MOTOROLA
Semiconductor Products Inc.

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Application Note

LOW POWER CONSIDERATIONS FOR MC146818 REAL TIME CLOCK APPLICATIONS

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INTRODUCTION

The MC146818 Real Time Clock (RTC) plus RAM is a peripheral device which includes: a complete time-of-day clock with alarm and a 100 year calendar, a periodic interrupt and square wave generator, and 50 bytes of low-power static RAM. The MC146818 RTC utilizes high-speed CMOS technology which allows it to interface with processor buses while consuming very little power. The low power consumption makes this an ideal device for use in a battery backup mode. For a complete list of features available on the RTC, consult the MC146818 data sheet.

This application note provides information concerning the use of a 32 kHz oscillator and battery backup with the MC146818 RTC. Although three different oscillator frequency inputs can be used with the RTC, the 32 kHz oscillator is chosen since it consumes the least power.

32 kHz OSCILLATOR

The MC146818 RTC is capable of operating with three different time base input options: 4.194304 MHz, 1.048576 MHz, or 32.768 kHz. However, the time base plays an important role in determining power consumption of the RTC. First, a CMOS device consumes most of its power during voltage transitions since both transistors in a CMOS cell are operating in the active region during the transition. Thus for fewer transitions by a CMOS cell in a given time, less power is consumed. Secondly, with a slower time base, fewer divider stages are required in the RTC divider chain. Typically, the MC146818 RTC requires between 4.0 and 20 mW typical operating power at the high frequency time base and only 40 to 200 μW at the low frequency time base. However, the actual oscillator frequency used for an RTC application is usually a tradeoff. For example: the 4.194304 MHz oscillator provides maximum time keeping reliability, the 1.048576 MHz oscillator is a good compromise between accuracy and power consumption, and the 32.768 kHz square wave oscillator provides minimum power consumption (with sightly added complexity). Connections for the 4.194304 MHz or 1.048576 MHz crystals are shown in the MC146818 data sheet.

A schematic diagram for a representative 32.768 kHz square wave oscillator is shown in Figure 1. The MC14069 CMOS Hex Inverter was chosen for this circuit because of its low power consumption and its ability to operate in the linear region with reasonable stability. Only two resistors are required for the oscillator: R1 is a bias resistor to ensure linear region operation and R2 provides current limiting protection for the crystal. Two load capacitors (C1 and C2) are required to ensure proper loading plus correct start-up frequency. Variable capacitor C1 also allows limited tuning of the output frequency. The low frequency crystal used in this oscillator is physically small and of unusual technology; therefore, it is not readily available from all crystal manufacturers. The two manufacturers that furnished crystals for this application note are listed in Table 1. The crystal for each manufacturer functioned satisfactorily; however, different values of C1 and C2 are required with each manufcturer's crystal. Again, these values are shown in Table 1. The oscillator, by itself, could function with only one inverter; however, to preclude excessive loading (which could result in slow startup), improper operating frequency, and insufficient drive to the MC146818 OSC1 pin, a second inverter is used in the oscillator circuit.

BATTERY BACKUP

A battery backup for the MC146818 RTC is extremely useful in many applications. A suggested circuit is shown in Figure 2. This circuit requires a regulator to convert the input voltage to a regulated +5.7 V which is then used to power the MC146818 RTC plus other devices.

Regulator (MC7805 or MC78L05)

This regulator circuit furnishes +5.7 V which is used to provide regulated +5 V to other devices via isolating diodes D1 and D3. Each isolating diode drops its output voltage from +5.7 V to +5 V thereby providing the correct voltage for each device. The regulator uses diode D4 to produce the +5.7 V output rather than +5 V. The input to the regulator should be more than +8 V but less than the rated input of the regulator. The actual input voltage may be either regulated or unregulated as long as these limits are not exceeded. Diode D2 is a disconnect diode which disconnects the +4.25 V battery voltage whenever D1 is forward biased. By furnishing a full +5 V to the MC146818 RTC, most of the CMOS to HMOS/TTL interface problems are eliminated.

Battery Backup Circuit

The circuit, as shown in Figure 2, also provides battery backup for the MC14069 Hex Inverter and the MC14584 Hex Schmitt Trigger. The circuit which uses the MC14584 holds the $\overline{CE}$ (chip enable) pin low during normal operation. If main system power is removed, the MC146818 $\overline{CE}$ input goes high and the RTC is deselected. This isolates the RTC from the bus. Also, when main system power is removed, diode D1 is reverse biased and the 4.25 V battery furnishes power to the MC146818, MC14069, and MC14584. This is not a problem since the power consumption of these CMOS devices is negligible.

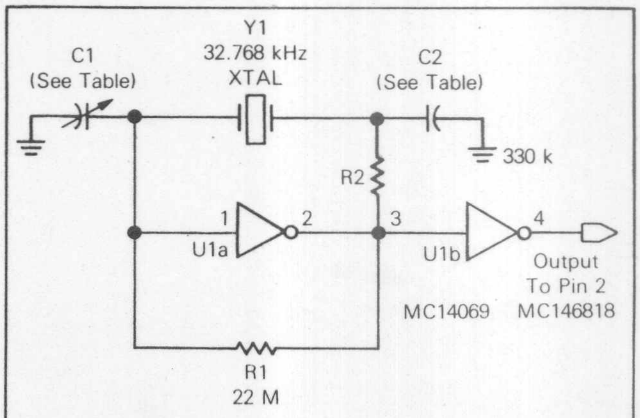
The $\overline{RESET}$ and PS pins of the MC146818 are also connected to the battery voltage and will not be affected by power shutdown. The R1-C1 network provides the necessary delay for resetting the RTC during power-on reset. Resistor R2 limits the battery charge current when rechargeable batteries are used. The value of this resistor should be calculated to provide a safe charging current for the particular battery in use. Considerations included in calculating the value of R2 should include: (1) will the system be off for extended periods of time which will require a medium to heavy charge during power-up, and (2) will the system operate continuously, requiring only a trickle charge. For systems that operate continuously and only need battery backup for emergency power outages, a non-rechargeable battery such as lithium type might be a better choice than a rechargeable battery. Typical current required for the MC146818 operating in the backup mode is less than 100 μA. The unused inverters and gates in the MC14069 and MC14584 should always have their input pins connected to V_{SS}.

ADDITIONAL CONSIDERATIONS

The 32 kHz oscillator described above functions properly and exhibits relatively good frequency stability over ambient temperature ranges. However, there is a possibility of minor frequency variations resulting from voltage fluctuation. The 32 kHz oscillator circuit, shown in Figure 1, will react only slightly to a decrease in V_{DD} from 5 V down to 3.9 V. The actual change in frequency over this 1.1 V range would be about 0.1 Hz and could result in an error of about 7.9 seconds per month.

With R2 as a 330 kΩ resistor, the oscillator is very sensitive to the values of capacitors C1 and C2 and at times the R2 value must be chosen to match the crystal. With R2 removed or decreased in value to 2 kΩ, the oscillator is less sensitive to C1 and C2; however, it is considerably more prone to frequency changes resulting from voltage variations. For example, with R2 at a value of 2 kΩ, a 1.1 voltage change in V_{DD} could result in a 1.2 Hz frequency change. This amounts to an error of 87 seconds in a month.

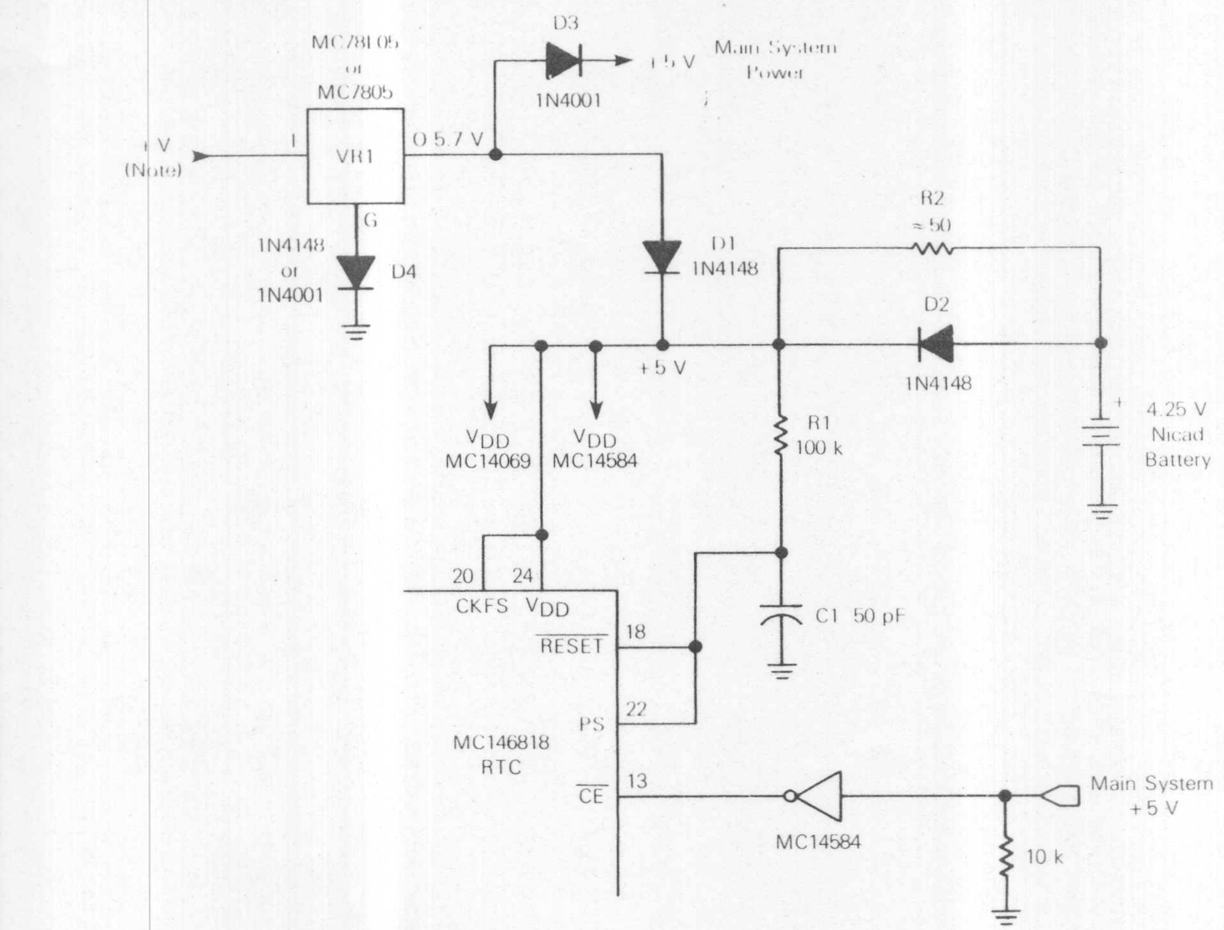
In many cases, either of the above discussed errors (7.9 or 87 seconds) is not acceptable. In these cases, there are two suggestions which might be helpful. The first, and possibly the easiest to implement, is to keep the battery backup voltage equal to V_{DD}. This would require a slightly higher power consumption from the backup battery but the frequency drift would be lessened or eliminated. A second method would be to use a voltage and temperature compensated oscillator to provide a stable 32.768 kHz source. The latter method is more complex and requires more power; however, in systems where accurate time is a requirement, a simple oscillator is not adequate. Higher frequency crystals exhibit similar voltage-frequency drift characteristics even when attached directly to the MC146818.



	C1	C2
STATEK	40-68 pF	50 pF
SEIKO	7-35 pF	27 pF

NOTE: Connect unused inputs on the MC14069 to V_{SS}.

FIGURE 1 — 32.768 kHz Square Wave Oscillator Schematic Diagram



NOTE: Input voltage to VR1 should be more than +8 V but less than the rated input of VR1. Input to VR1 may be regulated or unregulated.

FIGURE 2 — Battery Backup Schematic Diagram for MC146818 RTC

TABLE 1 — Parts List for 32.768 kHz Square Wave Oscillator

C1 Variable capacitor, value depends upon crystal manufacturer; see listing below.

C2 Fixed capacitor, value depends upon crystal manufacturer; see listing below.

Crystal Mfgr.	C1	C2
STATEK	40-68 pF	50 pF
SEIKO	7-35 pF	27 pF

R1 Resistor, 330 kΩ, ¼ W

R2 Resistor, 22 MΩ, ¼ W

U1 MC14069, Motorola Hex Inverter IC

Y1 32.768 kHz Crystal

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