AN896
APPLICATION NOTE

A BATTERY CHARGER USING THE TSM101

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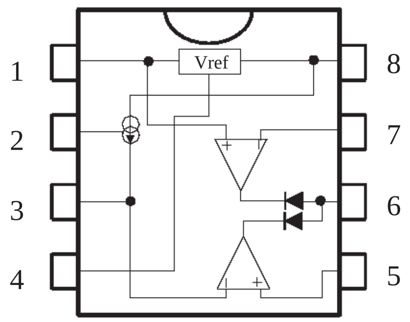
This technical note shows how to use the TSM101 integrated circuit with a switching mode power supply (SMPS) to realize a battery charger.

An example of realization of a 12V Nickel-cadmium battery charger is given.

1 - TSM101 PRESENTATION

The TSM101 integrated circuit incorporates a high stability series band gap voltage reference, two ORed operational amplifiers and a current source (Figure 1)

Figure 1 : TSM101 Schematic Diagram



This IC compares the DC voltage and the current level at the output of a switching power supply to an internal reference.It provides a feedback through an optocoupler to the PWM controller IC in the primary side.

The controlled current generator can be used to modify the level of current limitation by offsetting the information coming from the current sensing resistor.

A great majority of low or medium end power supplies is voltage regulated by using shunt programmable voltage references like the TL431 (Figure 2).

The galvanic insulation of the control information is done by using an opto-coupler in linear mode with a variable photo current depending on the difference between the actual output voltage and the desired one.

A current limitation is used to protect the power supply against short circuits, but lacks precision. This limitation is generally realized by sensing the current of the power transistor, in the primary side of the SMPS.

The role of the TSM101 is to make a fine regulation of the output current of the SMPS and a precise voltage limitation.

The primary current limitation is conserved and acts as a security for a fail-safe operation if a short-circuit occurs at the output of the charger.

2 - PRINCIPLE OF OPERATION

The current regulation loop and the voltage limitation loop use an internal 1.24V band-gap voltage reference. This voltage reference has a good precision (better than 1.5%) and exhibits a very stable temperature behavior.

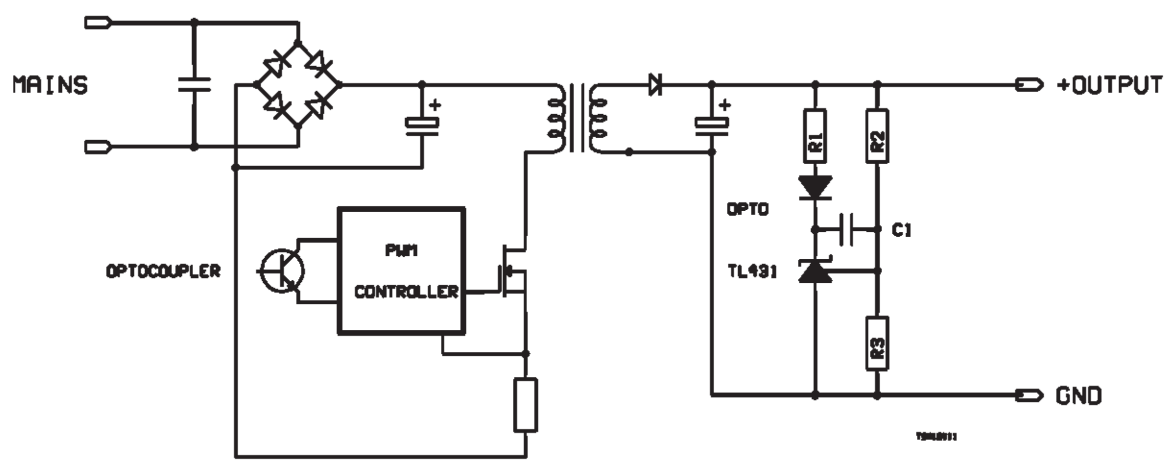
The current limitation is performed by sensing the voltage across the low ohmic value resistor R5 and comparing it to a fixed value set by the bridge composed by R2 and R3 (Figure 3).

When the voltage on R5 is higher than the voltage on R3 the output of the current loop operational amplifier decreases. The optocoupler current increases and tends to reduce the output voltage by the way of the PWM controller.

The voltage regulation is done by comparing a part of the output voltage (resistor bridge R6, R7 and P1) to the voltage reference (1.24V).

If this part is higher than 1.24V, the output of the voltage loop operational amplifier decreases.

Figure 2 : SMPS Using a TL431 as Voltage Controller



The optocoupler current increases and tends to reduce the output voltage by the way of the PWM controller.

By enabling the TSM101 current source (pin 2) it is possible to offset the current sensing by a voltage equal to :

- V_{off} # R4 * Io with I_o = 1.4mA

This offset lowers the output charge current and this function can be used to charge two types of batteries having different capacities. The current source is enabled by connecting pin 2 to ground

3 - CALCULATION OF THE ELEMENTS

The charge current is regulated at 700mA (if the charge control input is left open) or 200mA (if the charge control input is put to ground), allowing the charge of two different types of batteries.

3.1 - Voltage limitation

The end-of- charge voltage is limited at 1.45V/cell, this is the recommended voltage for an ambient temperature at 25^{o}C.

A diode is generally inserted at the output of the charger to avoid the discharge of the battery if the charger is not powered. This diode is sometimes directly integrated in the battery pack. The influence of this diode on the charge is negligible if the voltage drop (0.7V) is taken into account during the design of the charger.

The voltage at the output of the charger is :

- $V_{out} = \frac{R6+R7}{R6} x V_r$

and regarding R6 and R7 :

- $R6 = (\frac{V_{ref}}{V_{out} - V_{ref}}) \times R7$

P1, which is a part of R6 and R7 is not considered in this equation.

The following values are used on the application board :

- R7 = 12kΩ
- R6 = 1kΩ
- P1 = 220Ω, adjust for V_{output} = 15.2V with the battery replaced by a 1kΩ resistor
- R10 = short circuit
- C3 = 100nF

3.2 - Current regulation

R5 is the sense resistor used for current measurement.

The current regulation is effective when the voltage drop across R5 is equal to the voltage on pin 5 of the TSM101 (assuming that the internal current source is disabled).

For medium currents (<1A), a voltage drop across R5 of 200mV = Vr5 is a good value, R5 can be realized with standard low cost 0.5W resistors in parallel.

- $R5 = \frac{V_{r5}}{I_{ch}}$, R5 = 0.285Ω (four 1.2Ω resistor in parallel)

R2 and R3 can be chosen using the following formula :

- $R2 = R3\ x\ \frac{(V_{ref} - V_{r5})}{V_{r5}}$

CHARGE CONTROL

If the pin 2 is left open, the charge current is nominal at # 700mA.

If pin 2 is connected to ground, the internal current source is enabled, the current measurement is off-setted by a voltage equal to :

- $V_{r4} = I_o$ x R4 with Io = 1.4mA

This can be used to lower the charging current or eventually to stop the charge, if $V_{r4} > V_{r5}$

In our example, the current offset is equal to 700 - 200mA = 500mA, representing a voltage offset V_{r4} = 150mV across R4.

The following values are used on the application board :

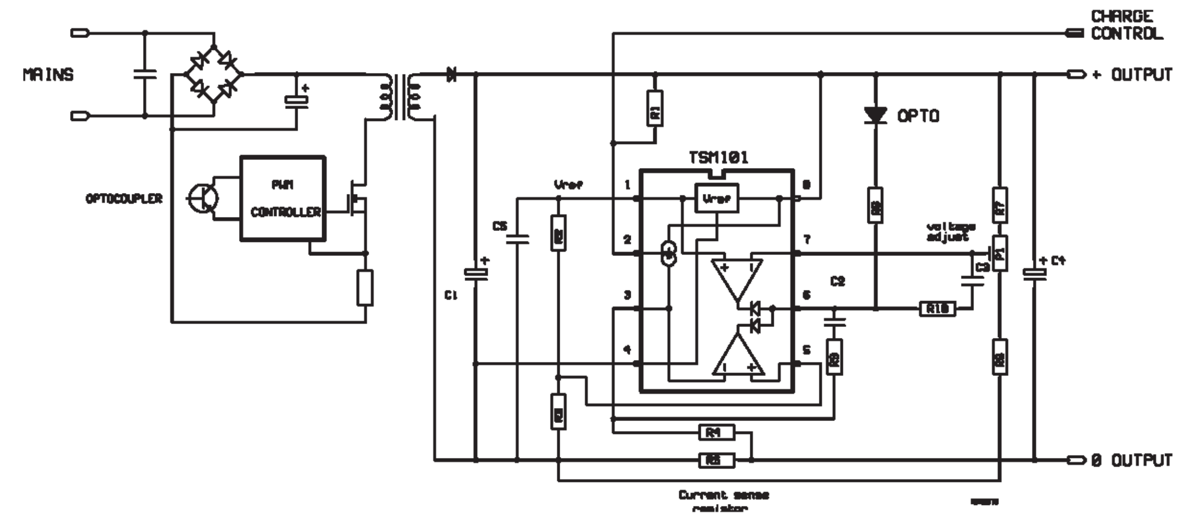
- R5 = 4 *1.2Ω 0.5W in parallel
- R4 = 130Ω
- R2 = 1.2kΩ
- R3 = 220Ω
- R9 = short circuit
- R1 = 10kΩ
- C2 = 100nF
- C5 = 100nF
- C1 = output capacitor of the SMPS
- C4 = 10µF

HIGH FREQUECY COMPENSATION

Two R-C devices (R9+C2 & R10+C3) are used to stabilize the regulation at high frequencies. The calculation of these values is not easy and is a function of the transfer function of the SMPS.

A guess value for the capacitors C2 and C3 is 100nF.

Figure 3 : SMPS Using the TSM101



4 - SCHEMATIC DIAGRAM

Figure 2 represents a schematic of the output circuit of a ”classical” SMPS using a TL431 for voltage regulation. This circuit is modified to use the TSM101 and the final circuit is represented in figure 3.

5 - IMPROVEMENT

In applications requiring low voltage battery charge or when the charger is in current regulation mode, the output voltage can be too low to supply correctly the TSM101.

The same problem occurs when the output is short-circuited.

A solution to provide a quasi constant supply voltage to the TSM101 is shown at figure 4 : an auxiliary winding is added at the secondary side of the transformer.

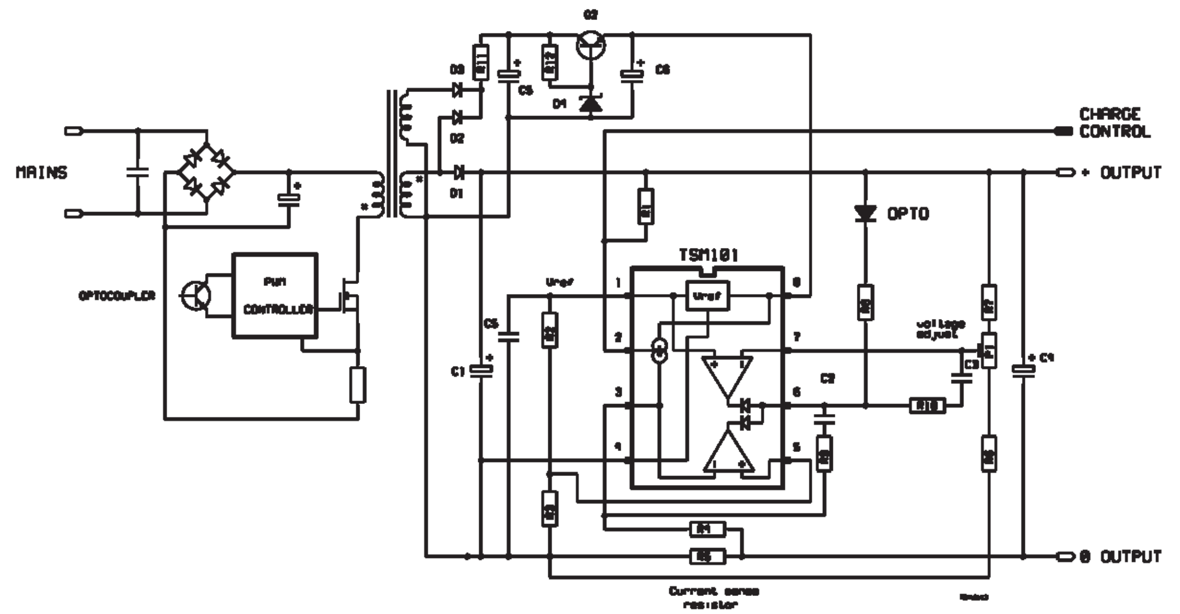
This winding is forward coupled to the primary winding, the voltage across it is directly proportional to the mains rectified voltage, even if the flyback voltage is close to zero.

As this auxiliary winding is a voltage source, it is necessary to add a resistor (R11) on the cathode of the rectifier (D3) to limit the current.

A low cost regulator (Q1 and Zener diode D4) is used to power the TSM101. This is necessary with autoranging SMPS with wide input voltages, for example 90 to 240V without switching.

In standard SMPS with voltage ranges from 200 to 240VAC or 100 to 130VAC, this regulator can be removed.

Figure 4



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