# Application Note 82
Using the Dallas Trickle
Charge Timekeeper

DESCRIPTION

The Dallas Semiconductor/Maxim real-time clock (RTC) family contains a number of parts within an integrated trickle-charging circuit. This application note describes the operation of the DS1302 trickle charger. Most of the data in this note can be applied to other Dallas RTC trickle chargers, with a few circuit-specific changes.

Figure 1. DS1302 PROGRAMMABLE TRICKLE CHARGER
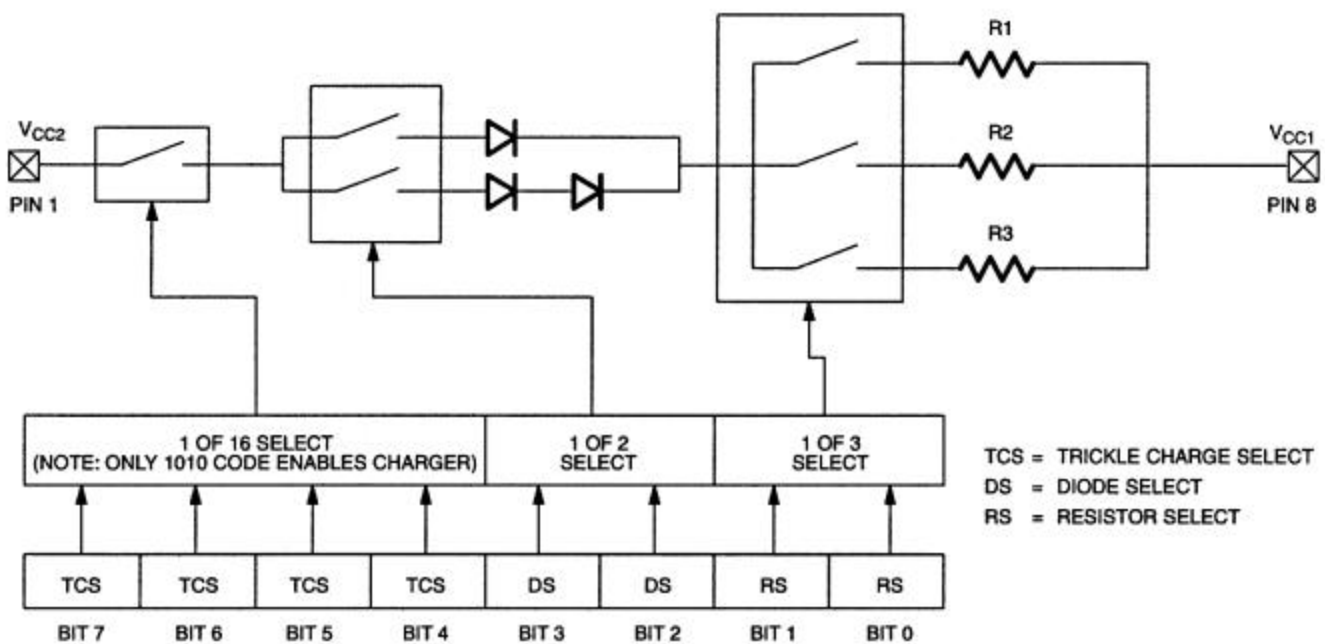
TRICKLE CHARGER

The trickle charge circuit is shown in Figure 1 along with the trickle charge register. To enable the trickle charger, the desired path through the circuit must be selected and the appropriate pattern written to the trickle charge register. The trickle charge select (TCS) bits (bits 4 to 7) control the selection of the trickle charger. In order to prevent accidental enabling, only a pattern of 1010 enables the trickle charger. All other patterns disable the trickle charger. The DS1302 powers up with the trickle charger disabled. The diode select (DS) bits (bits 2 to 3) select whether one diode or two diodes are connected between V_{CC2} and V_{CC1}. If DS is 01, one diode is selected or if DS is 10, two diodes are selected. If DS is 00 or 11 the trickle charger is disabled independently of TCS. The RS bits (bits 0 to 1) select the resistor that is connected between V_{CC2} and V_{CC1}. The resistor selected by the resistor select (RS) bits is as follows:

RS BITS	RESISTOR	TYPICAL VALUE
00	None	None
01	R1	2kΩ
10	R2	4kΩ
11	R3	8kΩ

If RS is 00 the trickle charger is disabled independently of TCS.

The user determines diode and resistor selection according to the maximum current desired for battery or super cap charging. The maximum charging current can be calculated as illustrated in the following example. Assume that a system power supply of 5V is applied to V_{CC2}a and a super cap is connected to V_{CC1}. Also, assume that the trickle charger has been enabled with one diode and resistor R1 between V_{CC2} and V_{CC1}. The maximum current I_{MAX} would, therefore, be calculated as follows:

$$I_{MAX} = (5.0V \text{ - diode drop}) / R1$$
$$\sim (5.0V{-}0.7V) / 2k\Omega$$
$$\sim 2.2mA$$

Obviously, as the super cap charges, the voltage drop between V_{CC2} and V_{CC1} decreased and, therefore, the charge current decreases. See curves in *Trickle Charge Characteristics*.

POWER CONTROL

The DS1302 can be powered in several different ways. The first method, shown in Figure 2, illustrates the DS1302 being supplied by only one power supply. In Figure 2a, the power supply is connected to V_{CC2} (pin 1) and in Figure 2b the power supply is connected to V_{CC1} (pin 8). In each case, the unused power pin, V_{CC1} or V_{CC2}, is grounded. The second method, Figure 3, illustrates the DS1302 being backed up using a nonrechargeable battery connected to V_{CC1}. In these two cases the trickle charge circuit has been disabled. In the final case, Figure 4, the DS1302 is being backed up by connecting a super cap, Figure 4a, or a rechargeable battery, Figure 4b, to V_{CC1}. In this case, the trickle charge circuit has been enabled.
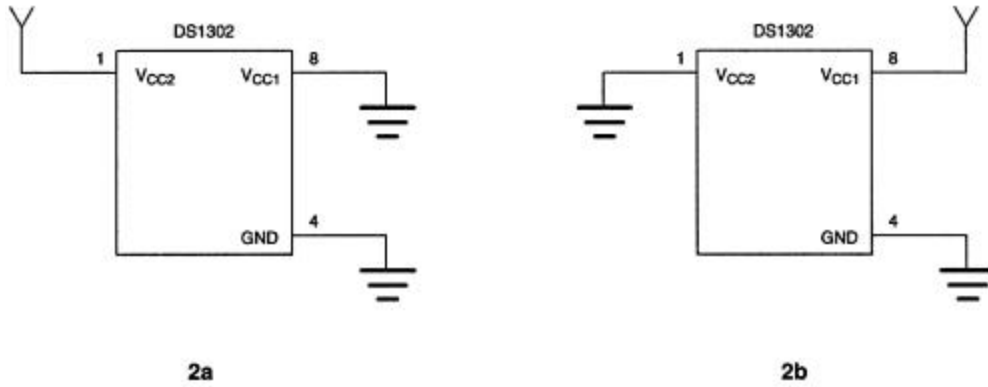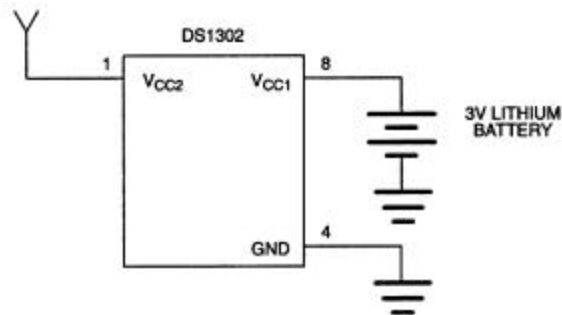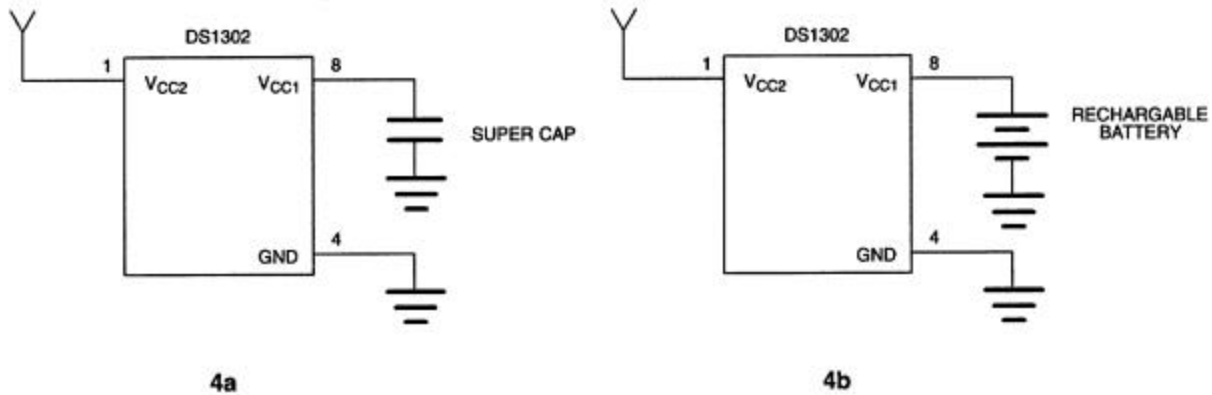
Figures 2a and 2b. SINGLE POWER SUPPLY OPTION

2a

2b

Figure 3. NONRECHARGABLE BATTERY BACKUP

Figures 4a and 4b. SUPER CAP OR RECHARGABLE BATTERY BACKUP

4a

4b

TRICKLE CHARGE CHARACTERISTICS

Charging the Super Cap

The maximum current, I_{MAX}, required by the trickle charge circuit can be calculated by inserting the correct values selected in the trickle charge register into the following equation

$$I_{MAX} = (V_{CC2} - \text{diode drop}) / R$$

Table 1 contains the values of I_{MAX} for V_{CC2} values of 4.5V, 5.0V, and 5.5V; 1 diode drop and 2 diode drops; resistor values of 2000Ω, 4000Ω and 8000Ω.

Also, the charging current can be modeled as a function of charge time. Both the super cap voltage and charging current as a function of time are represented in Figure 5. The equation to model the super cap voltage as a function of time is

$$V(t) = V_{MAX} [1 - e^{(-t/RC)}]$$

where

$V(t)$	=	Super Cap Voltage
V_{MAX}	=	(V_{CC2} - n Diode Drops), n = 1, 2
R	=	Internal Trickle-Charge Resistor
C	=	Super Cap Capacitance

The time needed to charge the super cap to 95% of V_{MAX} is given in Table 2. Note that the time required to charge the super cap to 95% of the value of V_{MAX} is independent of the value of V_{MAX}. The equation, which models the charging current as a function of time, is given as

$$I(t) = V_{MAX} / R \times e^{(-t/RC)}$$

where

$I(t)$	=	Charging Current
V_{MAX}	=	(V_{CC2} - n Diode Drops), n = 1, 2
R	=	Internal Trickle-Charge Resistor
C	=	Super Cap Capacitance

Discharging the Super Cap

When modeling the DS1302 for the time to discharge the super cap, the DS1302 characterization data was used to observe that the I_{CC1T}, timekeeping current through V_{CC1}, was linear. This implies that it is proper to represent the DS1302 as a resistive load, R_L, through which the super cap is discharged. Using the data sheet spec of I_{CC1T} max of 0.3µA at 2.0 V_{CC1} gives a value for R_L of 6.7MΩ. Then the equation modeling the discharging of the super cap is given by

$$V(t) = V_{MAX} \times e^{(-t / R_L C)}$$

where

$V(t)$	$=$	Super Cap Voltage
V_{MAX}	$=$	(V_{CC2} - n Diode Drops), n = 1, 2
R_L	$=$	DS1302 Load Resistance
C	$=$	Super Cap Capacitance

The calculated values for the time required to discharge the super cap to 2V are given in Table 3 and a sample of the super cap voltage as a function of discharge time is given in Figure 6. Figure 7 shows the typical I_{CC1T} current versus voltage at +25°C.

Table 1. CALCULATED VALUES OF I_{MAX}

V_{CC2} (V)	2000W		4000W		8000W		UNITS
	1 diode	2 diodes	1 diode	2 diodes	1 diode	2 diodes	
4.5	1.90	1.55	0.95	0.78	0.48	0.39	mA
5.0	2.15	1.80	1.08	0.90	0.54	0.45	mA
5.5	2.40	2.05	1.20	1.03	0.60	0.51	mA

Table 2. CHARGING TIME FOR SUPER CAP TO 95% OF V_{MAX}

CHARGE TIME	2000W	4000W	8000W	UNITS
Super Cap = 0.047	4.7	9.4	18.8	minutes
Super Cap = 0.47F	46.9	93.9	187.7	minutes
Super Cap = 1.5F	149.8	299.6	599.2	minutes

Table 3. SUPER CAP DISCHARGE TIME TO 2V

V_{CC2} (V)	0.047F		0.47F		1.5F		UNITS
	1 diode	2 diodes	1 diode	2 diodes	1 diode	2 diodes	
4.5	69.8	47.7	698.3	476.8	2228.7	1521.7	hours
5.0	83.3	63.9	832.8	639.5	2657.9	2040.9	hours
5.5	95.2	78.1	952.5	780.9	3039.8	2492.5	hours

Figure 5. SUPER CAP CHARGING CHARACTERISTICS

SUPER CAP CHARGE TIME – 0.47F

SUPER CAP CHARGE CURRENT – 0.47F
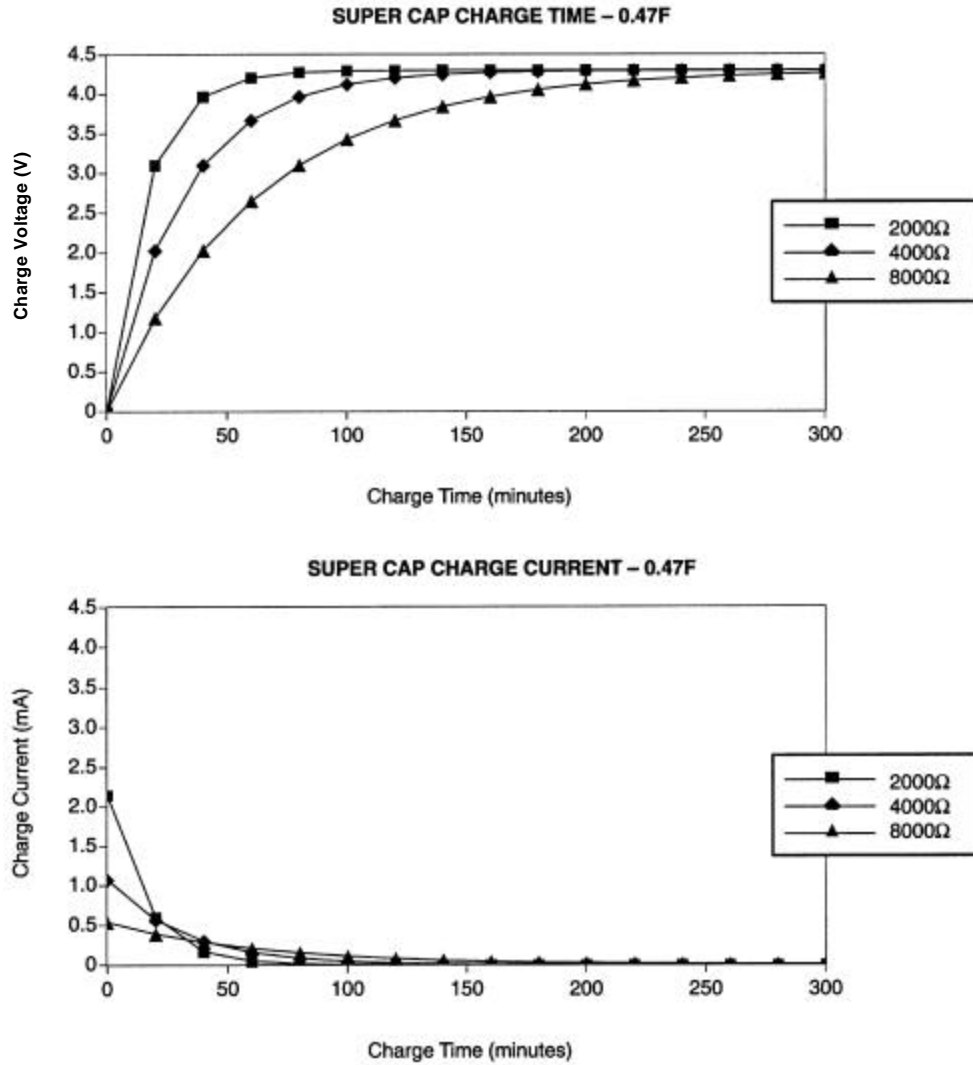
Figure 6. SUPER CAP DISCHARGING CHARACTERISTICS

SUPER CAP DISCHARGE TIME
$V_{MAX}=4.3V$

SUPER CAP DISCHARGE TIME
$V_{MAX}=3.6V$
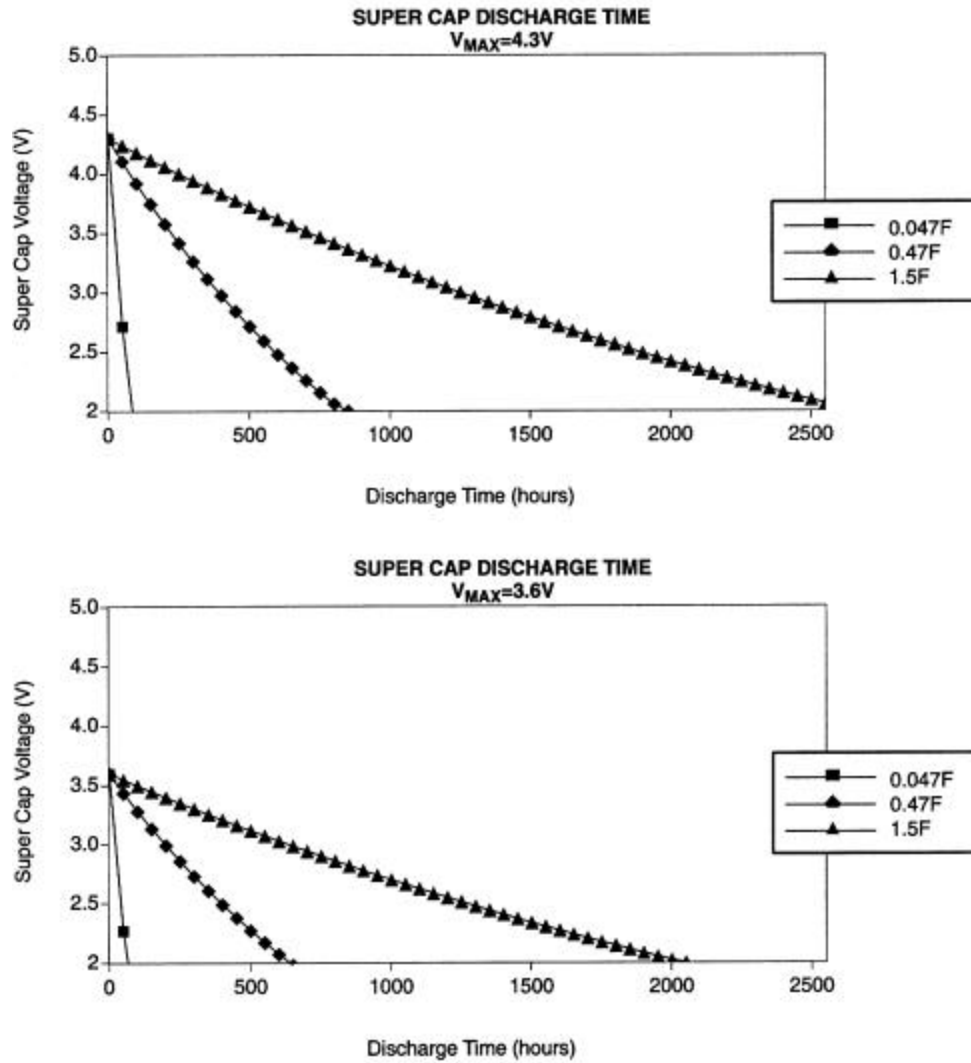
Figure 7. DS1302 AVERAGE I_{CC1T} at +25°C