Features

- **Constant Charge Current**
- **3 h - 24 h Charge Time Programmable**
- **Low-cost DC Regulator**
- **Overtemperature Protection**
- **Charge-mode Indication**
- **Operation Starts at the Moment of Battery Insertion**
- **Fast Charge-time Test Mode**

Applications

- **Cordless Telephones**
- **Low-cost Battery-charge Timers**
- **Entertainment Equipment**

Description

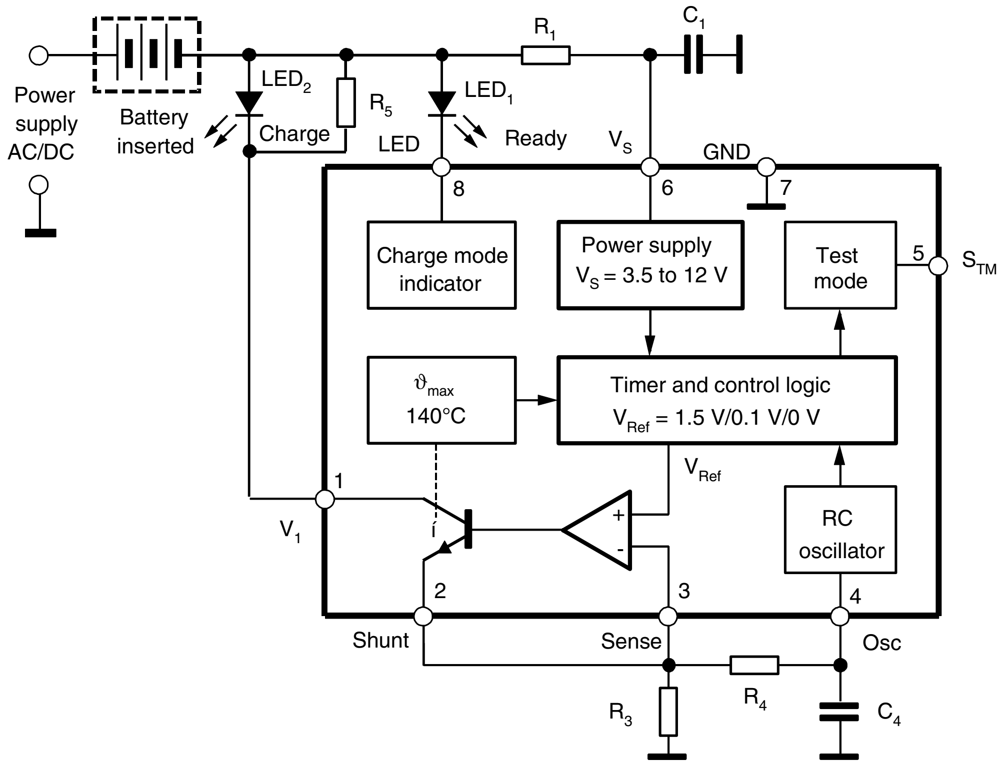
The U2403B is a monolithic integrated bipolar circuit which can be used in applications where time-controlled, constant current charge is required. The selection of the charge current versus timing is carried out by using the external circuit at pins 2, 3 and 4. For high current requirements, an external transistor is recommended in series with the battery. To protect the IC against high power loss (typically > 140°C), the oscillator will be shut down when the reference voltage is switched off (0 V). The latter also takes place when there is a saturation caused by collector voltage at pin 1. When the overtemperature has disappeared and the collector voltage at pin 1 has exceeded the supply voltage ($V_1 > V_S$), charge time operation continues (see flow chart in Figure 4 on page 6).

Charge Timer IC

U2403B

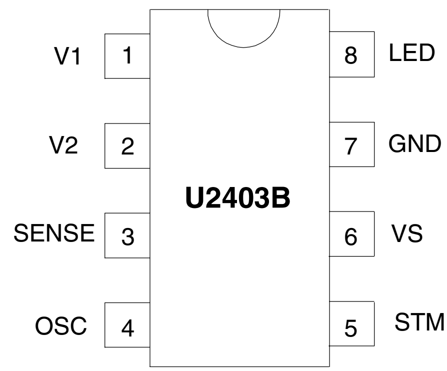
Rev. 4776A–INDCO–11/03

Figure 1. Block Diagram with External Circuit



Pin Configuration

Figure 2. Pinning DIP8/SO8



Pin Description

Pin	Symbol	Function
1	V1	Collector terminal
2	V2	Shunt emitter terminal
3	V3	Amplifier sense input
4	OSC	Oscillator input
5	STM	Test-mode switch
6	VS	Supply voltage
7	GND	Reference point, GND
8	LED	Charge-mode indicator

Pin 1, Collector Voltage V_1

Pin 1 is an open-collector output. When $V_1 \leq 3$ V, the charge cycle will be switched off until it has reached a value higher than the supply voltage, as shown in Figure 6 on page 10.

Pin 2, Shunt Emitter

The constant current source is supplied by the internal operational amplifier. The voltage across R_3 is determined via the internal reference source.

$I_{ch} = V_3/R_3 \qquad (V_3 = V_{sense})$

Pin 3, Amplifier Sense Input (Inverted)

The voltage-regulated current source has a closed loop at pin 2, pin 3, and resistor R_3.

Pin 4, Oscillator Input R_4, C_4

The selection of the current charge versus timing is carried out by using the external circuit at pins 2, 3, and 4. Typical values are given in Table 1 on page 5.

Pin 5, Test-mode Switch for Charging Time

The charging time, t_{ch}, is given by the following equation:

$$t_{ch} = \frac{1}{f_{osc}} \times 2^n$$

where:

f_{osc} = oscillator frequency (see Figure 3)

n = frequency divider

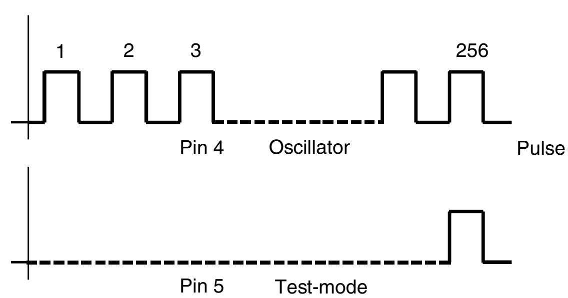
= 26, if S_{TM} open

= 17, if S_{TM} = GND

= 8, if $S_{TM} = V_S$

The first eight divider stages can be tested directly. 256 input tact signals at pin 4 create one tact signal at pin 5.

Figure 3. Quick Test Timer 1/3



Example

The charge time is assumed to be 6 h.

The values of R_4 and C_4 can be selected from Table 1 on page 5.

For example: R_4 = 470 kΩ

C_4 = 680 pF

There is a frequency of approximately 3100 Hz at pin 4. It is possible to test the charge time of 6 h by running through the charge cycle for a very short time. By connecting pin 5 with GND, the test time is 42 s. By connecting pin 5 with pin 1 (V_1), the test time is reduced to about 82.4 ms. R_5 is connected in parallel to the LED2 and provides a protective bypass function for the LED (see Figure 1 on page 2).

Pin 6, Supply Voltage, V_S

$V_S \approx 3.1$ V Power-on reset release (turn-on)

$V_S \approx 2.9$ V Under-voltage reset

$V_S \approx 13$ V Supply voltage limitation

Pin 7, Ground

Pin 8, Charge Mode Indicator

An open-collector output supplies constant current to LED1 after the active charge phase has been terminated. ϑ_{max} controls the function temperature for the final stage range. This is when the temperature is above 140°C and the charge function is therefore switched off.

Trickle Charge

The trickle charge starts after the charge has been terminated. In this case, the internal reference voltage is reduced from 1.5 V to approximately 0.1 V. This means the charge current is decreased by the factor:

K = 1.5 V/0.1 V = 15

Trickle current = I_{ch}/15 + I_6 (supply current) + I_8

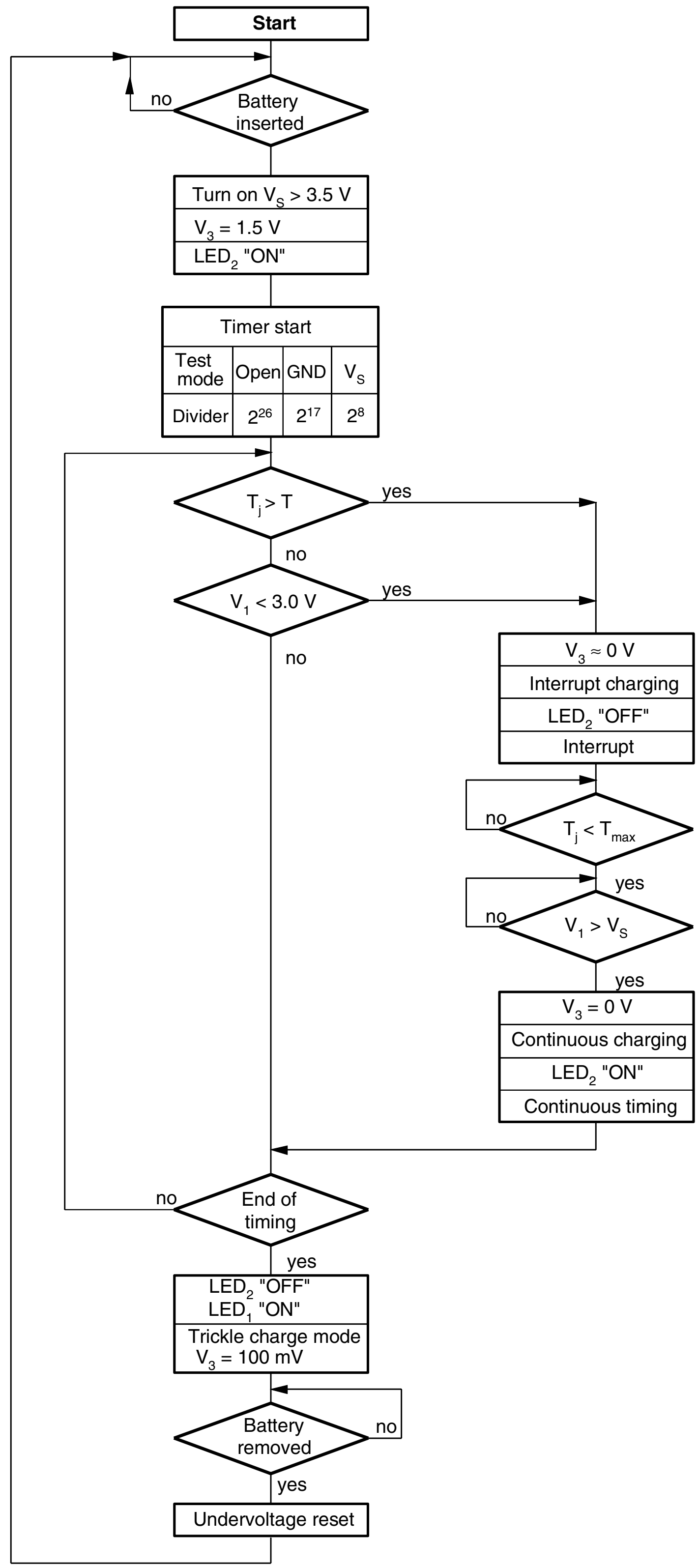
It is possible to reduce the trickle charge with resistor R_6, as shown in Figure 7 on page 11 and Figure 8 on page 13.

Charge Characteristics

Table 1. Charge Time

Test Time/Test-mode Switch S_{TM}			Oscillator Components		Frequency
Open	**V_S**	**GND**	**R_4 (kΩ)**	**C_4 (pF)**	**f_{osc} (Hz)**
3 h	41.2 ms	21 s	510 430 300	270 330 470	6213
4 h	54.9 ms	28 s	620 430 300	330 470 680	4660
5 h	68.6 ms	35 s	510 390 300	470 680 1000	3728
6 h	82.4 ms	42 s	620 470 360	470 680 1000	3105
7 h	96.1 ms	49 s	560 430 220	680 1000 2200	2663
8 h	109.8 ms	56 s	620 470 200	680 1000 2200	2330
9 h	123.6 ms	1 min 3 s	750 510 240	680 1000 2200	2071
10 h	137.3 ms	1 min 10 s	620 270 130	820 2200 4700	1864
12 h	164.8 ms	1 min 24 s	390 150	2200 4700	1553
16 h	219.7 ms	1 min 56 s	470 200	2200 4700	1165

Figure 4. Flow Chart



Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Reference point pin 7 (GND), unless otherwise specified.

Parameters	Pin	Symbol	Value	Unit
Supply current $t \le 100$ µs	6	I_S i_s	20 100	mA mA
Currents	1 2 3 4 5 8	I_1 $-I_2$ I_3 I_4 I_5 I_8	300 310 1 15 -75 to +120 8	mA mA µA mA µA mA
Voltages	1, 3, 5, 6, 8 2 4	V V_2 V_4	13.5 1.6 1.5	V V V
Junction temperature		T_j	150	°C
Ambient temperature		T_{amb}	-10 to +85	°C
Storage temperature range		T_{stg}	-50 to +150	°C

Thermal Resistance

Parameters		Symbol	Value	Unit
Junction ambient	DIP8 SO8 on PC-board SO8 on ceramic SO8 on ceramic with thermal compound	R_{thJA} R_{thJA} R_{thJA} R_{thJA}	120 220 140 80	K/W K/W K/W K/W

Electrical Characteristics

V_S = 6 V, T_{amb} = 25°C, reference point pin 7 (GND), unless otherwise specified.

Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit
Supply voltage limitation	I_S = 4 mA I_S = 20 mA	6 6	V_S V_S	12.5 12.6		13.5 13.7	V V
Supply current	V_S = 6 V		I_S	1.4		2.2	V
Voltage Monitoring		6					
Turn-on threshold			V_{TON}	2.8		3.5	V
Turn-off threshold			V_{TOFF}	2.5		3.2	V
Charge-mode Indicator (LED)		8					
LED current			I_8	3.0		6.0	mA
LED saturation voltage	I_8 = 3.7 mA		V_8			960	mV
Leakage current			I_{lkg}	-0.35		1.1	µA
Collector Terminal, Figure 6 on page 10		1					
Open-collector current			I_{CO}	15		55	µA
Saturation threshold	V_S = 6 V		V_{TON} V_{TOFF}	2.55 V_S - 1 V	3.0 V_S	3.35 V_S - 0.4 V	V V
Shunt emitter current	R_3 = 5.6 Ω	2	I_2	250		285	mA
Operational Sense Amplifier, Figure 1 on page 2		3					
Input current	V_3 = 0 V		I_3	-0.6		0.08	µA
Input voltage	V_{Ref} = 1.5 V V_{Ref} = 100 mV V_{Ref} = 0 V		V_3 V_3 V_3	1.42 40 -0.4	1.5 70	1.58 100 40	V mV mV
Oscillator		4					
Leakage current	V_4 = 0 to 0.85 V		I_{lkg}	-0.5		0.1	µA
Threshold voltage	Upper		$V_{T(u)}$	875		985	mV
Oscillator frequency	R_4 = 160 kΩ, C_4 = 2.2 nF R_4 = 680 kΩ, C_4 = 4.7 nF		f_{osc} f_{osc}	2700 305		3050 345	Hz Hz
Test Mode Switch (S_{TM})		5					
Input current	V_5 = 6 V V_5 = 0 V		I_5 I_5	40 -75		120 - 20	µA µA
Output voltage	High Low		$V_{0(H)}$ $V_{0(L)}$	1.7 0.5		2.5 1.0	V V

Internal Temperature Switch

The internal temperature monitoring is active if the chip temperature rises above 140°C. Above this temperature, the voltage at pin 3 returns to zero. Similarly, the charge current, I_{ch}, reduces according to the equation:

$I_{ch} = V_3/R_3$

where I_{ch} = 1 to 2 mA (IC supply current)

The oscillator is connected to GND via pin 3 (V_3) which holds the present time status. When the chip temperature decreases below the transition value, all functions are released and the charge time is continued. The process is reversible. If there is a higher power dissipation in the circuit (T_j > 140°C), the temperature monitoring remains permanently activated (ON). The total cycle time is prolonged according to the interrupt-time duration, see Figure 5.

Automatic Control Protection

To reduce design costs, it is possible to select a transformer that requires minimum power supply.

The output stage of the control is selected so that it is switched off before saturation is achieved (V_{CEsat} = 3.0 V). In this case, the voltage at pin 3 is kept at a value of zero. The charge current is also zero, and the transformer is now an open-circuit impedance. The system becomes active again if $V_1 \geq V_S$.

The advantage of the system is that if sags of short duration appear on the mains voltage, or if the transformers used are too small, the charge duration will be increased, but the charge capacity remains the same, see Figure 6 on page 10.

Figure 5. Charge Duration - Overtemperature

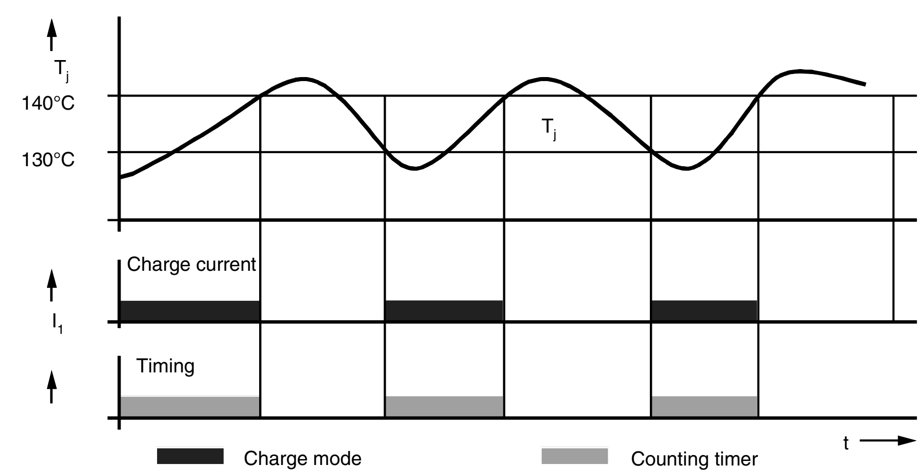
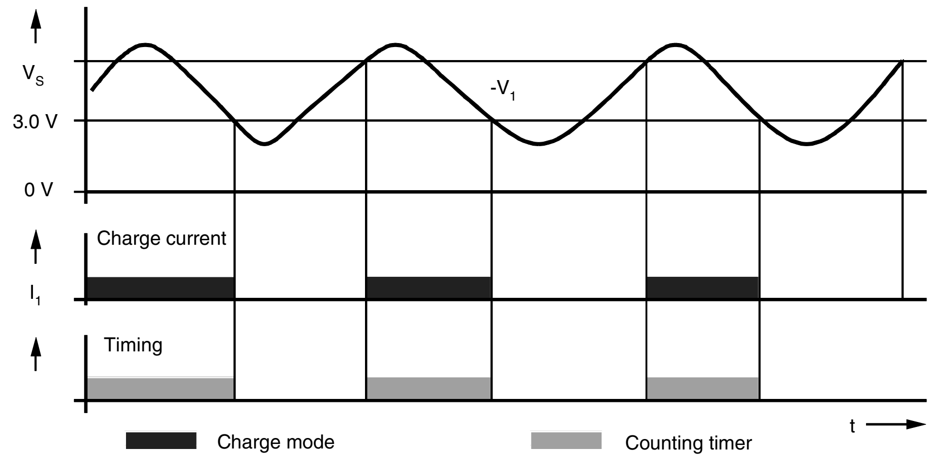


Figure 6. Charge Duration – V_1



Standard Applications

Basic Example

NiCd battery 750 mAh

Charging time: 3 h

Charge current: 240 mA, 1/3 C

Trickle charge: 19 mA < 1/40 C

R_1 = 510 Ω, 1/8 W

C_1 = 47 µF/ 16 V

R_3 = 6.2 Ω, 1/2 W

R_4 = 300 kΩ

C_4 = 470 pF

R_5 = 8.2 Ω, 1/2 W

Table 2. Minimum Supply Voltage

Number of Cells	DC Supply Minimum
1	6.8 V
2	8.3 V
3	9.8 V
4	11.3 V
5	12.8 V

Special Requirements of Different Charge Times

Table 3. R_4, C_4 Values for Different Charging Times

Components	2 h	4 h	6 h	7 h	12 h
R_4	300 kΩ	430 kΩ	470 kΩ	470 kΩ	390 kΩ
C_4	330 pF	470 pF	680 pF	1 nF	2.2 nF

Special Requirements for Different Charge Currents

Table 4. R_3, R_5 Values for Different Charge Currents

Components	240 mA	150 mA	100 mA	50 mA
R_3	6.2 Ω	10 Ω	15 Ω	30 Ω
R_5	8.2 Ω	15 Ω	22 Ω	68 Ω

Basic Equations

$R_1 = 0.5\ V/IS$

$I_S = 1.8\ mA$

$R_5 = V_5/(I_{ch} - 20\ mA)$

Nominal Charge Current

$I_{ch} = V_3/R_3$ where $V_3 = 1.48\ V$ (typically)

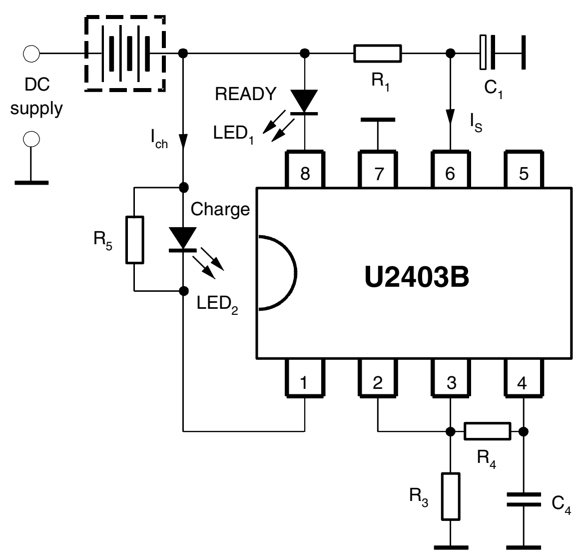
Trickle Current:

$I_{ch} = V_3/R_3 + I_8 + I_S$

Typical values are:

$V_3 = 100\ mV$, $I_8 = 4.5\ mA$

Figure 7. Standard Application



Booster and Trickle Charge Reduction

Basic Example

NiCd battery 1000 mAh	R_1 = 510 Ω, 1/8 W
Charging time: 2 h	C_1 = 1000 µF/ 16 V
Charge current: 500 mA	R_3 = 3 Ω, 1 W
Trickle charge: 22 mA < 1/22 C	R_4 = 300 kΩ
	C_4 = 330 pF
	R_5 = 3.9 Ω, 1 W
	C_2 = 1 µF

Table 5. Supply Voltage

Number of Cells	DC Supply Minimum
1	6.5 V
2	8.0 V
3	9.5 V
4	11.0 V
5	12.5 V

Special Requirements of Different Charge Times

Table 6. R_4, C_4 Values for Different Charge Times

Components	2 h	4 h	6 h	7 h	12 h
R_4	300 kΩ	430 kΩ	470 kΩ	470 kΩ	390 kΩ
C_4	330 pF	470 pF	680 pF	1 nF	2.2 nF

Special Requirements for Different Charge Currents

Table 7. R_3, R_5 Values for Different Charge Currents

Components	616 mA	493 mA	411 mA	296 mA
R_3	2.4 Ω	3 Ω	3.6 Ω	5 Ω
R_5	3.9 Ω	3.9 Ω	4.7 Ω	6.8 Ω

R_6 = 560 Ω, reduced trickle charge

Basic Equations

$R_1 = 0.5\ V/I_S$

$R_5 = V_{(LED2)}/(I_{ch} - 20\ mA)$

Nominal Charge Current

$I_{ch} = V_3/R_3$

V_3 = 1.48 V, typically

Trickle Current: $I_{ch} = V_3/R_3 + I_{LED1} + I_S - I_6$

Typical values:

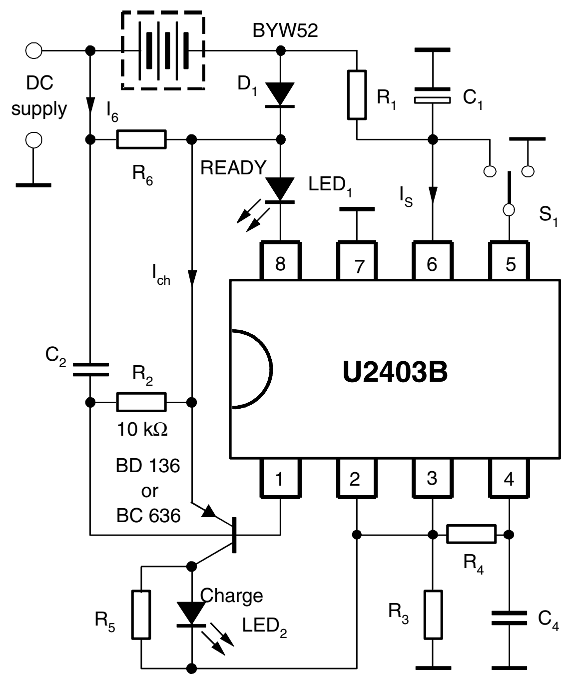
$V_3 = 100$ mV

$I_{LED1} = 4.5$ mA

$I_S = 1.8$ mA

Trickle-charge Reduction (I_6) $I_6 = (V_{Batt} + V_{D1})/R_6$ $V_{D1} = 0.75$ V

Figure 8. Application for Charge Current > 250 mA



To meet the requirements of higher charge currents, an external booster transistor can be used (see Figure 8). As the temperature cannot be monitored in this case, a heat sink with a resonable size should be used for safe operation. The test mode switch S_1 can be used for accelerated production check.

Charge System at Higher Voltage up to 30 V

Charge systems with higher voltages than V_{Smax} can be realized with the additional expander circuitry, as shown in Figure 9 on page 14. This circuit contains a simple temperature monitoring function. When the temperature level is reached, the transistor, T_3, is switched on. If T_3 is switched on and there is current flow into pin 5, normal charge is terminated.

Figure 9. U2403B for Higher Supply Voltage up to 30 V with Integrated Temperature Monitoring

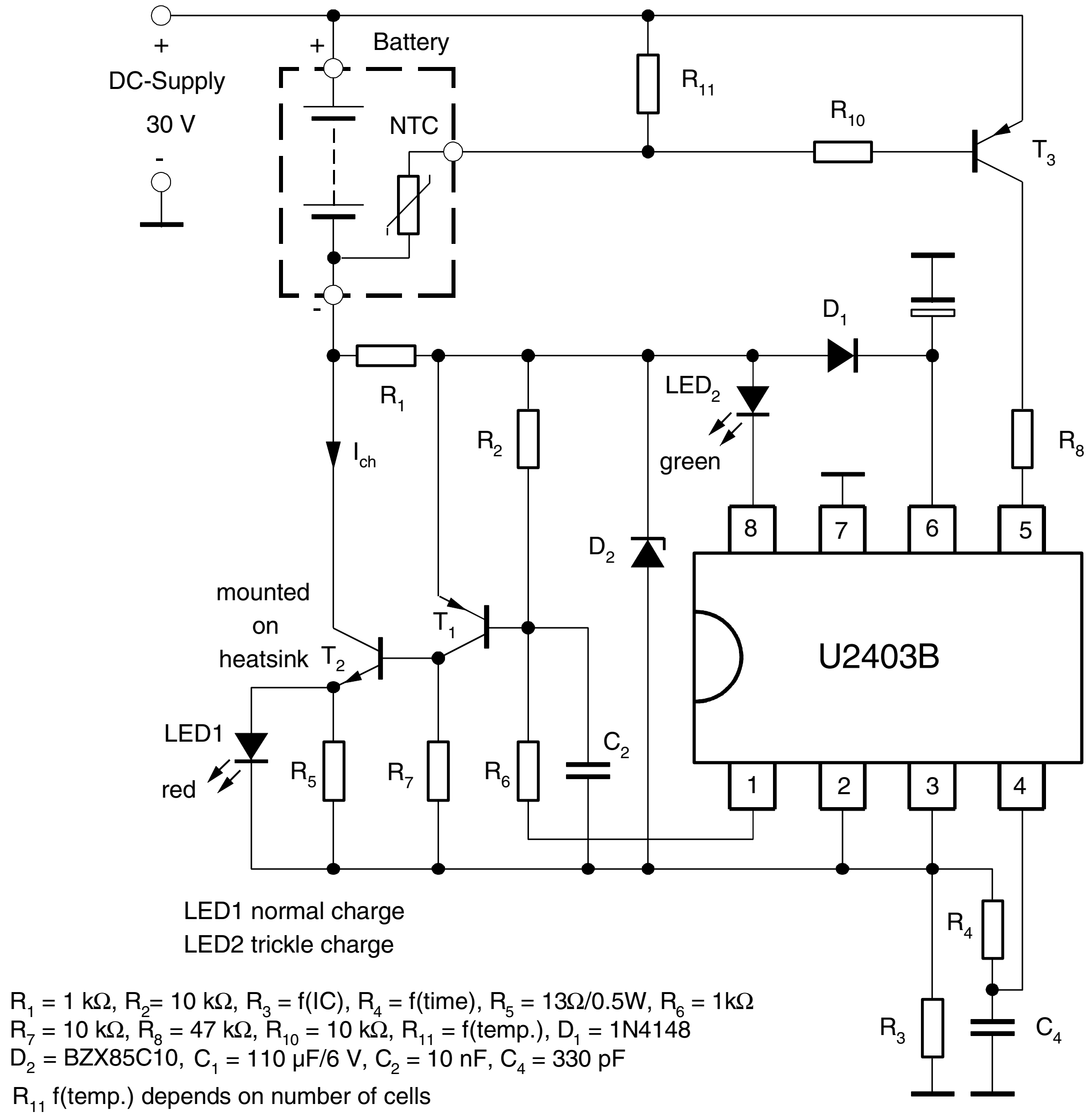


Table 8. Value of R_{11} for Different Number of Cells

Number of Cells	R_{11}
2	13 kΩ
3	8.2 kΩ
4	6.2 kΩ
5	4.7 kΩ

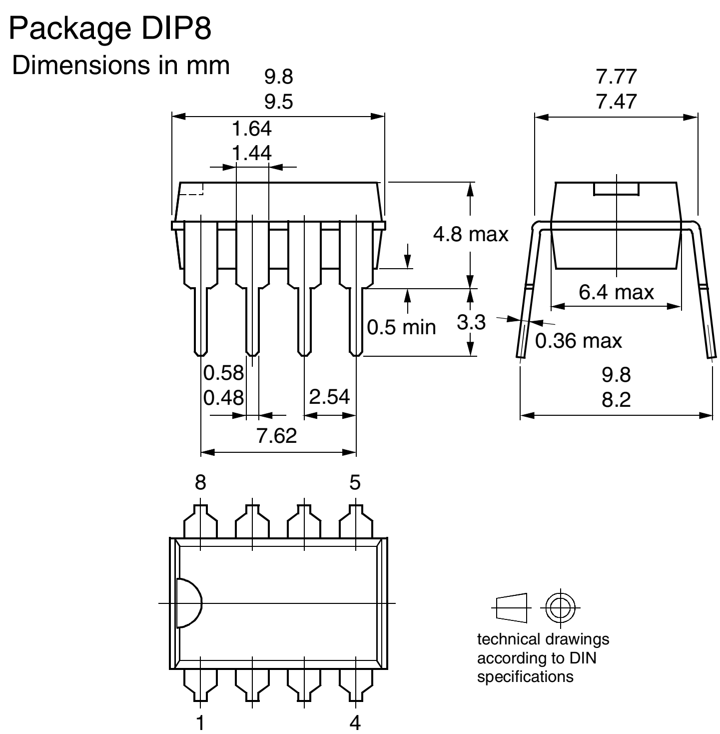
Table 9. NTC Resistance at Different Temperatures

NTC Value	NTC Resistance
25°C	6.8 kΩ
40°C	3.9 kΩ
50°C	2.8 kΩ

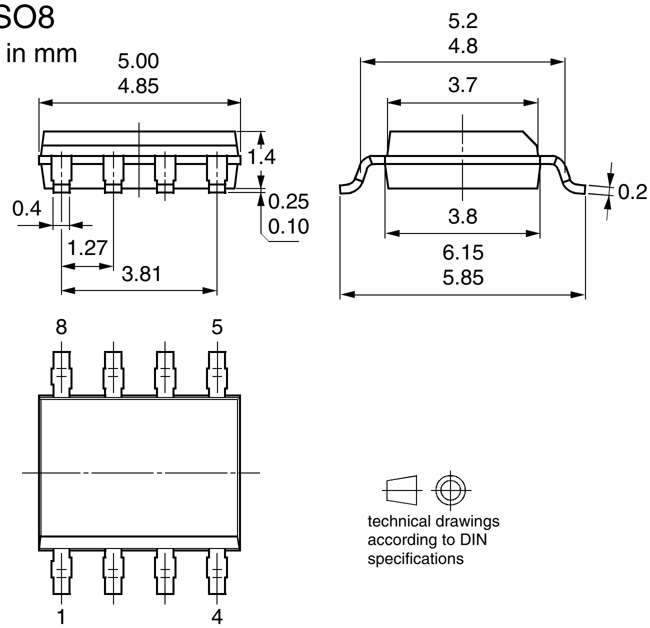
Ordering Information

Extended Type Number	Package	Remarks
U2403B-x	DIP8	Tube
U2403B-xFP	SO8	Tube
U2403B-xFPG3	SO8	Taped and reeled

Package Information



Package SO8
Dimensions in mm



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