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## 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  $> 140^{\circ}\text{C}$ ), 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).



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**Charge Timer IC**

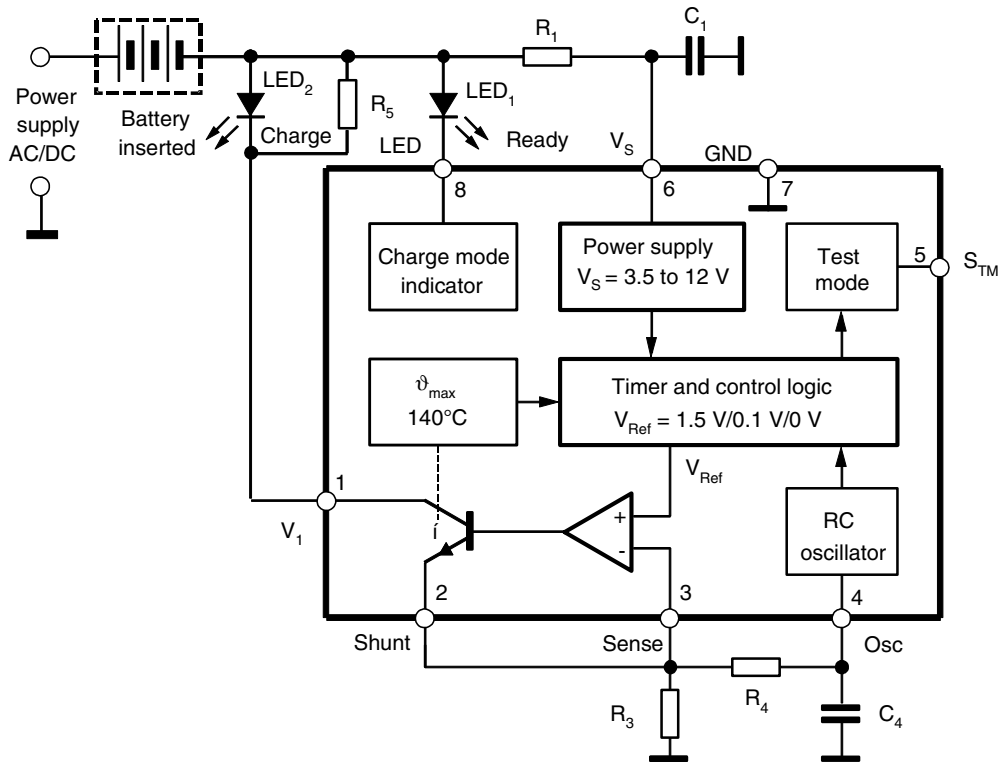
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**U2403B**

Rev. 4776A-INDCO-11/03

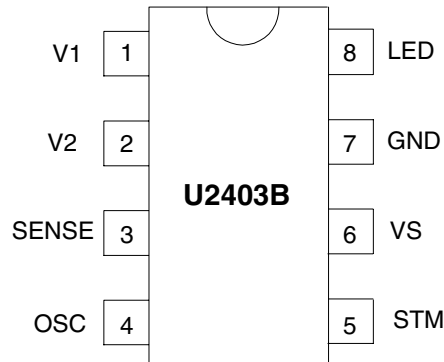


**Figure 1.** Block Diagram with External Circuit



## 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  $V_1 \leq 3\text{ V}$ , 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.

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

### 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

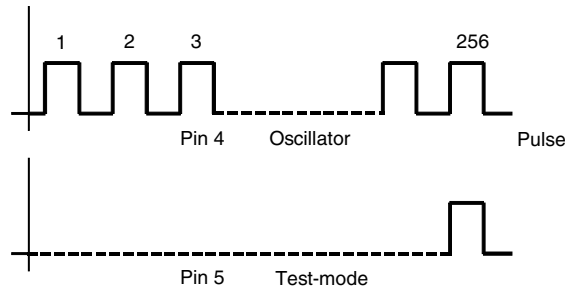
= 26, if  $S_{TM}$  open

= 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:  $R_4 = 470 \text{ k}\Omega$

$C_4 = 680 \text{ pF}$

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,  $V_S$**   $V_S \approx 3.1 \text{ V}$  Power-on reset release (turn-on)

$V_S \approx 2.9 \text{ V}$  Under-voltage reset

$V_S \approx 13 \text{ V}$  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.  $\vartheta_{max}$  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:

$$K = 1.5 \text{ V} / 0.1 \text{ V} = 15$$

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

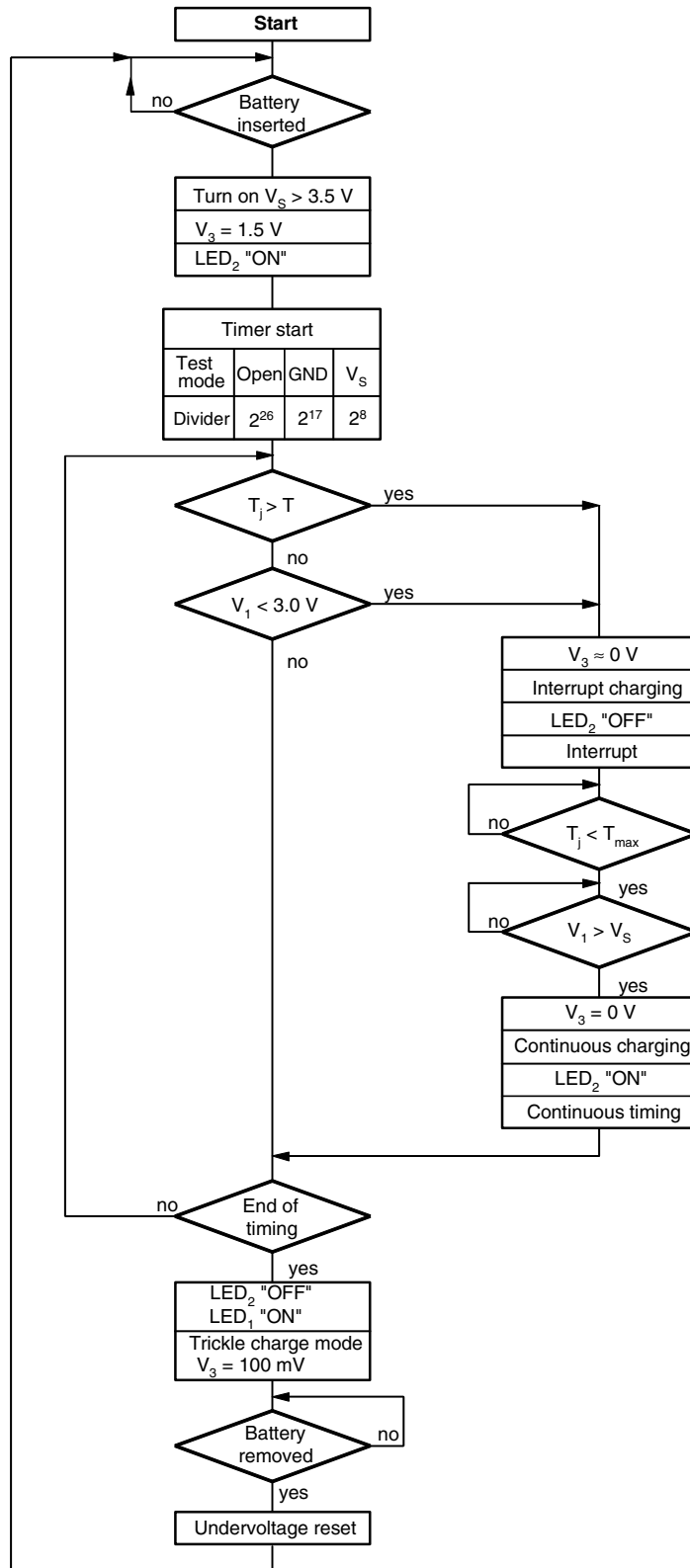
It is possible to reduce the trickle charge with resistor  $R_6$ , as shown in Figure 7 on page 11 and Figure 8 on page 13.

## Charge Characteristics

Table 1. Charge Time

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

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 $t \leq 100 \mu\text{s}$	6	$I_S$	20	mA
		$i_s$	100	mA
Currents	1	$I_1$	300	mA
	2	$-I_2$	310	mA
	3	$I_3$	1	$\mu\text{A}$
	4	$I_4$	15	mA
	5	$I_5$	-75 to +120	$\mu\text{A}$
	8	$I_8$	8	mA
Voltages	1, 3, 5, 6, 8	V	13.5	V
	2	$V_2$	1.6	V
	4	$V_4$	1.5	V
Junction temperature		$T_j$	150	$^{\circ}\text{C}$
Ambient temperature		$T_{\text{amb}}$	-10 to +85	$^{\circ}\text{C}$
Storage temperature range		$T_{\text{stg}}$	-50 to +150	$^{\circ}\text{C}$

## Thermal Resistance

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



## Electrical Characteristics

$V_S = 6\text{ V}$ ,  $T_{\text{amb}} = 25^\circ\text{C}$ , reference point pin 7 (GND), unless otherwise specified.

Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit
Supply voltage limitation	$I_S = 4\text{ mA}$	6	$V_S$	12.5		13.5	V
	$I_S = 20\text{ mA}$	6	$V_S$	12.6		13.7	V
Supply current	$V_S = 6\text{ V}$		$I_S$	1.4		2.2	V
<b>Voltage Monitoring</b>		6					
Turn-on threshold			$V_{\text{TON}}$	2.8		3.5	V
Turn-off threshold			$V_{\text{TOFF}}$	2.5		3.2	V
<b>Charge-mode Indicator (LED)</b>		8					
LED current			$I_8$	3.0		6.0	mA
LED saturation voltage	$I_8 = 3.7\text{ mA}$		$V_8$			960	mV
Leakage current			$I_{\text{lk}}$	-0.35		1.1	$\mu\text{A}$
<b>Collector Terminal, Figure 6 on page 10</b>		1					
Open-collector current			$I_{\text{CO}}$	15		55	$\mu\text{A}$
Saturation threshold	$V_S = 6\text{ V}$		$V_{\text{TON}}$	2.55	3.0	3.35	V
			$V_{\text{TOFF}}$	$V_S - 1\text{ V}$	$V_S$	$V_S - 0.4\text{ V}$	V
Shunt emitter current	$R_3 = 5.6\ \Omega$	2	$I_2$	250		285	mA
<b>Operational Sense Amplifier, Figure 1 on page 2</b>		3					
Input current	$V_3 = 0\text{ V}$		$I_3$	-0.6		0.08	$\mu\text{A}$
Input voltage	$V_{\text{Ref}} = 1.5\text{ V}$ $V_{\text{Ref}} = 100\text{ mV}$ $V_{\text{Ref}} = 0\text{ V}$		$V_3$	1.42	1.5	1.58	V
			$V_3$	40	70	100	mV
			$V_3$	-0.4		40	mV
<b>Oscillator</b>		4					
Leakage current	$V_4 = 0\text{ to }0.85\text{ V}$		$I_{\text{lk}}$	-0.5		0.1	$\mu\text{A}$
Threshold voltage	Upper		$V_{\text{T(u)}}$	875		985	mV
Oscillator frequency	$R_4 = 160\text{ k}\Omega$ , $C_4 = 2.2\text{ nF}$ $R_4 = 680\text{ k}\Omega$ , $C_4 = 4.7\text{ nF}$		$f_{\text{osc}}$	2700		3050	Hz
			$f_{\text{osc}}$	305		345	Hz
<b>Test Mode Switch (<math>S_{\text{TM}}</math>)</b>		5					
Input current	$V_5 = 6\text{ V}$		$I_5$	40		120	$\mu\text{A}$
	$V_5 = 0\text{ V}$		$I_5$	-75		-20	$\mu\text{A}$
Output voltage	High		$V_{0(\text{H})}$	1.7		2.5	V
	Low		$V_{0(\text{L})}$	0.5		1.0	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 ( $T_j > 140^\circ\text{C}$ ), the temperature monitoring remains permanently activated (ON). The total cycle time is prolonged according to the interrupt-time duration, see Figure 5.

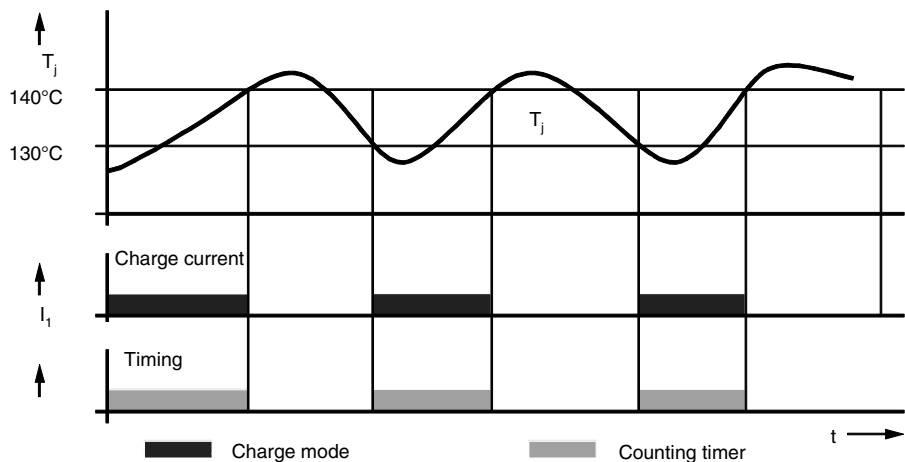
### Automatic Control Protection

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

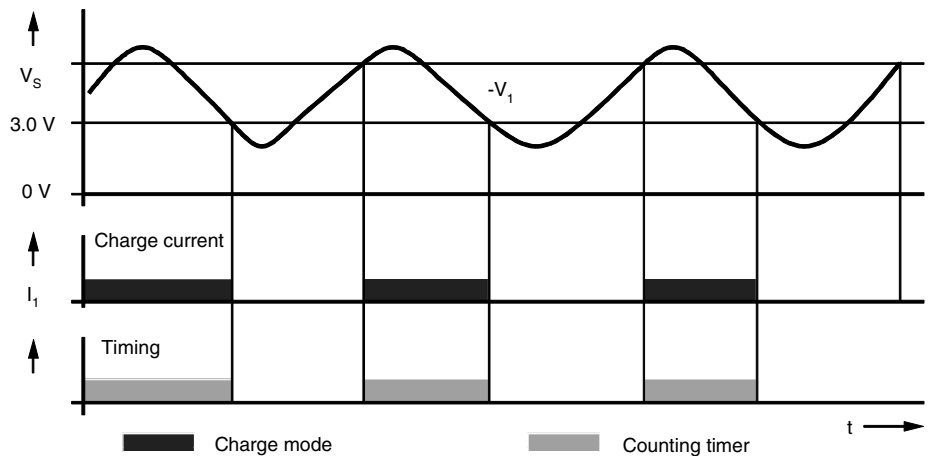
The output stage of the control is selected so that it is switched off before saturation is achieved ( $V_{CEsat} = 3.0\text{ V}$ ). In this case, the voltage at pin 3 is kept at a value of zero. The charge current is also zero, and the transformer is now an open-circuit impedance. The system becomes 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	$R_1 = 510 \Omega$ , 1/8 W
Charging time: 3 h	$C_1 = 47 \mu\text{F}$ / 16 V
Charge current: 240 mA, 1/3 C	$R_3 = 6.2 \Omega$ , 1/2 W
Trickle charge: 19 mA < 1/40 C	$R_4 = 300 \text{k}\Omega$
	$C_4 = 470 \text{pF}$
	$R_5 = 8.2 \Omega$ , 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 k $\Omega$	430 k $\Omega$	470 k $\Omega$	470 k $\Omega$	390 k $\Omega$
$C_4$	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 $\Omega$	10 $\Omega$	15 $\Omega$	30 $\Omega$
$R_5$	8.2 $\Omega$	15 $\Omega$	22 $\Omega$	68 $\Omega$

## Basic Equations

$$R_1 = 0.5 \text{ V}/I_S$$

$$I_S = 1.8 \text{ mA}$$

$$R_5 = V_3 / (I_{ch} - 20 \text{ mA})$$

## Nominal Charge Current

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

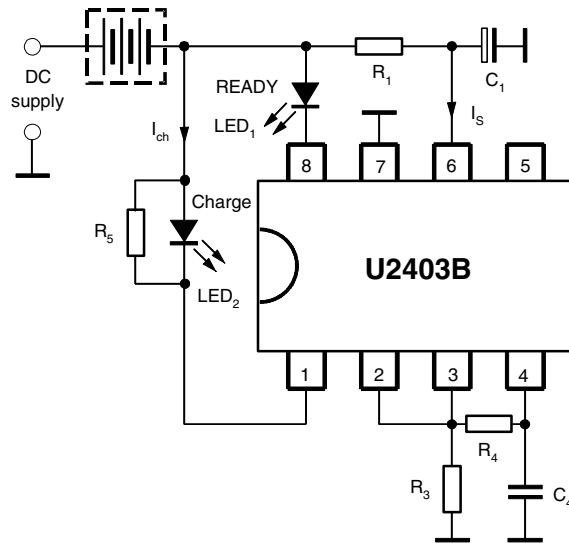
Trickle Current:

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

Typical values are:

$$V_3 = 100 \text{ mV}, I_g = 4.5 \text{ mA}$$

**Figure 7.** Standard Application



## Booster and Trickle Charge Reduction

### Basic Example

NiCd battery 1000 mAh	$R_1 = 510 \Omega$ , 1/8 W
Charging time: 2 h	$C_1 = 1000 \mu\text{F}$ / 16 V
Charge current: 500 mA	$R_3 = 3 \Omega$ , 1 W
Trickle charge: 22 mA < 1/22 C	$R_4 = 300 \text{ k}\Omega$
	$C_4 = 330 \text{ pF}$
	$R_5 = 3.9 \Omega$ , 1 W
	$C_2 = 1 \mu\text{F}$

**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 k $\Omega$	430 k $\Omega$	470 k $\Omega$	470 k $\Omega$	390 k $\Omega$
$C_4$	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 $\Omega$	3 $\Omega$	3.6 $\Omega$	5 $\Omega$
$R_5$	3.9 $\Omega$	3.9 $\Omega$	4.7 $\Omega$	6.8 $\Omega$

$R_6 = 560 \Omega$ , reduced trickle charge

### Basic Equations

$$R_1 = 0.5 \text{ V}/I_S$$

$$R_5 = V_{(\text{LED}2)}/(I_{\text{ch}} - 20 \text{ mA})$$

### Nominal Charge Current

$$I_{\text{ch}} = V_3/R_3$$

$$V_3 = 1.48 \text{ V, typically}$$

**Trickle Current:**

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

Typical values:

$$V_3 = 100 \text{ mV}$$

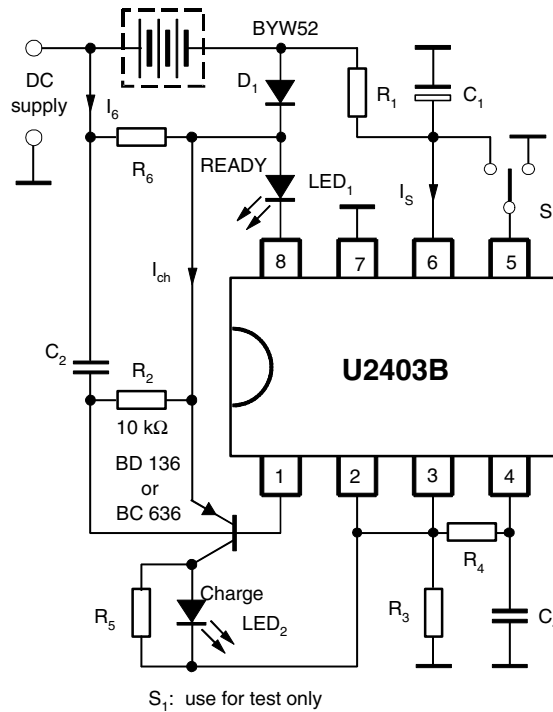
$$I_{LED1} = 4.5 \text{ mA}$$

$$I_S = 1.8 \text{ mA}$$

**Trickle-charge Reduction ( $I_6$ )**

$$I_6 = (V_{Batt} + V_{D1})/R_6 \quad V_{D1} = 0.75 \text{ V}$$

**Figure 8.** Application for Charge Current > 250 mA

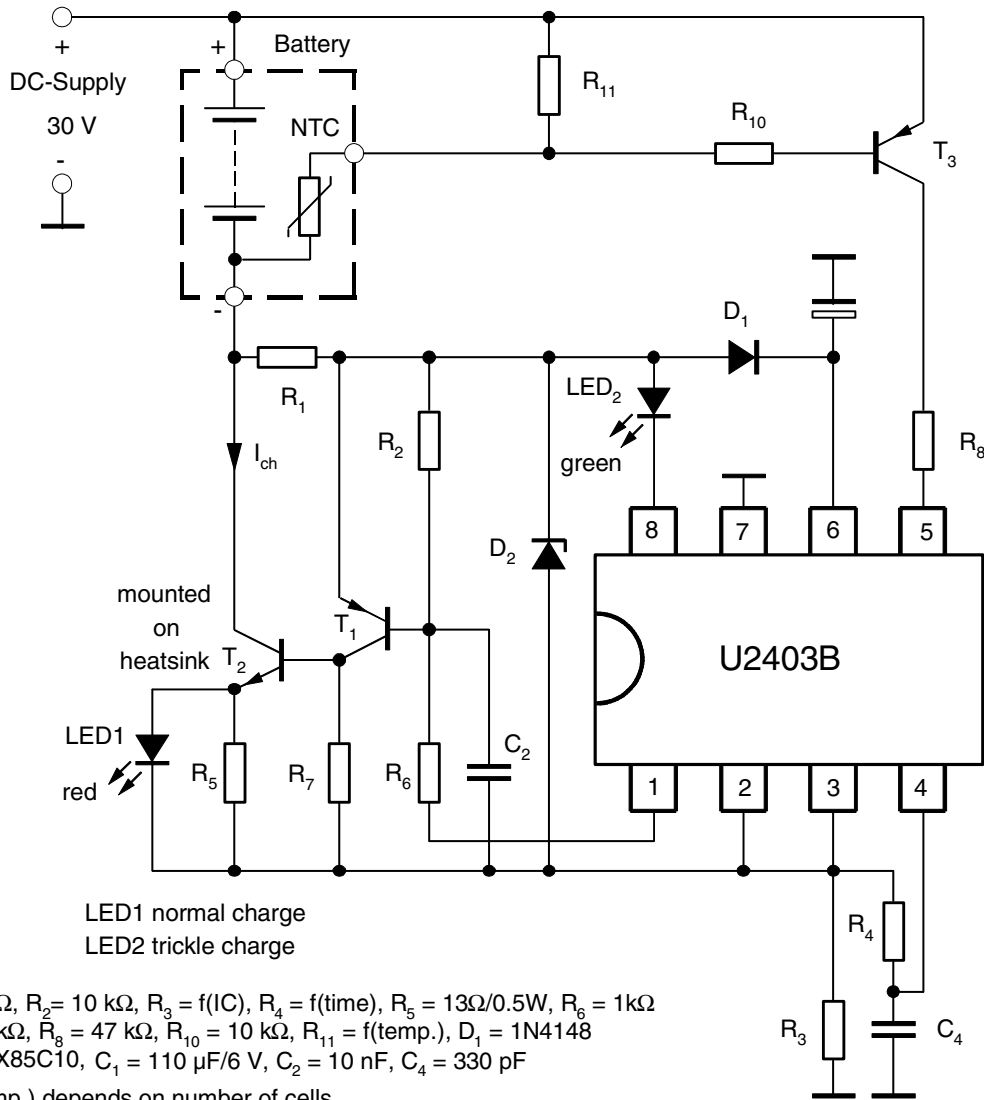


To meet the requirements of higher charge currents, an external booster transistor can be used (see Figure 8). As the temperature cannot be monitored in this case, a heat sink with a reasonable size should be used for safe operation. The test mode switch S<sub>1</sub> can be used for accelerated production check.

**Charge System at Higher Voltage up to 30 V**

Charge systems with higher voltages than V<sub>Smax</sub> 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<sub>3</sub>, is switched on. If T<sub>3</sub> 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 k $\Omega$
3	8.2 k $\Omega$
4	6.2 k $\Omega$
5	4.7 k $\Omega$

**Table 9.** NTC Resistance at Different Temperatures

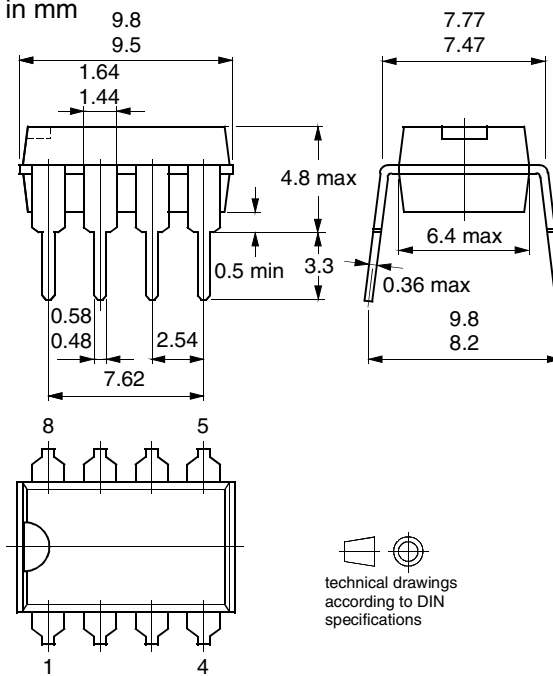
NTC Value	NTC Resistance
25°C	6.8 k $\Omega$
40°C	3.9 k $\Omega$
50°C	2.8 k $\Omega$

### Ordering Information

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

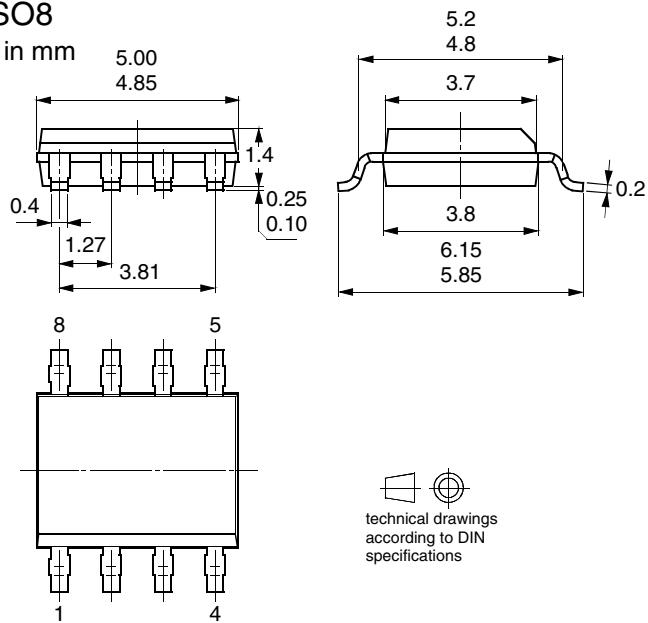
### Package Information

Package DIP8  
Dimensions in mm





Package SO8  
Dimensions in mm





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