Cost effective battery monitor and fast charge IC for NiCd and NiMH chargers

TEA1104; TEA1104T

FEATURES

- Accurate detection of fully charged batteries by currentless peak voltage sensing
- Switch-over from fast to safe trickle charge current at battery full detection
- Fast charge termination back-up by maximum time and maximum temperature detection
- Several trickle charge drive possibilities for mains isolated and non-mains isolated systems
- Battery checking to protect against short-circuited and open batteries
- Battery monitor allows recharging of different battery packs in the same charger
- Dual LED indicator provision
- External regulator not required because of large input voltage range
- Few low cost external components required.

APPLICATIONS

- Portable telephone
- Portable computer
- Portable audio
- Portable video.

GENERAL DESCRIPTION

The TEA1104 is manufactured in a BiCMOS process intended to be used as a battery monitor circuit in charge systems for NiCd and NiMH batteries. It is especially designed for cost effective compact consumer applications.

The circuit is able to detect fully charged batteries by currentless battery voltage sensing. Several output drive functions are available to control the (reduced) trickle charge current to keep the batteries full with maximum life expectations.

The battery full detection is backed up by two independent mechanisms to make the system fail safe; maximum time and maximum temperature.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_P	supply voltage		5.45	–	11.5	V
I_P	supply current	outputs off	–	–	3	mA
V_{bat}	voltage range of battery full detection		0.81	–	3.6	V
$\Delta V_{bat}/V_{bat}$	voltage peak detection level with respect to top value		–	0.25	–	%
I_{bat}	battery monitor input current		–	–	1	nA
$V_{bat(l)}$	battery voltage protection low		–	0.81	0.91	V
$V_{bat(h)}$	battery voltage protection high		3.5	3.6	–	V
f_{osc}	oscillator frequency		10	–	100	kHz

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
TEA1104	DIP8	plastic dual in-line package; 8 leads (300 mil)	SOT97-1
TEA1104T	SO8	plastic small outline package; 8 leads; body width 3.9 mm	SOT96-1

BLOCK DIAGRAM

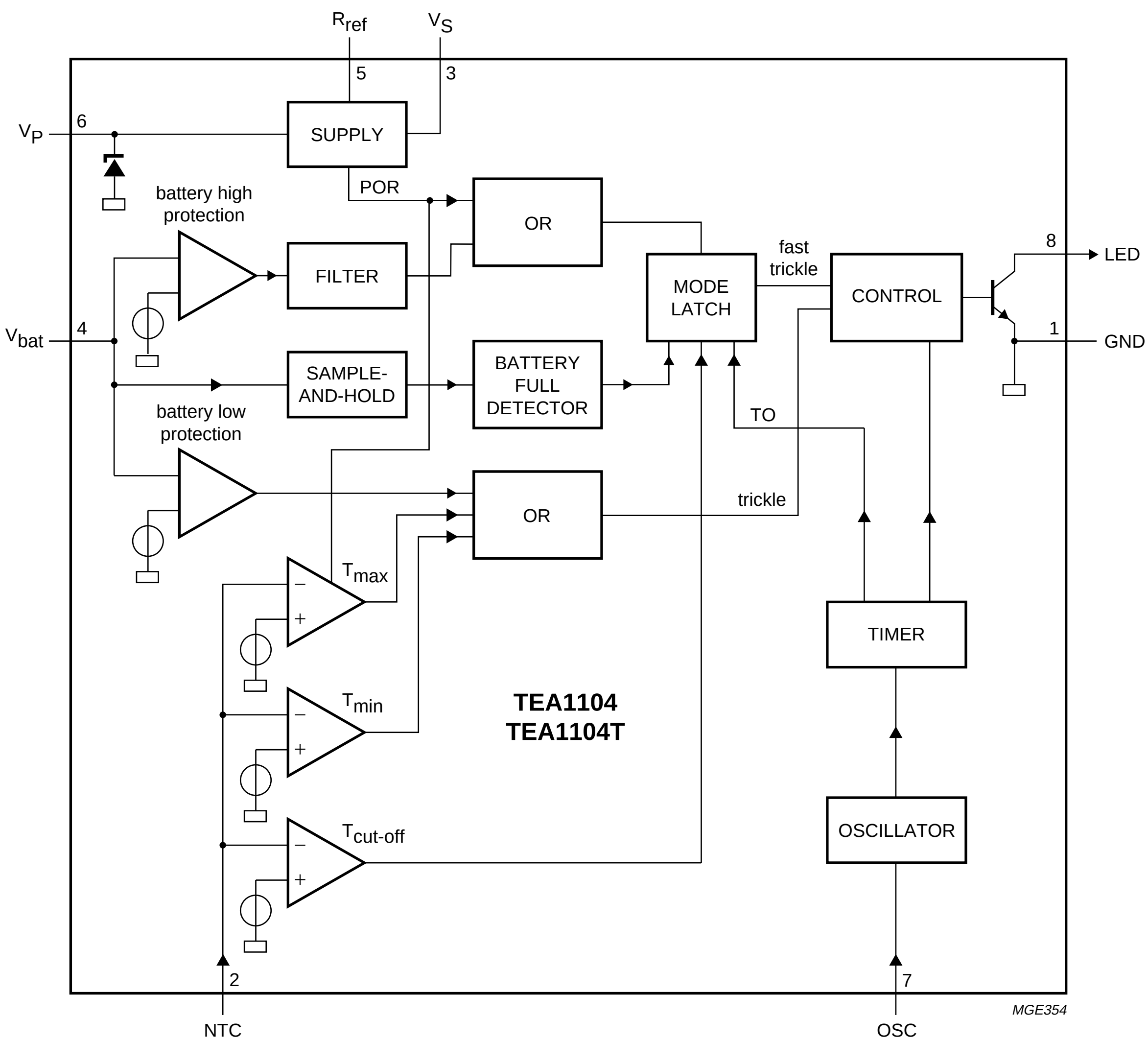


Fig.1 Block diagram.

PINNING

SYMBOL	PIN	DESCRIPTION
GND	1	ground
NTC	2	negative temperature coefficient resistor input
V_S	3	stabilized supply voltage
V_{bat}	4	battery voltage sensing
R_{ref}	5	reference resistor
V_P	6	positive supply voltage
OSC	7	oscillator input
LED	8	LED output

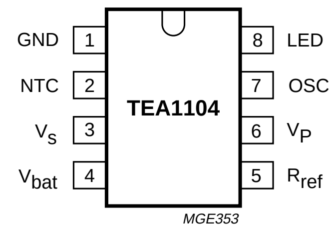


Fig.2 Pin configuration.

INTRODUCTION

The operation of the TEA1104; TEA1104T is explained with the aid of the application diagram illustrated in Fig.7.

An application note (AN95085) is available describing the versatility of the TEA1104; TEA1104T.

An external power current source charges the batteries via an electronic switch which is controlled by the TEA1104. The TEA1104 monitors the battery voltage. Fully charged batteries are detected when the battery voltage peaks. In fact, a voltage drop of 0.25% with respect to the top value is detected. Fast charging is initiated at ‘power on’ or at ‘replaced batteries’. The switch is continuously on, providing that all protection levels are met. At battery full detection, the charge current is duty cycled to reduce the average charge current to a lower level, keeping the batteries fully charged but at he same time assuring long battery life. In Fig.3 the battery voltage during fast charge is plotted.

FUNCTIONAL DESCRIPTION

A block diagram of the TEA1104; TEA1104T is illustrated in Fig.1

Mode latch

The Mode latch determines if the system is in the fast or in the slow charge mode.

- Fast charge is active at:
  - power switch-on and battery connected
  - temperature between minimum and maximum value
  - battery insert
- Trickle charge is active if:
  - battery full is detected
  - maximum time is exceeded
  - maximum cut-off temperature is exceeded after the initial phase.

Supply block

For correct start-up, the IC supply current is limited to 35 µA (typ.) until the start-up voltage of 6.4 V is reached (standby mode). Thereafter, the operating supply voltage V_P has to be within the window of 5.45 to 11.5 V, meaning that there is no need for an external voltage regulator to supply the IC.

The supply block delivers the following outputs:

- With the help of an external resistor (pin R_{ref}), a reference current is obtained which defines the accuracy of all IC timing characteristics
- Externally available 4.25 V stabilized voltage source (V_{source}). This source is used internally to supply a large part of the circuit and can be used to set the NTC biasing and to supply other external circuitry with a maximum current of 1 mA. Protection information is provided via V_S, to design a dual LED indicator
- Power-on reset pulse resets all digital circuitry after a start or restart, due to an interrupted V_S.

Open battery protection

When the rechargeable battery is removed, the output voltage V_{bat} will rise to a high level. The ‘open battery protection’ block will detect this voltage and the charge current will be switched off. A digital filter prevents false open battery protection. The open battery signal (V_{bat} > 3.6 V) must be present for a duration of at least 4 clock pulses.

Battery monitor

One or two cell packs can be connected directly to V_{bat} (battery connection) without an external resistor divider. At larger cell packs the battery voltage must be scaled down to a voltage range of 0.81 to 3.6 V. It is also possible to take a tap on the chain of batteries. Battery full is recognized by voltage peak detection (V_{peak}), meaning a decrease of 0.25% (typ.) with respect to the top value. Keeping in mind a battery voltage range of 0.81 to 3.6 V and an accuracy of 10% at V_{bat} = 2.4 V for battery full detection, means that the internal ADC has to be 13 bits. Several filters are included to prevent false full detection. The series resistance of the battery and battery connection can cause battery voltage fluctuations and therefore it is necessary to stop the charging before sensing; this is called the ‘inhibit time’. This will be performed automatically via the regulation output pin LED. The charging is stopped for ten oscillator periods at the end of which sampling is performed. The battery voltage will now be sensed in a currentless way.

Timer/oscillator

The oscillator has a sawtooth shape.

The period time is defined by: $t_{osc} = K \times R_{ref} \times C_{osc}$

The oscillator frequency is used in the timer block. In this block several important signals are created.

- Time-out for protecting the fast charge process in time. Time-out is normally chosen to be 25% longer than the associated fast charge time. So for a one hour charge time, time-out = 1.25 hours. The relationship with the oscillator period time is:
  - Time-out = 2 exp28 $\times t_{osc}$
- The duty factor in the trickle charge mode: The duty factor is fixed to $\frac{1}{40}$, meaning that the average:
  - $I_{trickle} = \frac{1}{40} \times I_{fast}$
  - $t_{on} = \frac{3}{4} \times 2$ exp9 $\times t_{osc}$
  - $t_{off} = 2$ exp14 $\times t_{osc}$.
- The battery voltage is sensed each ‘cycle time’. The cycle time is defined as:
  - $T_{cycle} = 2$ exp16 $\times t_{osc}$
- The ‘inhibit time’ is the time that the charger current is disabled, after which the battery voltage is sensed in a currentless way.
  - $t_{inhibit} = 10 \times t_{osc}$

  Battery sampling takes one oscillator period for each cycle interval.
  - $t_{sample} = t_{osc}$
- The ‘disable time’ is present to correct start-up with flat or polarized batteries. During the disable time, the battery full detection is not active.
  - $t_{disable} = 2$ exp –5 $\times$ time-out

The timer is reset by battery full detection, but is on hold during the temperature and battery-low protection modes.

Temperature protection block

Temperature sensing is achieved by using a cheap thermistor. Two temperature windows are built in:

- If the temperature at power-on reset is above the maximum temperature protection level, the trickle charge current is active. The same applies for temperatures below the minimum temperature. Fast charging starts when the temperature is in between the minimum and the maximum temperature levels.
- If the temperature is between the maximum and minimum temperature at power-on reset, the fast charge current level is active. If the temperature sinks below the minimum temperature level, again the trickle charge level is active. At rising temperature, the fast charge current is latched off at the ‘cut off’ temperature level.

To avoid switching on and off with temperature, a hysteresis is built in for low temperature level. If the temperature protection is not necessary, pin ‘Negative Temperature Coefficient resistor’ (NTC) must be connected to pin R_{ref}.

Battery low protections

When the battery voltage is less than 0.81 V, the circuit assumes that there are short circuited batteries and the charge current is reduced to the trickle charge level. If the batteries are flat, the trickle charge current is able to raise the battery voltage within an acceptable period of time, after which fast charging starts.

Output drivers

Several output drive possibilities are supported by the TEA1104, to limit the fast charge current and to indicate the mode that the charge is in.

In mains isolated systems, output drive current is available for a bipolar or MOS switching device. Moreover, current regulators can be driven (see Fig.4).

In non mains isolated systems, the current source can be switched via the auxiliary winding (see Fig.6) using the TEA140X power plugs.

In the application section, an example is shown driving two LEDs that are indicating fast charging, protection during fast charging, full status and removed batteries. It is also possible to output the same information via one LED only.

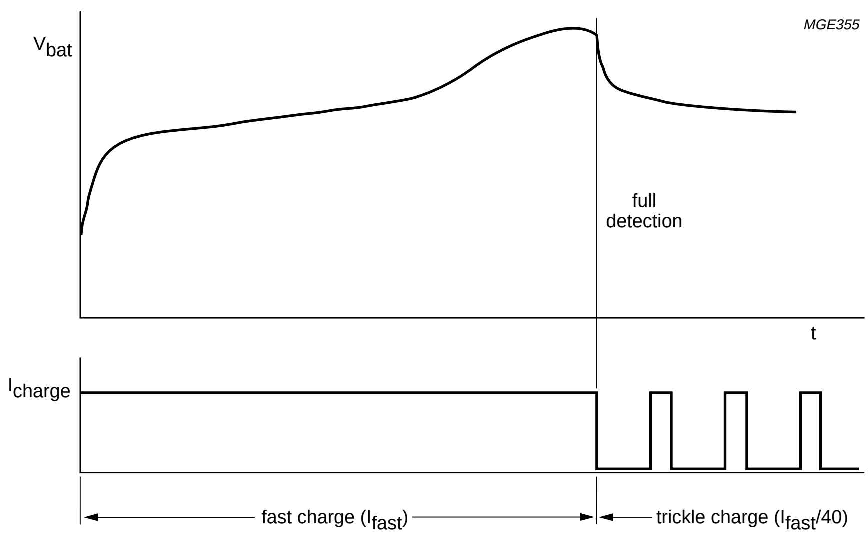


Fig.3 NiCd battery characteristics during a 1.25C charge cycle.

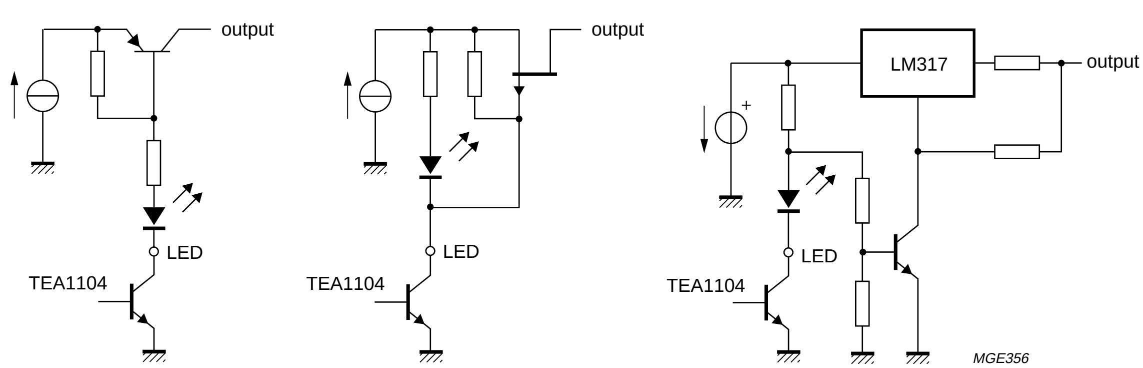
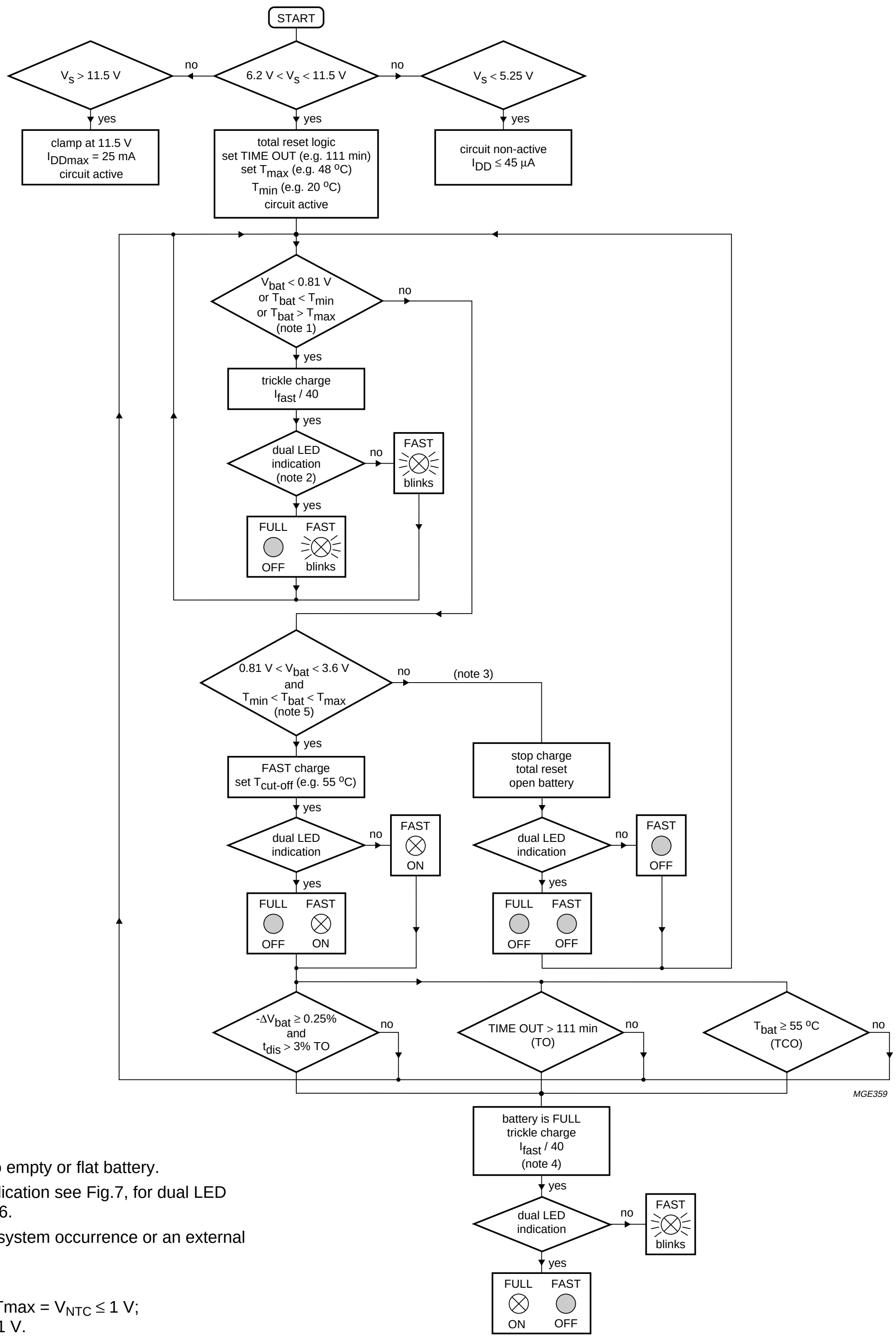


Fig.4 Output drivers.



(1) V_{bat} < 0.81 V due to empty or flat battery.

(2) For single LED application see Fig.7, for dual LED application see Fig.6.

(3) V_{bat} > 3.6 V due to system occurrence or an external inhibit via pin V_{bat}.

(4) Release via reset.

(5) $T_{min} = V_{NTC} \geq 2$ V; $Tmax = V_{NTC} \leq 1$ V; $T_{cut\text{-}off} = V_{NTC} \leq 0.81$ V.

Fig.5 Flow chart of the TEA1104.

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134); note 1.

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_P	supply voltage		–0.5	+13.2	V
V_{oLED}	LED output voltage (pin 8)		–0.5	V_P	V
V_{iNTC}	negative temperature coefficient resistor input voltage (pin 2)		–0.5	+5	V
$V_{i(OSC)}$	oscillator input voltage (pin 7)		–0.5	+5	V
$V_{i(bat)}$	battery input voltage (pin 4)		–0.5	+5	V
V_{Rref}	reference resistor voltage (pin 5)		–0.5	+5	V
I_{source}	output source current		–3	+0.01	mA
I_{oLED}	LED output current		–	25	mA
I_{Rref}	reference resistor current		–1	+0.01	mA
I_{bat}	battery current		–1	+1	mA
V_P	supply current		–	25	mA
P_{tot}	total power dissipation	T_{amb} = 70 °C			
		TEA1104	–	0.5	W
		TEA1104T	–	0.35	W
T_{amb}	operating ambient temperature		–20	+70	°C
$T_{j(max)}$	maximum operating junction temperature		–	+150	°C
T_{stg}	storage temperature		–55	+150	°C

Note

1. All voltages are measured with respect to ground; positive currents flow into the IC. The voltage ratings are valid provided that other ratings are not violated; current ratings are valid provided that the power rating is not violated.

QUALITY SPECIFICATION

In accordance with *“SNW-FQ-611 part E”*. The numbers of the quality specification can be found in the *“Quality Reference Handbook”*. The handbook can be ordered using the code 9397 750 00192.

CHARACTERISTICS

V_P = 10 V; T_{amb} = 25 °C; R_{ref} = 33 kΩ; C_{OSC} = 1 nF; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_P	supply voltage		5.45	–	11.5	V
$\Delta V_P/\Delta t$	supply voltage start rate		–	–	0.5	V/µs
V_{clamp}	clamping voltage	I_{clamp} = 25 mA	11.5	–	12.8	V
V_{start}	start-up voltage		6.1	6.4	6.7	V
V_{pd}	power-down voltage level		4.65	5.05	5.45	V
I_P	supply current	outputs off	–	–	3	mA
I_{start}	start-up current	V_P = 4 V	–	45	50	µA
V_S	stabilized voltage	I_S = 1 mA	4.03	4.25	4.46	V
V_{Rref}	voltage range at reference resistor	I_{Rref} = 20 µA	1.18	1.25	1.31	V
TC_{Vref}	temperature coefficient of the reference voltage	T_{amb} = 0 to 45 °C	–	±60	±120	ppm/K
I_{Rref}	current range of the reference resistor		10	–	100	µA
Temperature related input; NTC						
$V_{i(co)}$	input voltage level for detecting temperature cut-off		0.75	0.81	0.87	V
$V_{i(co;\ max)}$	maximum input voltage level for detecting temperature cut-off		0.92	1.0	1.08	V
$V_{i(co;\ min)}$	minimum input voltage level for detecting temperature cut-off		1.85	2.0	2.15	V
I_{NTC}	input current	V_{NTC} = 1.5 V	–5	–	+5	µA
Output drivers						
δ_{LED}	LED pulse duty factor		2.4	2.5	2.6	%
$V_{LED(sat)}$	LED saturation voltage	$I_{LED(sat)}$ = 15 mA	–	–	600	mV
$I_{LI(LED)}$	LED input leakage current	V_{LED} = 15 V	–	–	5	µA
Battery monitor						
$I_{i(bat)}$	input battery current	V_{bat} = 2.4 V	–	1	–	nA
V_{bat}	voltage range for peak detection		0.81	–	3.6	V
$\Delta V_{bat}/V_{bat}$	peak detection level with respect to top level	V_{bat} = 2 V	–	0.25	–	%
T_j	temperature range of peak detection		0	–	50	°C
Protections; BAT						
$V_{bat(l)}$	low level battery protection voltage		–	0.81	0.91	V
$V_{bat(h)}$	high level battery protection voltage		3.5	3.6	4.5	V
Oscillator						
k	correction factor		0.84	0.93	1.02	
f_{osc}	frequency range		10	–	100	kHz

APPLICATION INFORMATION

A guideline for the settings of TEA1104 and its external components selection is given based on an example of a 1 hour charger for a 4 cell NiCd or NiMH battery pack. The basic application diagram as illustrated in Fig.6 which is based on the application diagram illustrated in Fig.7 with some additional components; a 2 LED charge status indication has been provided.

For charging a battery within one hour the charge current rating should be as follows:

Required minimum charge current = battery capacity × 1.2/charge time.

Therefore, for a 1 Ah battery the external charge current supply has to deliver at least 1.2 A.

TEA1104 settings

The fast charge back-up timer period, time-out, has to be set in relation to the expected maximum charge time. Normally, a safety back-up time is chosen approximately 25% longer than the maximum expected fast charge time. For a one hour charger the time-out period can be set to 1.25 h.

Time-out relationship with the oscillator repetition time is as follows;

t_{osc} = time-out (h) × 3600/2 exp28

t_{osc} = 17µs for time-out = 1.25 h

t_{osc} is set with the combination of C_{osc} and R_{ref}; where $t_{osc} = 0.93 \times R_{ref} \times C_{osc}$.

R_{ref} can be chosen between 13 and 120 kΩ, but a 27 kΩ resistor is recommended. The oscillator capacitor can be calculated which is 668 pF; the nearest higher practical value is 680 pF.

In the trickle charge mode the LED output will pulsate with a repetition time; $t_{trickle}$ = 2 exp14 × t_{osc} = 0.28 s.

The duty factor of the pulse is 2.5% of $t_{trickle}$. This duty factor also applies to the charge current as the charge current switch is driven by the LED output. Therefore, the average trickle charge current is I_{fast} /40. The V_{bat} input can be adapted to the battery voltage via the resistor dividers R1 and R2. When an NTC thermistor has been incorporated into the battery, the minimum, maximum and cut-off temperature levels can be set with the resistors R3 and R4. For an NTC with a common sensitivity of 3965 and adjustment resistor values R3 = 13 kΩ, R4 = 20 kΩ the minimum, maximum and cut-off temperatures will be 5, 42 and 50 °C respectively.

The flow chart of the TEA1104; TEA1104A is given in Fig.5. The load state of the batteries can be displayed by one or two LEDs. The flow chart is not to be regarded as sequential. Each mode of operation is a purely separate continuous process.

Table 1 Dual LED indication

CHARGER MODE	V_{LED}	V_S	LED 1	LED 2
Fast charging	low	high	on	off
Fast charging protection	low/high	high	on/off	off
Full (trickle charging)	low/high	low	off	on
Battery open	high	high	off	off

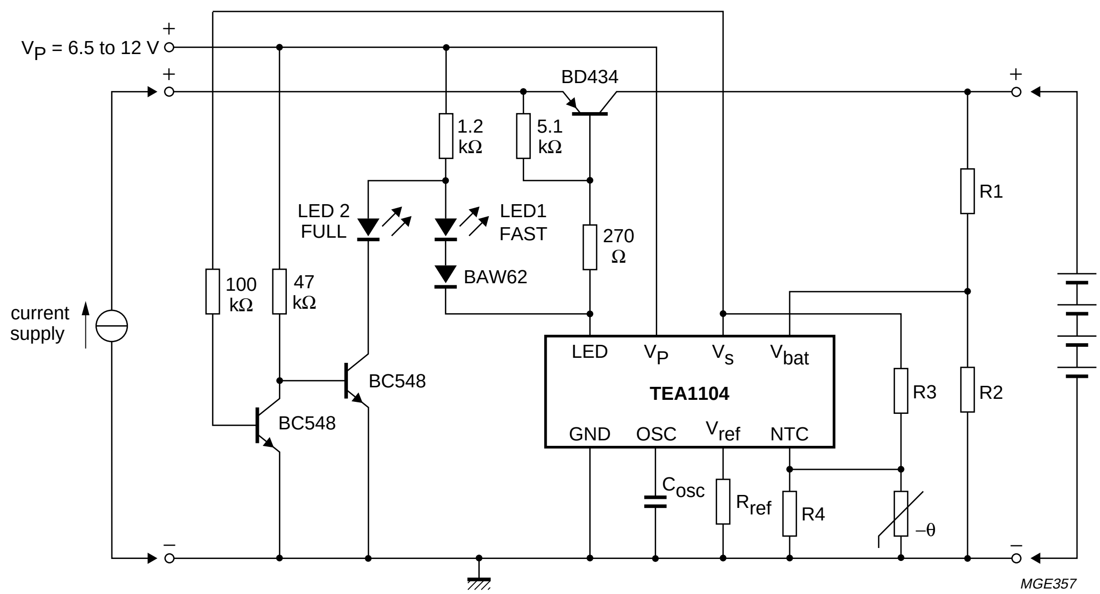


Fig.6 Basic application diagram.

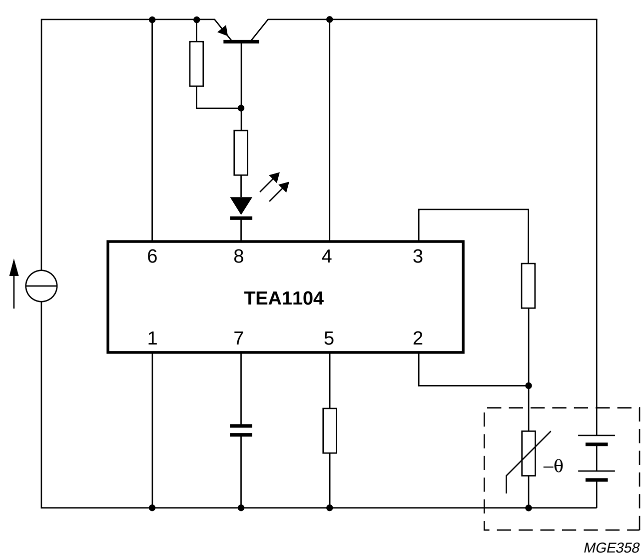


Fig.7 Application diagram.