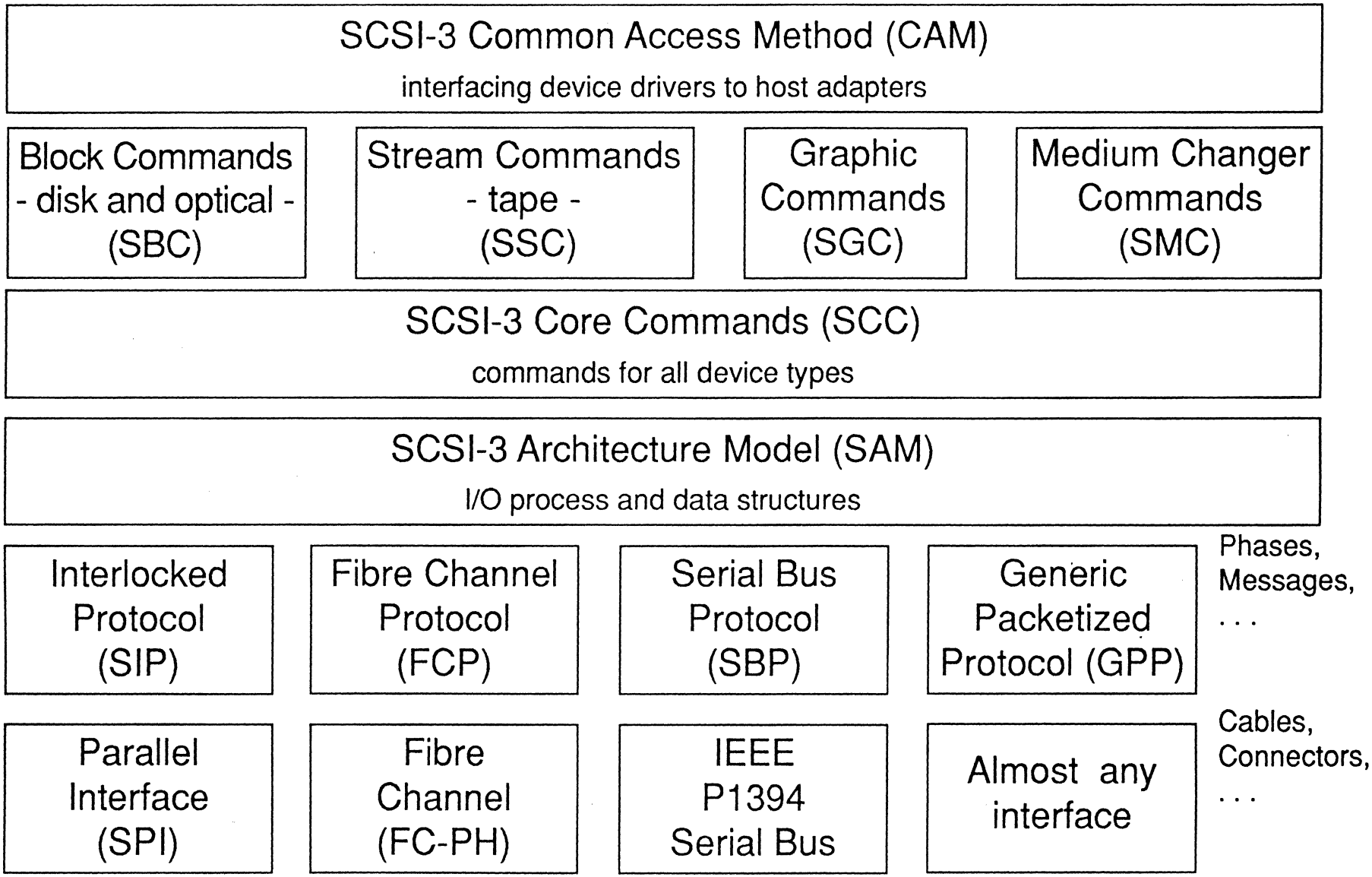
# SCSI-3

- Single Cable Wide Bus
- Max Devices: 16 or 32
- Max Logical Units: 32
- Diagnostic Command Set for Direct Access Devices
- Mode Select and Sense Enhancements

# SCSI - 3
(Continued)



# SCSI - 3 Documents



# Index