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Keywords: tricklecharger,trickle,charger,supercap,super cap, app note 3517

APPLICATION NOTE 3517

Estimating Super Capacitor Backup Time on Trickle-Charger Real-Time Clocks

May 24, 2005

Abstract: The Maxim real-time clock (RTC) family includes a number of parts with integrated trickle-charging circuitry. The trickle charger can be used to charge a secondary battery or capacitor. The battery or capacitor is used to maintain operation of the clock when the supply voltage on V_{CC} is absent. The energy stored in the capacitor will maintain clock operation for a period of time that is determined by several factors. This application note discusses methods used to calculate backup time based on capacitor size.

Also see application note 3816, "Selecting a Backup Source for Real-Time Clocks."

The Charging Circuit

A typical trickle-charger circuit diagram is shown in **Figure 1**. A specific four-bit pattern in the upper nibble of the trickle-charger register is used to enable the trickle charger. The lower four bits are used to select a voltage-dropping diode and current-limiting resistor. In the diagram below, either one diode or no diode can be inserted into the charging path, and the resistor values that can be selected are 250Ω, 2kΩ, or 4kΩ. Some devices provide different diode and resistor configurations (check the device data sheet for details). The capacitor is connected from V_{BACKUP} to ground (**Figure 2**).

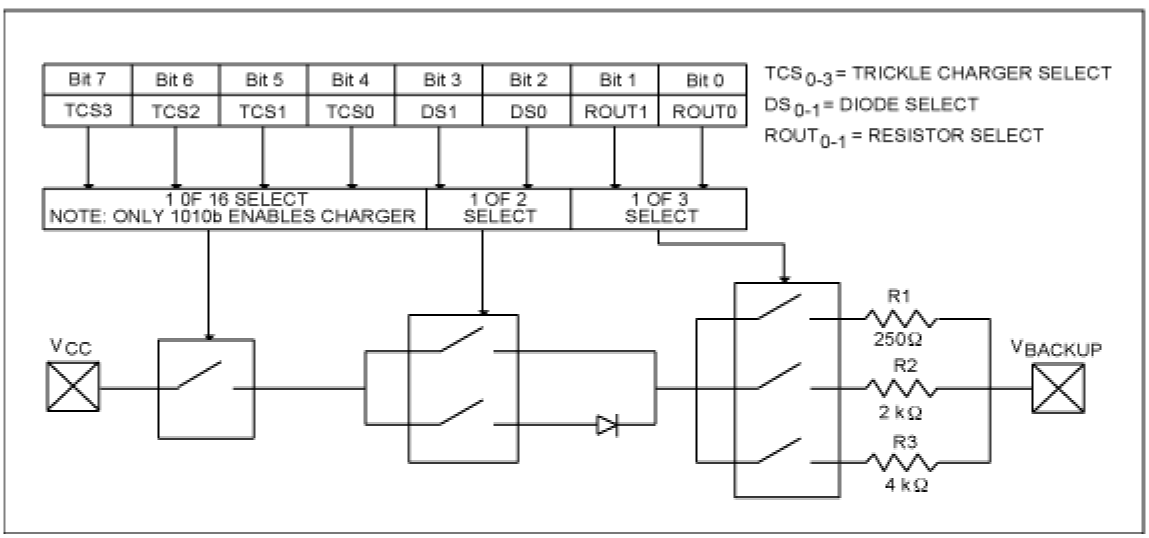

Figure 1. Typical trickle-charging circuit.

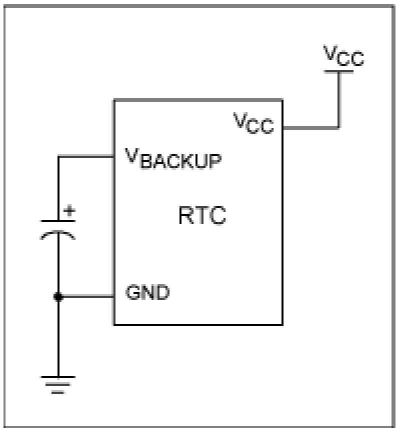

Figure 2. Typical circuit.

The user determines the diode and resistor selection according to the maximum current required for capacitor charging. Contact the manufacturer of the capacitor or check the capacitor data sheet for charging-current limits.

Charging-Current Calculations

The maximum charging current can be calculated as follows: assume that a system power supply of 3.3V is applied to V_{CC}, and that the trickle charger has been enabled with no diode and a 2kΩ resistor. The maximum current, when the capacitor voltage is zero, would be calculated as:

I_{MAX} = (V_{CC} - diode drop)/R2
= (3.3V - 0V)/R2
≈ (3.3V - 0V)/2kΩ
≈ 1.65mA

As the voltage on V_{BACKUP} increases, the charging current decreases.

Calculating Backup Time

Now we need to determine how large the capacitor needs to be. Given the desired backup time, we need to know several other parameters: the starting and ending voltage on the capacitor, the current draw from the capacitor, and the capacitor size.

If we assume that the RTC draws a constant current while running from V_{BACKUP}, then calculating the worst-case backup time in hours would use the formula:

$$[C(V_{BACKUPSTART} - V_{BACKUPMIN})/I_{BACKUPMAX}]/3600$$

Where:
C is the capacitor value in farads
$V_{BACKUPSTART}$ is the initial voltage in volts (the voltage applied to V_{CC}, less the voltage drop from the diodes, if any, used in the charging circuit)
$V_{BACKUPMIN}$ is the ending voltage in volts (the minimum oscillator operating voltage)
$I_{BACKUPMAX}$ is the maximum data sheet V_{BACKUP} current in amps

Given that C = 0.2F, $V_{BACKUPSTART}$ = 3.3V, $V_{BACKUPMIN}$ = 1.3V, and $I_{BACKUPMAX}$ = 1000nA, then:

Hours = [0.2(3.3 - 1.3)/(1e - 6)]/3600 = [0.2(2.0)/(1e - 6)]/3600 = 111.1

If we want to know what the typical backup time should be, we would substitute the I_{BACKUP} typical value ($I_{BACKUPTYP}$)for I_{BACKUP} maximum ($I_{BACKUPMAX}$).

Therefore, if $V_{BACKUPTYP}$ is 3.3V (typ) and $I_{BACKUPTYP}$ is 600nA (typ), then:

Hours = [0.2(3.3 - 1.3)/(600e - 9)]/3600 = [0.2(2.0)(600e - 9)]/3600 = 185.2

These calculations assume that I_{BACKUP} is constant, regardless of the voltage on V_{BACKUP}. The oscillator on Maxim RTCs tends to act more like a resistor, so that backup current tends to decrease with the backup voltage. It should, therefore, be possible to calculate a more realistic backup time.

From basic electronics, the formula to determine the voltage across a capacitor at any given time (for the discharge circuit in **Figure 3**) is:

$$V(t) = E(e^{-\tau/RC})$$

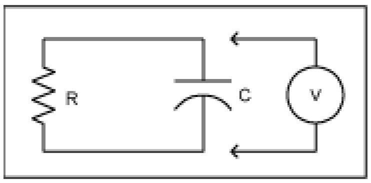

Figure 3. Discharge circuit.

Where:
τ is the time in seconds
E is the initial voltage in volts
V is the ending voltage in volts
R is the resistive load in ohms
C is the capacitor value in farads

Rearranging the equation to solve for t, we get:

$$-\ln(V/E)(RC) = t$$

From the RTC data sheet, we can get the minimum oscillator operating voltage as well as the maximum V_{BACKUP} current ($I_{BACKUPMAX}$). To estimate the load resistance, R, we divide the data sheet $V_{BACKUPMAX}$ by $I_{BACKUPMAX}$ (because the worse-case current occurs at the maximum input voltage). For this example, $V_{BACKUPMAX}$ is 3.7V and $I_{BACKUPMAX}$ is 1000nA, or 3.7/1e-6 or 3,700,000Ω. Assuming that the capacitor value is 0.2F and has been charged to 3.3V, that the $I_{BACKUPMAX}$ is 1000nA, and that the minimum oscillator operating voltage is 1.3V, the backup time would be calculated as:

$$-\ln(V_{BACKUP}MIN/V_{BACKUP}MAX)[(V_{BACKUPMAX}/I_{BACKUPMAX}) \times C] =$$
$$-\ln(1.3/3.3)(3{,}700{,}000 \times 0.2) =$$
689,353s (191.5hrs)

By changing the value of C, the estimated operating time while running from the backup capacitor can be determined.

These calculations can be done using the on-line calculator. This Supercapacitor Calculator implements the three equations shown above.

Related Parts		
DS1302	Trickle-Charge Timekeeping Chip	Free Samples
DS1305	Serial Alarm Real-Time Clock	Free Samples
DS1306	Serial Alarm Real-Time Clock	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
DS1374	I²C, 32-Bit Binary Counter Watchdog RTC with Trickle Charger and Reset Input/Output	Free Samples
DS1388	I²C RTC/Supervisor with Trickle Charger and 512 Bytes EEPROM	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
DS1394	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS1672	I²C 32-Bit Binary Counter RTC	Free Samples

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