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APPLICATION NOTE 3816

Selecting a Backup Source for Real-Time Clocks

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Abstract: Most Maxim real-time clocks (RTCs) include a supply input for a backup power source. This alternate supply source allows the RTC to maintain the current time and date while the main power source is absent. This application note discusses the various types of alternate supplies that can be used, as well as some of the criteria that a designer should consider when selecting a backup source.

Introduction

Maxim's first real-time clocks (RTCs) were designed so that a backup source, such as a primary (nonrechargeable) lithium coin cell, could be used as the backup supply. Since then, Maxim has introduced additional RTCs with built-in trickle chargers. There are changes that affect system requirements since the first RTCs were introduced, including the shift to IR reflow in manufacturing and restrictions on transportation and disposal of lithium cells. The following paragraphs discuss battery backup techniques and the advantages and limitations of commonly used backup supply sources.

Backup Supply Operation

Early Maxim RTCs had a relatively simple voltage-comparator circuit to monitor V_{CC} and switch between the V_{CC} and V_{BAT} supplies. The DS1307, for example, uses a comparator and a voltage divider to switch to V_{BAT} when V_{CC} drops below approximately 1.25 times the voltage on V_{BAT}. Other RTCs, such as the DS1305/DS1306, switch when V_{CC} drops below the V_{BAT} input voltage. When using these devices, care must be taken to ensure that the voltage on V_{BAT} never rises high enough to cause the device to inadvertently switch over to V_{BAT} while V_{CC} is at the normal operating voltage. An external charging circuit must limit the maximum charging voltage to prevent such an occurrence. Newer Maxim RTCs, which are designed to allow operation whether V_{CC} is above or below the voltage on V_{BAT}, use an internal bandgap voltage reference to determine when V_{CC} is too low for normal operation.

The following table lists the common supply technologies used for backup power. The table lists key parameters that affect selection. The paragraphs following the table discuss each technology and their advantages and drawbacks.

Table 1. Common Backup Supply Sources and Key Selection Criteria

Technology	Operating Temperature (°C)	PC Board Attachment	Self-Discharge Rate	Disposal/Transportation Restrictions	Charging Circuit/Cycles	Backup Time
Primary Lithium	-30 to +80	Wave solder[1]	Low	High	N/A	Long
Capacitor	-40 to +85	SMT	High	Low	Simple/unlimited	Short
Rechargeable (NiCd/NiMh)	0 to +40[2]	Hand solder[3]	Medium	Medium	Simple/≈500	Short
Reflowable ML	-20 to +60	SMT	Low	High	Voltage 12 - > 1000	Medium[4]

1. Primary lithium cells may be wave soldered as long as the cell temperature does not exceed +85°C. Cells may be placed in a holder or hand soldered after reflow (tabbed cells).
2. Ambient temperature during charging. The allowed ambient temperature during discharge may be higher.
3. Batteries may be placed in a holder or hand soldered after reflow (tabbed batteries).
4. Total backup time is dependent upon the depth of discharge between each charging cycle.

Lithium Primary (BR and CR) Cells

Primary lithium coin cells are commonly used for RTC and memory backup. Lithium cells have a high energy density, thus taking up a small amount of room on a PC board. Lithium cells cannot withstand IR reflow, so the cell must either be soldered on after reflow or inserted in a holder, thus increasing cost. Self-discharge near room temperature and below is typically less than 1% per year. At temperatures above about +60°C, self-discharge quickly increases. Recent regulations limit the transportation of lithium primary cells aboard passenger aircraft. Other regulations govern disposal of the cells at end of life, in some cases placing the burden on the manufacturer.

Lithium primary cells are usually sized to power the RTC for the expected life of the product. To calculate cell life based upon the current draw of the RTC, divide the cell capacity in ampere-hours by the timekeeping current draw of the RTC. For example, the timekeeping current of the DS1307 RTC (with the square-wave output off) is specified as 500nA maximum. A BR1225 lithium primary cell is rated at 48mAh. Therefore, (0.048 / 500e) - 9 = 96,000 hours, or 4,000 days (almost 11 years). For additional information regarding calculating cell life, please refer to application note 505, Lithium Coin-Cell Batteries: Predicting an Application Lifetime.

The following is a list of links to some lithium coin-cell manufacturer web sites:
Panasonic®: Primary Batteries
Sony®: Micro Batteries

Capacitors

Large low-leakage capacitors, sometimes called supercaps, are sometimes used for backup. The advantages of a capacitor over primary lithium cells include the ability to IR reflow the capacitor and fewer regulations concerning shipment and disposal. However, capacitors require a charging circuit, and provide backup operation for a relatively short time. Capacity may decrease with use, especially at higher operating temperatures.

For additional information about capacitors for backup and how to calculate the backup time for a given capacitor size, please refer to application note 3517, Estimating Super Capacitor Backup Time on Trickle-Charger Real-Time Clocks. To determine backup time, please refer to the online *Super Capacitor Calculator (For Trickle Charger RTCs)*.

The following is a list of links to some capacitor manufacturer web sites:
Panasonic: Gold Capacitors
TOKIN Corporation: Super Capacitors
Kanthal: Double Layer Capacitors
Cooper Electronic Technologies: Supercapacitors

NiMH and NiCd Batteries

Rechargeable nickel metal hydride (NiMH) or nickel cadmium (NiCd) batteries are incompatible with the float-charging technique used in this trickle charger. Consequently, care must be taken to avoid potentially dangerous side effects when utilizing either of these battery chemistries.

Caution: Do not enable the trickle charger if using NiMH or NiCD batteries.

Charging NiMH or NiCD cells requires both control of the charge current and monitoring of the battery's temperature to prevent overcharging/internal gas formation. These batteries could be safely charged (externally), using an appropriate circuit for that specific chemistry. Then the battery should be installed in the final application as if it were a primary (nonrechargeable) battery.

NiMH and NiCD batteries have a relatively high self-discharge rate: about 10% per month for NiCd and 20% per month for NiMH at room temperature. The typical operating charging temperature range is approximately 0°C to +40°C. NiMH and NiCd batteries must be hand soldered or placed in a battery holder after the PC board has gone through reflow. Overcharging can reduce the life of the battery. Disposing of the battery at its end of life may be regulated in some regions. NiMH and NiCd battery life is limited by the number of charge/discharge cycles.

The following is a list of links to some rechargeable battery manufacturer web sites:
Panasonic®: Primary Batteries
Toshiba's SCiB™ Rechargeable Battery

Lithium Secondary (ML) Cells

ML cells require a regulated-voltage-charging source. The maximum voltage must be closely regulated or permanent damage will occur, while too low a voltage results in incomplete charging. ML cells are subject to the same transportation and disposal regulations as lithium primary cells. The DS12R885/DS12R887 RTCs include a charger with the required voltage and current limits on-chip. The DS12R887 RTC integrates the ML cell in a BGA package.

One issue with secondary cells is the number of charge/discharge cycles that they can withstand during the normal service life. For ML cells, the number of charging cycles is directly related to the depth of discharge as detailed in the Manganese Lithium Rechargeable Cell Lifetime Calculator, an on-line tool for determining ML cell lifetime.

The following is a list of links to some rechargeable lithium ML coin cell manufacturer web sites:
Panasonic®: Primary Batteries
Sony®: Micro Batteries

Conclusion

No single RTC backup power source is perfect for every application. The designer must use such criteria as expected system lifetime, governmental regulations, and manufacturing requirements to select a backup supply that is best suited for the application. Using such criteria, the system designer can select a suitable RTC backup supply technology.

Related Parts		
DS12885	Real-Time Clocks	Free Samples
DS12R885	RTCs with Constant-Voltage Trickle Charger	Free Samples
DS12R887	RTCs with Constant-Voltage Trickle Charger	
DS1302	Trickle-Charge Timekeeping Chip	Free Samples
DS1305	Serial Alarm Real-Time Clock	Free Samples
DS1306	Serial Alarm Real-Time Clock	Free Samples
DS1307	64 x 8, Serial, I²C Real-Time Clock	Free Samples
DS1308	Low-Current I²C RTC with 56-Byte NV RAM	Free Samples
DS1315	Phantom Time Chip	Free Samples
DS1318	Parallel-Interface Elapsed Time Counter	Free Samples
DS1337	I²C Serial Real-Time Clock	Free Samples

DS1338	I²C RTC with 56-Byte NV RAM	Free Samples
DS1339	I²C Serial Real-Time Clock	Free Samples
DS1339A	Low-Current, I²C, Serial Real-Time Clock	Free Samples
DS1340	I²C RTC with Trickle Charger	Free Samples
DS1343	Low-Current SPI/3-Wire RTCs	Free Samples
DS1344	Low-Current SPI/3-Wire RTCs	Free Samples
DS1390	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS1391	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS1392	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS1393	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS14285	Real-Time Clock with NV RAM Control	
DS1500	Y2K-Compliant Watchdog RTC with NV Control	Free Samples
DS1501	Y2K-Compliant Watchdog Real-Time Clocks	Free Samples
DS1670	Portable System Controller	Free Samples
DS1672	I²C 32-Bit Binary Counter RTC	Free Samples
DS1673	Portable System Controller	Free Samples
DS1677	Portable System Controller	Free Samples
DS1678	Real-Time Event Recorder	
DS1685	3V/5V Real-Time Clock	Free Samples
DS17285	3V/5V Real-Time Clocks	Free Samples
DS17485	3V/5V Real-Time Clocks	Free Samples
DS17885	3V/5V Real-Time Clocks	Free Samples
DS3231	Extremely Accurate I²C-Integrated RTC/TCXO/Crystal	Free Samples
DS3231M	±5ppm, I²C Real-Time Clock	Free Samples
DS3232	Extremely Accurate I²C RTC with Integrated Crystal and SRAM	Free Samples
DS3232M	±5ppm, I²C Real-Time Clock with SRAM	Free Samples
DS3234	Extremely Accurate SPI Bus RTC with Integrated Crystal and SRAM	Free Samples
DS32KHZ	32.768kHz Temperature-Compensated Crystal Oscillator	Free Samples

More Information

For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
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Application Note 3816: http://www.maximintegrated.com/an3816
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