

T-58-11-31

Data sheet	
status	Product specification
date of issue	April 1991

# TEA1088T

## SMPS battery charger control circuit

### FEATURES

- SMPS control circuit  
fixed frequency/duty factor regulation  
emitter drive for power switch  
current mode control  
dynamic primary current limiting
- Charge control circuit  
accurate output current setting  
fast, two stages, charge mode  
two hours fast charge protection limit  
trickle charge mode for full batteries
- Voltage control circuit  
voltage regulation for connected mains and load
- Battery monitor circuit  
accurate fully charged detection (-dV phenomenon)  
LOW-level detection and indication  
protection against faulty batteries, short or open-circuit  
data output for condition of charge processing  
very LOW stand-by current, < 10 µA

### GENERAL DESCRIPTION

The TEA1088T is a control circuit which has been designed for use in a battery charger and/or monitor system. The device incorporates all the control and protection functions that are required in a switched-mode power supply used to deliver charge current. The circuit also achieves direct drive to the emitter of the SMPS power transistor.

The battery monitor circuit includes a reliable battery-full detector which controls the switch-over from fast charge to trickle charge mode and, in the discharge mode, a battery-LOW detector with two outputs for an LED or buzzer warning indicator.

Protections are provided against

open-circuit, short-circuit or faulty batteries.

The device is primarily designed to control two batteries in series. The number of cells can be extended by using a tap.

### ORDERING INFORMATION

EXTENDED TYPE NUMBER	PACKAGE			
	PINS	PIN POSITION	MATERIAL	CODE
TEA1088T	16	SO16	plastic	SOT162A



Product specification

**SMPS battery charger control circuit****TEA1088T****QUICK REFERENCE DATA**

SYMBOL	PARAMETER	CONDITION	MIN.	TYP.	MAX.	UNIT
V <sub>6</sub>	supply voltage	charge	5.5	-	31.0	V
I <sub>6</sub>	supply current	charge	-	-	19	mA
I <sub>10</sub>	supply current	discharge	-	-	12	mA
I <sub>10</sub>	stand by current		-	-	10	μA
I <sub>1</sub>	SMPS transistor bias current		-	-2	-	mA
V <sub>2-V3</sub>	saturation voltage emitter switch	I <sub>2</sub> = 350 mA	0.9	-	1.4	V
V <sub>10</sub>	battery voltage range	2 cells	1.8	-	4.0	V
V <sub>11</sub>	threshold battery LOW indication		1.17	-	1.33	V
I <sub>13,14</sub>	LED output currents	V <sub>13,14</sub> = 0.5 V	21	30	39	mA
V <sub>10</sub>	voltage range of battery full detection		2.3	-	4.3	V
V <sub>10</sub>	threshold for full indication		-	-22	-	mV

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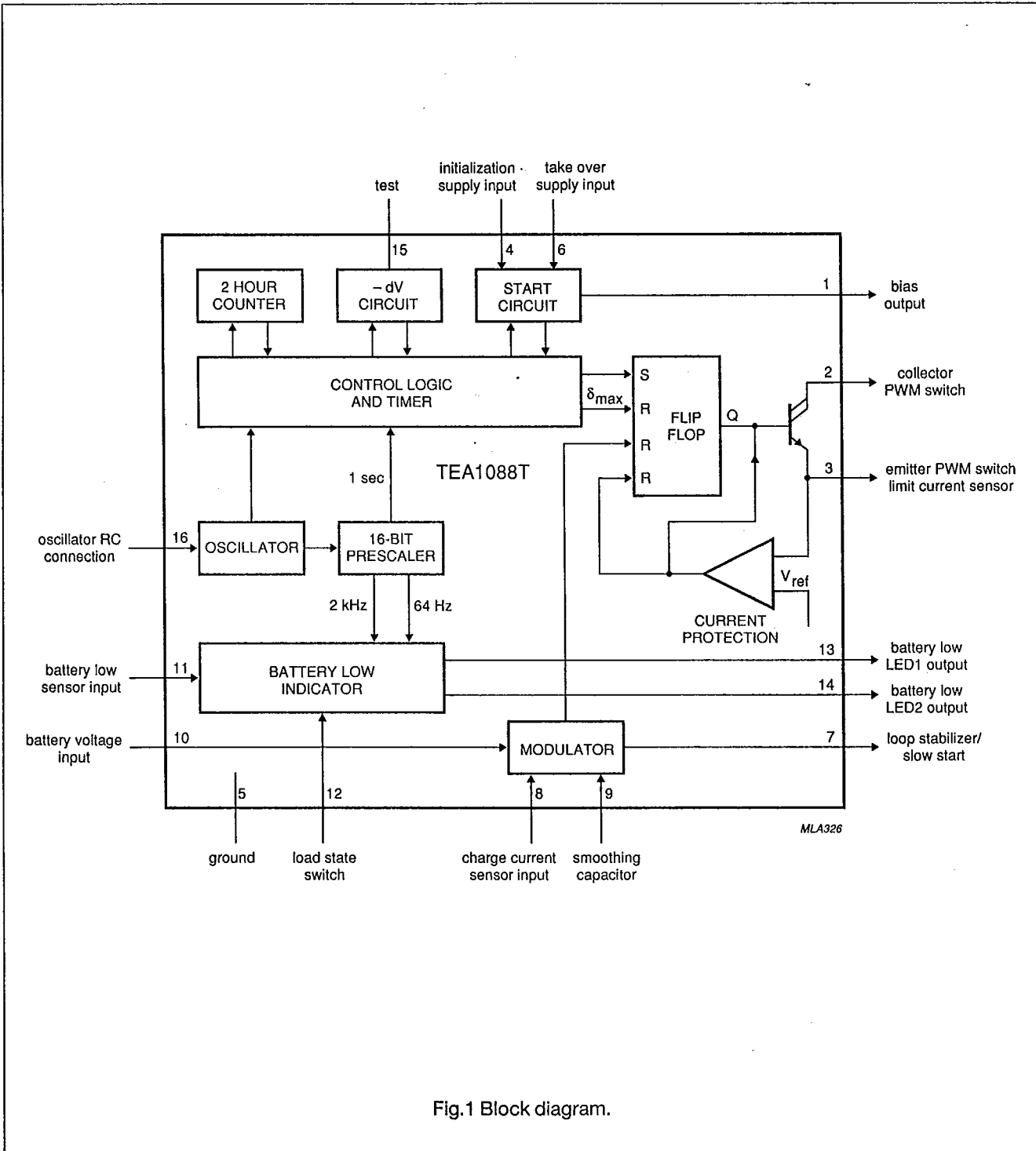


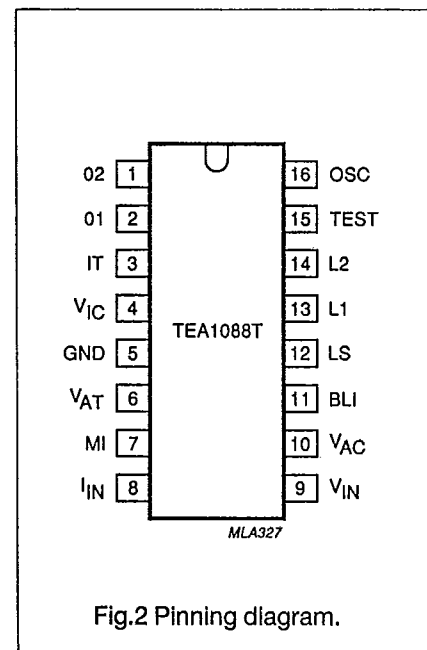
Fig.1 Block diagram.

## SMPS battery charger control circuit

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## PINNING

SYMBOL	PIN	DESCRIPTION
O2	1	bias output
O1	2	collector PWM switch
IT	3	emitter PWM switch/limit current sensor
V <sub>IC</sub>	4	initialization supply input
GND	5	ground
V <sub>AT</sub>	6	take over supply input
MI	7	loop stabilizer/slow start
I <sub>IN</sub>	8	charge current sense input
V <sub>IN</sub>	9	"V <sub>AC</sub> " smoothing capacitor
V <sub>AC</sub>	10	battery voltage input
BLI	11	battery LOW sense input
LS	12	load state switch
L1	13	battery LOW LED1 output
L2	14	battery LOW LED2 output
TEST	15	test pin
OSC	16	oscillator RC connection



## FUNCTIONAL DESCRIPTION

The pin description of the device refers to external components as illustrated in the test circuit diagram (Fig.9). In this circuit the TEA1088T directly drives the emitter of the SMPS Darlington power transistor to provide fast switching and a wide reverse bias SOAR.

The supply output characteristics are shown in Fig.4 and the operational cycles of the charger system are shown in Fig.5.

The battery monitor circuit includes a reliable battery-full detector which controls switch-over from the fast charge to the trickle charge mode. The battery-full detector employs the phenomenon of an increase in battery voltage during charge due to the conversion of charge current into stored energy and, when the battery is full, a slight decrease in voltage due to a negative temperature coefficient when the charge current

is only dissipative.

During charging the battery voltage is carefully sampled every second, the SMPS is then stopped to prevent interference. When a reducing voltage,  $-dV$ , is measured in succession the detector circuit sets the trickle charge mode.

In the discharge mode the battery LOW detector monitors the battery voltage and an output is given when the voltage drops below a set value. The output signals on the L1 and L2 pins are given in Figure 6. The device can also be employed purely as a monitor, this is because the monitor circuit is separate from the charge circuit. Figure 8 gives an application example.

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**SMPS battery charger control circuit****TEA1088T****LIMITING VALUES**

In accordance with the Absolute Maximum System (IEC134); voltage with respect to 0 V.

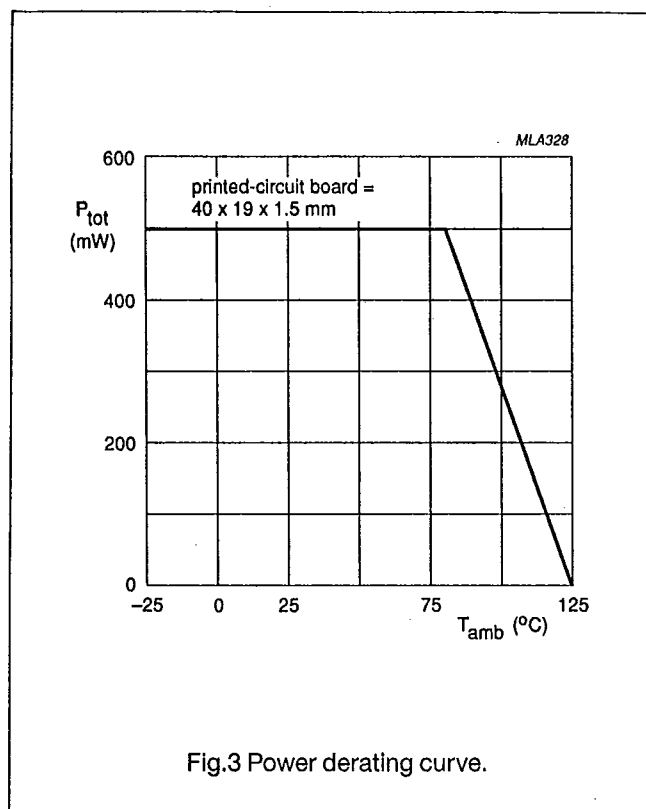
SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
$T_j$	junction temperature		-25	+125	°C
$T_{stg}$	storage temperature range		-25	+125	°C
$V_6$	voltages	continuous	-2.0	31	V
		peak during 100 ms; non-repetition	-	45	V
$V_{10}$		continuous	-	4.0	V
		peak during 2 $\mu$ s; 50 ms repetition	-	12	V
$V_1$			-5.0	15	V
$V_2$		$I_2 = 0$ mA	-0.5	30	V
$V_{11}, V_{12}$			-0.5	4.0	V
		$V_{10} < 4$ V	-0.5	$V_{10} + 0.3$	V
$V_8$			-0.5	0.5	V
$V_{13}, V_{14}$			-0.5	10	V
$I_2, I_3$	currents	continuous	0	350	mA
		peak 1 $\mu$ s	0	1.0	A
$I_8, I_9, I_{11}$			-	2.0	mA
$I_{13}$			-	10	mA
$I_{14}$	battery LOW LED1 output		-	50	mA
$P_{tot}$	total power dissipation	Fig.3	-	500	mW

**THERMAL RESISTANCE**

SYMBOL	PARAMETER	TYP.	MAX.	UNIT
$R_{th\ j-a}$	from junction to ambient in free air	-	90	K/W

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**Supply** (pins 4 and 6)

Pin 6 is the main supply input for the device if it is employed as a battery charger. It can be fed from a DC or AC voltage source; the latter can be provided by a SMPS transformer winding. The positive value of an AC voltage has to be between 7 and 31 V (45 V peak) while the negative value is restricted to -2 V.

Internally, the main supply voltage is series regulated to approximately 6 V which is available at pin 4 for connection of a smoothing capacitor. Initialization is also accomplished via pin 4 by pre-charging the capacitor up to 7.5 V via a resistor from the system power source. At the start of system operation the supply on pin 6 must take over.

When the voltage at pin 4 drops below 3.9 V the circuit switches off and restart occurs via initialization.

**Output stage** (pins 1, 2 and 3)

The PWM output stage consists of a Darlington power transistor with the collector and emitter connected to pins 2 and pin 3 respectively. The current capability is 500 mA peak. This transistor drives a Darlington high voltage transistor switch directly at its emitter to ensure a large reverse bias SOAR and fast switching. The base of the Darlington high voltage transistor is biased by a current source (>1 mA) from pin 1 in combination with an external Zener diode and capacitor (pre-charged at initialization) in order to provide a low impedance base path during switching.

**Dynamic primary current limit (cycle-by-cycle)** (pin 3)

The primary switching current is sensed across an external resistor connected to the emitter of the PWM output switch at pin 3. Internally, the voltage on pin 3 is compared to a reference voltage which in turn is inversely proportional to the voltage difference between V<sub>AT</sub> (pin 6) and V<sub>AC</sub> (pin 10). This voltage difference reflects the input voltage of the system. This method compensates for primary current overshoot variations with input voltage which are caused by internal delay in the IC and storage time in the power transistor. The voltage reference level is defined by:

$$V_{\text{ref}} = 0.44 - 5 \times 10^{-3} \times V_{\text{IN}}/N \text{ [V]}$$

where (N = transformer winding ratio)

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If the sense voltage rises above  $V_{ref}$  then the output is terminated every cycle.

### Modulator (pins 7 to 10)

The PWM is connected with two error amplifiers for regulation of the SMPS output current and voltage. Voltage regulation is enabled only when the SMPS is operative and while the batteries are loaded (pin 12 connected to ground). The current feedback input, pin 8, receives the current information from a resistor  $R_S$  in the output current loop. The voltage waveform across this resistor is negative-going but is shifted to a positive value by addition of a voltage  $I_B \times R_8$  and integration with C8. ( $I_B$  is a reference current from pin 8). This feedback voltage is compared and regulated to the common potential, the output current is defined by:

$$I_O = R_9/R_S.$$

The value of the reference current  $I_B$  depends on the operational state set by the control block which distinguishes:

- First 17 minutes of charge  $I_B$ (typ.)  
= 40  $\mu$ A (2C)
- Proceeding charge  
= 20  $\mu$ A (1C)
- Trickle charge (on/off = 1/9)  
= 20  $\mu$ A (0.1C)
- Current limit at voltage regulation  
= 46  $\mu$ A

In the voltage regulation mode the battery output voltage is sensed at pin 10. Internally, this voltage is divided by two and made available at pin 9, for smoothing purpose only, and compared with a 1.25 V reference voltage.

Pin 7 is connected directly to the summing point of the PWM input and the output from both error amplifiers. By connecting a capacitor between pin 7 and pin 3, the primary current sense voltage is added to the error signal which results in a current mode control that enhances load response and control loop stability. This capacitor also provides slow start at a start cycle.

When the device is supplied via pin 6 the minimum duty factor is restricted to 3% to ensure a continuous supply from the SMPS. The maximum duty factor is limited to 60%.

Open or short-circuit battery output is detected via pin 10. If the voltage at pin 10 rises above 5 V or, in the charging mode, remains below 2 V during the first 4 charge minutes, the circuit will switch off and the start-up procedure will be resumed.

### Load identification (pin 12)

The switch input recognizes a load connected to the output by the state of switch S1. The difference between a closed switch or an open switch with short-circuit or flat batteries is identified if the external resistance value of  $R_{11} + R_{12}$  is greater than 4.2 k $\Omega$ .

### Battery LOW sense (pin 11)

In the battery discharge mode the battery voltage is protected at pin 11 via a resistor divider. The input is immune to any spurious interference from the load. When the voltage level drops below 1.25 V the indicator output at pin 13 is set. At load switch OFF (S1 open) the indicator outputs (pin 13 and pin 14) will give alternating bursts for 4 seconds.

### Indicator outputs (pins 13 and 14)

The indicator outputs have an open collector with set current sink capability. When active, the output generates pulses at 2 kHz. When pins 13 and 14 are alternating, the output generates two bursts of these pulses at 4 Hz per cycle. More detailed information is given in Figure 6. These signals are suitable for driving LED and buzzer indicators.

Serial data concerning the status of circuit operation from which the battery state-of-charge can be processed is also output from pin 13.

### Test pin (pin 15)

This pin must not be connected.

### Oscillator (pin 16)

An R-C network sets the frequency of the oscillator. The switching frequency of the SMPS and all the internal timing is derived from this oscillator which should be nominally 33 kHz. The capacitor is charged via pin 16 (flyback) and discharged by the parallel resistor. The required frequency is set with  $R = 36$  k $\Omega$  and  $C = 560$  pF.

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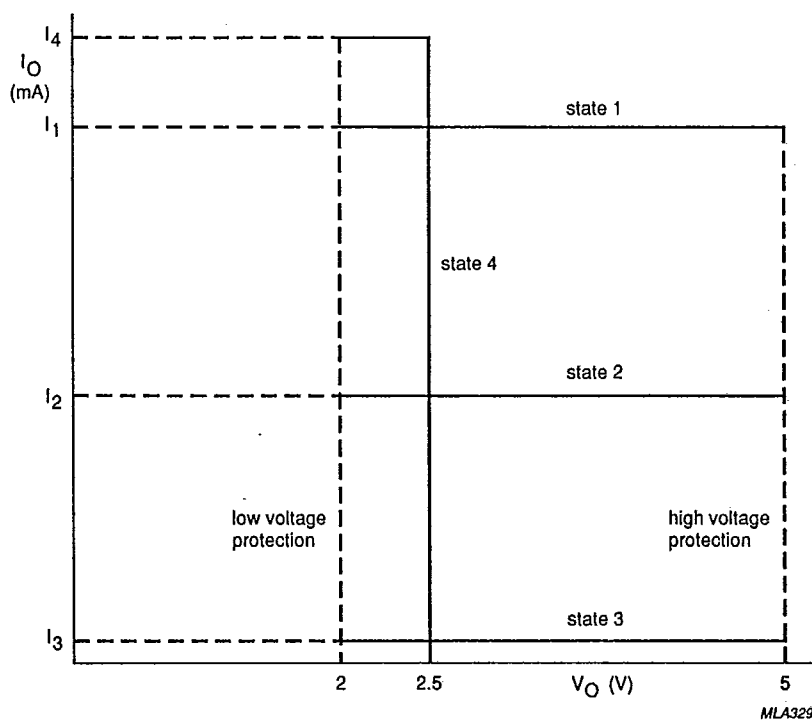
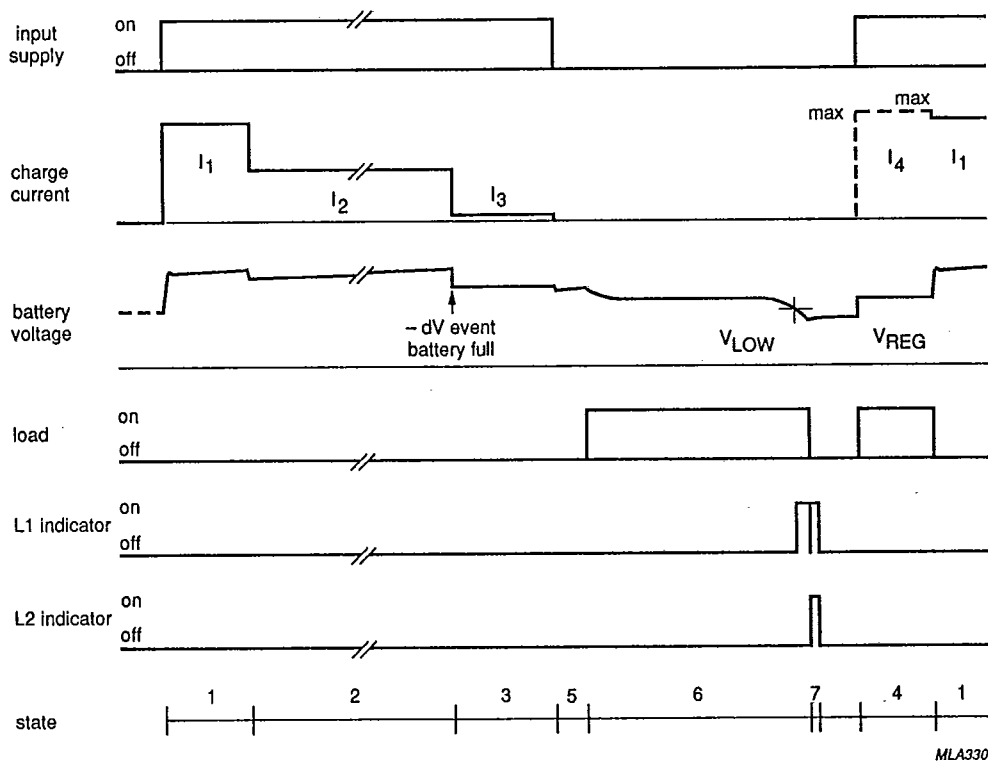


Fig.4 Supply output characteristics.



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- State 1; Boost charge.  $I_1 = 2 \times I_2$
- State 2; Fast charge.  
 $I_2 = (20 \times 10^{-6}) \times R_8/R_S$ .
- State 3; Trickle charge.  $I_3 = 0.1 \times I_2$   
(i.e.  $I_2$  pulsed with 10% duty factor at 1 Hz rate).
- State 4; Voltage regulation.  
 $V_O = 2.5 \text{ V}; I_{O(max)} = 2.3 \times I_2$ .

Fig.5 Operational cycles of the SMPS charger system.

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**SMPS battery charger control circuit****TEA1088T**

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**State 1;** Boost charge current during 17 minutes after supply turn on. The current  $I_1$  is twice the fast charge current  $I_2$ . This state helps completely empty batteries, possibly reversed in polarity, to quickly regain their charge store potential. Within the first 4 charge minutes the battery voltage should rise above 2 V otherwise protection occurs by stop and initialization in repeating succession.

**State 2;** Fast charge current that proceeds until either battery full is detected ( $-dV$ ) or a maximum charge time of 2 hrs is reached.

**State 3;** Trickle charge which keeps the batteries fully charged. This current is sufficiently low not to harm the batteries when maintained for a long period.

**State 4;** Output voltage regulation when both the charger is on and a load is applied to the batteries. This provides direct output power to the load even when the batteries are empty.

**State 5;** Stand-by at neither input nor output. Negligible IC current (to keep the internal memories active) is drawn from the batteries.

**State 6;** Discharge of the batteries. The monitor circuit is activated and senses the battery voltage. Signal output (L1) is given when the sense voltage drops below a set value ( $V_{Low}$ ).

**State 7;** By removing the load after state 6, both indicator outputs give signals in an alternating mode for 4 seconds (see also Fig.6).

## SMPS battery charger control circuit

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## CHARACTERISTICS

$V_6 = 10\text{ V}$ ;  $V_{10} = 2.5\text{ V}$ ;  $R_{16} = 36\text{ k}\Omega$ ;  $C_{16} = 560\text{ pF}$ ;  $T_{\text{amb}} = 25\text{ }^\circ\text{C}$ ; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
<b>Supply</b>						
$V_6$	take over supply		5.5	-	31.0	V
$I_6$	supply current		10	15	19	mA
$V_4$	initialization level		6.5	7.0	7.5	V
$V_4$	internal supply voltage output		5.4	6.5	6.9	V
$I_4$	supply current	$V_6 = 0\text{ V}$	6.5	9.5	12.5	mA
$I_{10}$	input current	stand-by	-	5.0	10.0	$\mu\text{A}$
		battery discharge	6.0	9.0	12.0	mA
		BLI blinking	7.0	10.5	14	mA
		count 2 hr timer	4.9	7.8	10.8	mA
		charging	0.3	0.5	0.7	mA
<b>Protection circuits</b>						
$V_4$	LOW supply protection		3.0	3.5	3.9	V
$V_{10}$	minimum input voltage	charge period > 4 min.	1.8	2.0	2.2	V
$V_{10}$	maximum input voltage		4.5	5.0	5.5	V
<b>Oscillator (supplied via <math>V_4</math> or <math>V_{10} = V_P</math>)</b>						
$V_{16}$	voltage level HIGH		-	$4/5 V_P$	-	V
$V_{16}$	voltage level LOW		-	$1/5 V_P$	-	V
	initial accuracy excluding external components	$V_4 = 5.7\text{ V}$	-10.0	-	+10.0	%
$\Delta f$	frequency deviation	$V_4$ to $V_{10}$ supply	-	1.5	3.0	%
$f$	frequency	$R = 36\text{ k}\Omega$ ; $C = 560\text{ pF}$	-	33.0	-	kHz
$TC_f$	temperature coefficient of frequency		-	-150	-	$10^{-6}/^\circ\text{C}$
<b>BLI function</b>						
$V_{10}$	input voltage range		1.8	-	4.0	V
$V_{11}$	BLI reference voltage		1.17	-	1.33	V
$TC_{\text{ref}}$	temperature coefficient reference		-250	-	+250	$10^{-6}/^\circ\text{C}$
$\phi$	hysteresis reference voltage output		2.0	3.5	6.0	mV
$I_{13,14}$	BLI output current	$V_O = 0.5\text{ V}$	21	30	39	mA
$I_{13}/I_{14}$	output currents match		0.9	1.0	1.1	mA
$V_{13,14}$	saturation voltage	$I_O = 10\text{ mA}$	-	-	200	mV
$I_{13,14}$	leakage current	$V_O = 4\text{ V}$	-	-	10	$\mu\text{A}$
$V_{13}$	breakdown voltage	$I_O = 10\text{ mA}$	15.0	17.0	18.5	V
$V_{14}$	breakdown voltage	$I_O = 50\text{ mA}$ during burst	15.0	17.0	18.5	V
$f_{13,14}$	frequency output signal		-	2	-	kHz
$f_{13,14}$	burst frequency	load switch off	-	1	-	Hz
$f_{13,14}$	alternating frequency	load switch off	-	4	-	Hz
<b>-dV detector</b>						
$V_{10}$	minimum input level		-	2.3	2.5	V
$V_{10}$	maximum input level		4.0	4.3	-	V
$-dV_{10}$	detector threshold		15	22	30	mV
$t_m$	sampling time		-	1	-	ms
$t_{\text{rep}}$	sampling repetition		-	1	-	s

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SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
<b>SMPS outputs</b>						
$I_1$	bias output		1.0	2.0	4.0	mA
$V_2-V_3$	saturation voltage	$I_2 = 350 \text{ mA}$	0.9	-	1.4	V
$V_3$	current protection threshold voltage	$V_6-V_{10} = 3 \text{ V}$	340	425	510	mV
$t_p(V_2)$	minimum output pulse	$V_6-V_{10} = 22 \text{ V}$	262	328	394	mV
$t_d$	current trip delay to output	$V_6-V_{10} > 25 \text{ V}$ $V_3 = 1.2 \times V_{\text{threshold}}$	0.3	0.6	1.6	$\mu\text{s}$
			-	0.6	-	$\mu\text{s}$
<b>Modulator</b>						
$V_{10}$	reference level	voltage regulation	2.4	2.55	2.7	V
TC	temperature coefficient		-	+25	-	$10^{-6}/^\circ\text{C}$
$I_8$	reference input current	fast charge	-10	-20	-30	$\mu\text{A}$
		boost charge	-20	-40	-60	$\mu\text{A}$
		voltage regulation	-26	-46	-69	$\mu\text{A}$
	ratio reference current	boost/fast charge	1.9	2.0	2.1	
		voltage regulator/ boost charge	1.09	1.15	1.21	
$V_8$	reference level	current regulation	-10	-	+10	mV
$I_7$	PWM input source current	voltage level HIGH	-6.5	-10.0	-13.5	$\mu\text{A}$
	PWM input sink current	voltage level LOW	6.5	10.0	13.5	$\mu\text{A}$
$V_7$	maximum PWM input voltage	slow start	-	$0.8 \times V_4$	-	V
d	maximum duty factor		55	60	65	%
<b>Periods</b>						
$t_{\text{inh}}$	inhibit time of -dV circuit	start boost charge	-	4.3	-	min
		start fast charge	-	4.3	-	min
$t_{\text{bc}}$	boost charge duration		-	17	-	min
$t_{\text{fc}}$	maximum fast charge time		-	2.1	-	hr
<b>Computer control interface</b>						
$I_{13}$	status indication current source at L1		-490	-820	-1150	$\mu\text{A}$

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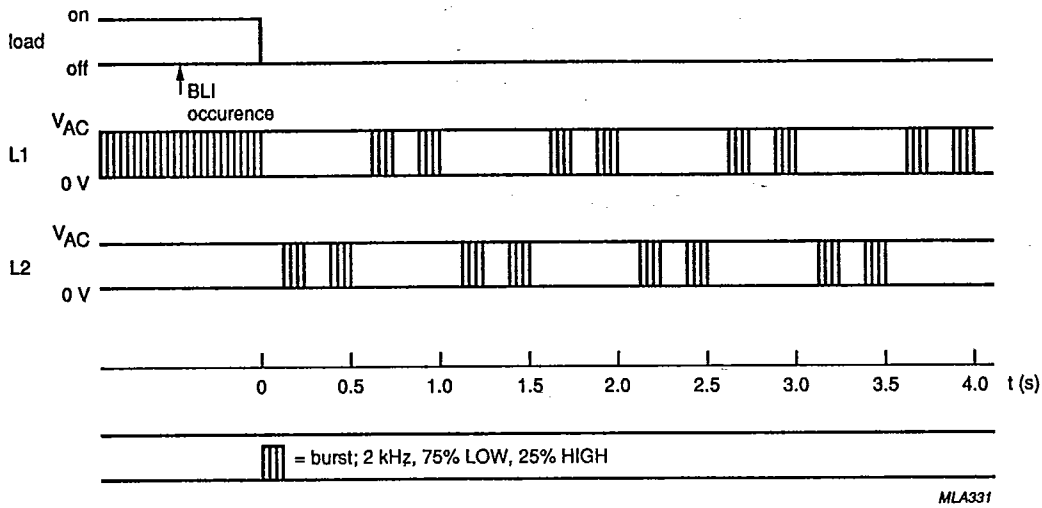
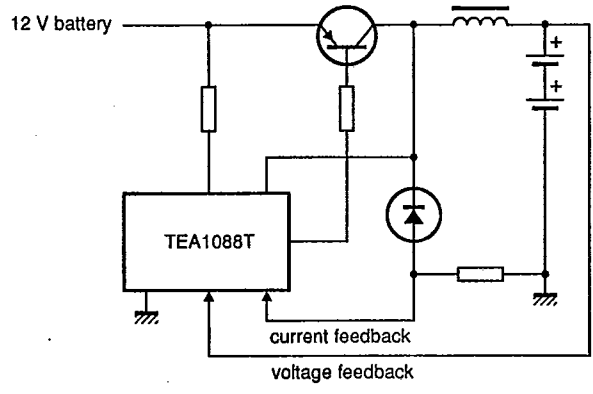
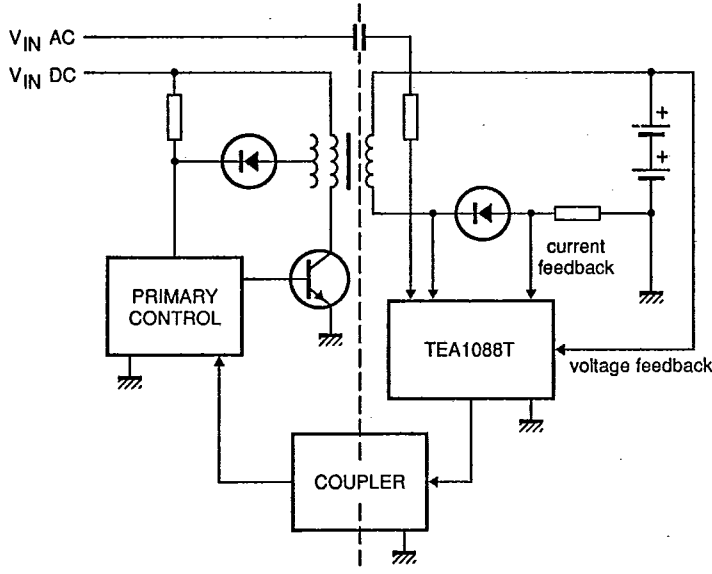
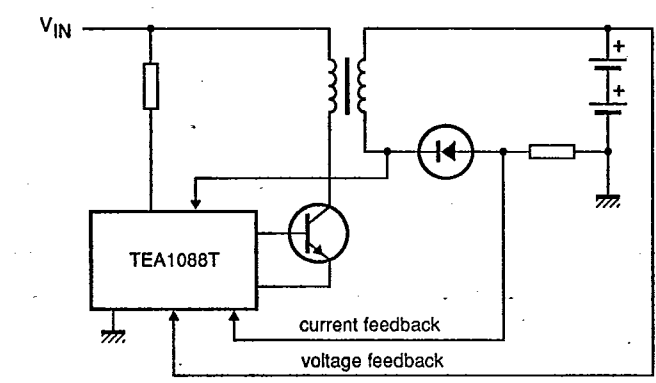


Fig.6 BLI signalling scheme.

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Fig.7 Simplified charger configurations.

SMPS battery charger control circuit

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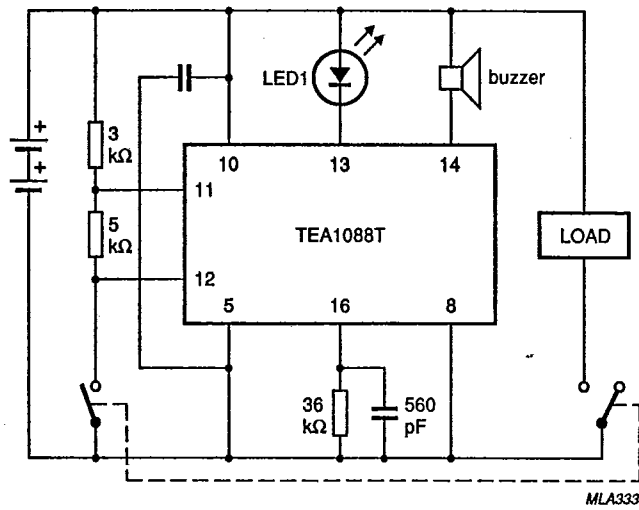


Fig.8 Battery monitor application.

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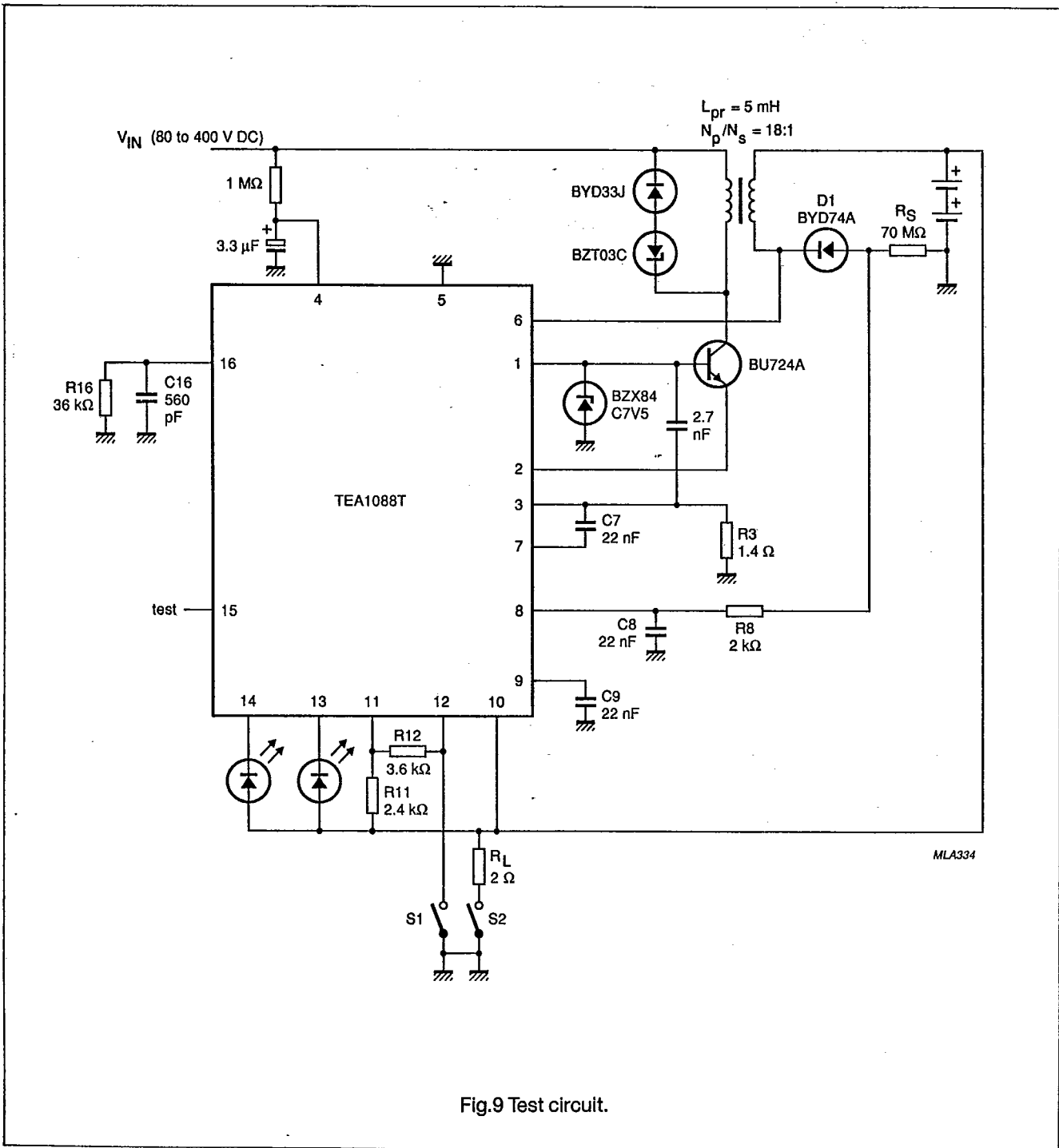


Fig.9 Test circuit.

Note

1.  $I_{charge} = I_{ref} \times (R8/R_S)$

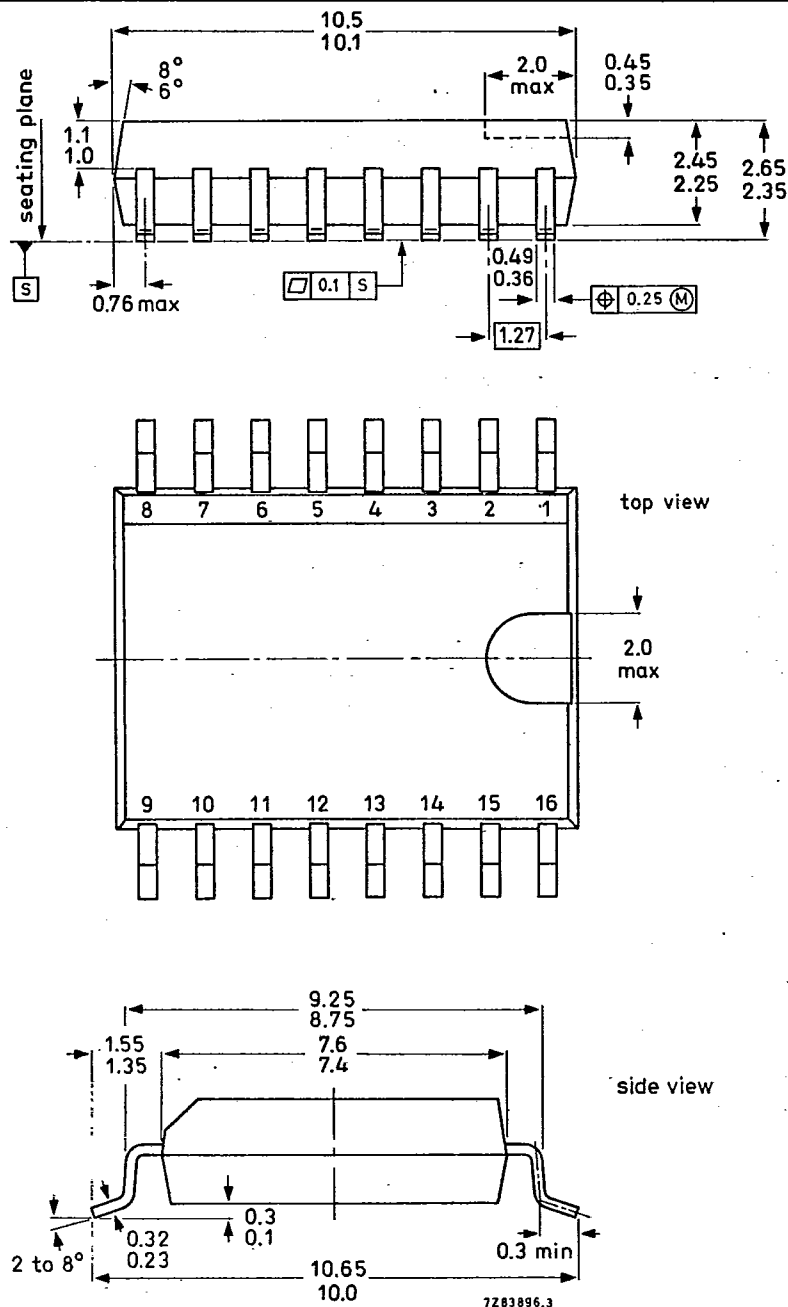
With  $I_{ref} = 20 \mu A$ ,  $R8 = 2 k\Omega$  and  $R_S = 70 M\Omega$ , the charge current level is 570 mA which is approximately 1C for 'half sub C' cells.



SMPS battery charger control circuit

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PACKAGE OUTLINE



Dimensions in mm

- ⊕ Positional accuracy.
- Ⓜ Maximum Material Condition.

Fig.10 16-lead mini-pack; plastic (SO16L; SOT162A).

**SMPS battery charger control circuit****TEA1088T****SOLDERING****Plastic mini-packs****By WAVE**

During placement and before soldering, the component must be fixed with a droplet of adhesive. After curing the adhesive, the component can be soldered. The adhesive can be applied by screen printing, pin transfer or syringe dispensing.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder bath is 10 s, if allowed to cool to less than 150 °C within 6 s. Typical dwell time is 4 s at 250 °C.

A modified wave soldering technique is recommended using two solder waves (dual-wave) in which a turbulent wave with high upward pressure is followed by a smooth laminar wave. Using a

mildly-activated flux eliminates the need for removal of corrosive residues in most applications.

**By SOLDER PASTE REFLOW**

Reflow soldering requires the solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the substrate by screen printing, stencilling or pressure-syringe dispensing before device placement.

Several techniques exist for reflowing; for example, thermal conduction by heated belt, infrared, and vapour-phase reflow. Dwell times vary between 50 and 300 s according to method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 min at 45 °C.

**REPAIRING SOLDERED JOINTS  
(BY HAND-HELD SOLDERING IRON OR  
PULSE-HEATED SOLDER TOOL)**

Fix the component by first soldering two, diagonally opposite, end pins. Apply the heating tool to the flat part of the pin only. Contact time must be limited to 10 s at up to 300 °C. When using proper tools, all other pins can be soldered in one operation within 2 to 5 s at between 270 and 320 °C. (Pulse-heated soldering is not recommended for SO packages).

For pulse-heated solder tool (resistance) soldering of VSO packages, solder is applied to the substrate by dipping or by an extra thick tin/lead plating before package placement.

**SMPS battery charger control circuit****TEA1088T****DEFINITIONS**

<b>Data sheet status</b>	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
<b>Limiting values</b>	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of this specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
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