

A BATTERY CHARGER USING TSM101

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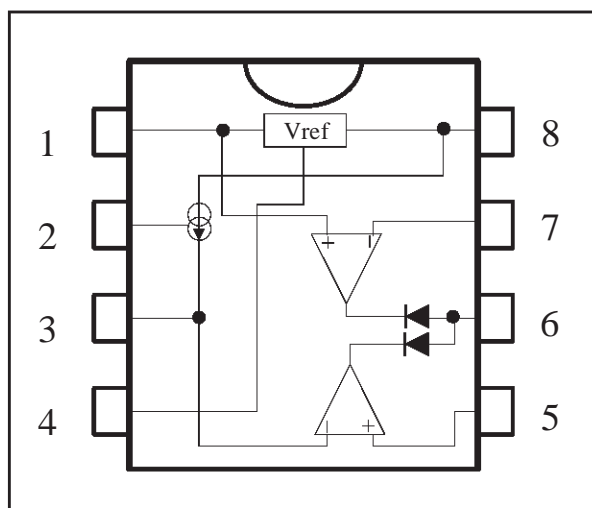
This technical note shows how to use the TSM101 integrated circuit with a switching mode power supply (SMPS) to realize a battery charger.

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.

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 :

$$V_{\text{off}} = R_4 \cdot I_0 \text{ with } I_0 = 1.4\text{mA}$$

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°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 :

$$V_{out} = \frac{R6 + R7}{R6} \times V$$

and regarding R6 and R7 :

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

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.

$$R5 = \frac{Vr5}{I_{ch}}, R5 = 0.285\Omega$$

(four 1.2Ω resistor in parallel)

R2 and R3 can be chosen using the following formula :

$$R6 = R3 \times \frac{(V_{ref} - V_{R5})}{V_{R5}}$$

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-set by a voltage equal to :

$$\square Vr4 = I_o \times R4 \text{ with } I_o = 1.4mA$$

This can be used to lower the charging current or eventually to stop the charge, if $Vr4 > Vr5$.

In our example, the current offset is equal to 700 - 200mA = 500mA, representing a voltage offset $Vr4 = 140mV$ across R4.

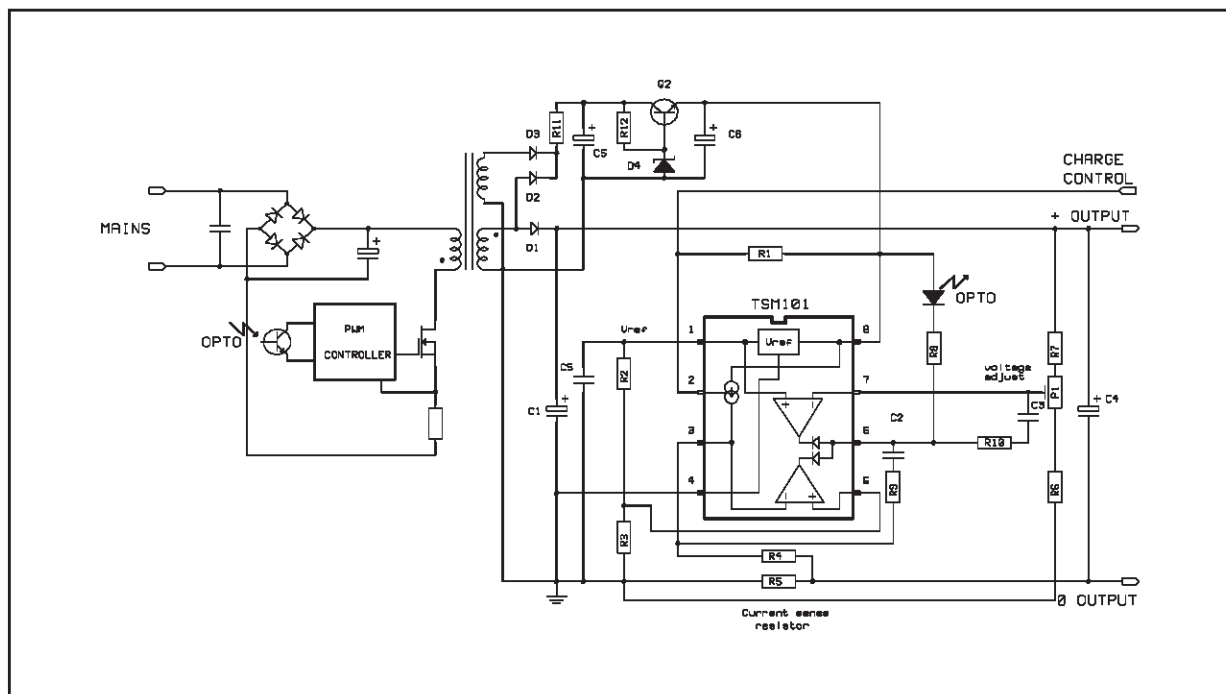
The following values are used on the application board :

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

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.

Figure 4 : An Auxiliary Winding for TSM101 Power Supply



5.3. Higher Precision for the Voltage Control

The voltage drop through the sense resistor R5 offsets the voltage measurement. In most battery charging applications, this offset is not taken into account because the error is negligible compared to the end-of-charge voltage due to the fact that the charging current value decreases drastically during the final phase of the battery charging. But in other applications needing highest possible precision in voltage control, another connecting schematic is possible for TSM101 as shown on figure 5.

In this schematic, the 0V reference is defined as the common point between the sense resistor, the 0V Output Voltage, the foot of the resistor bridge R6/R7, and the ground (pin 4) of the TSM101. TSM101A (1% internal voltage reference precision) is required in such applications.

5.4. An example of application where the charging current is different according to the charging phase.

The following application includes a specific recommendation which requires that the charging current should be fixed to $I_{ch1} = 800\text{mA}$ in normal charging conditions, and $I_{ch2} = 200\text{mA}$ when the cell voltage is below $V_l = 2.5\text{V}$ to optimize the cell life-time.

Moreover, an Charging Status LED should be switched off when the cell voltage is above $V_h=6.5V$.

Figure 6 shows how this can easily be achieved using an additional dual comparator (type LM393) where the first operator (C1) is used to activate the TSM101 internal current generator to offset the current measurement thanks to R4, and the second (C2) is used to switch the status LED off.

On figure 6, the status signal is determined by voltage measurement, this could as well be achieved by current measurement.

If $V_5 = 100\text{mV}$ is the maximum tolerable voltage drop through the sense resistor R5 during normal charging conditions, then the following calculations apply :

Current Control :

$$R5 = V5 / I_{ch1} = 0.1 / 0.8 = 0.125$$

$$R5 = 125m\Omega$$

$V_5 = V_{ref} \times R_3 / (R_2 + R_3)$ with $R_2 + R_3 \sim 12k\Omega$
and $V_{ref} = 1.24V$

$$R3 = 1k\Omega, R2 = 11.4k\Omega$$

$V_5 = R_4 \times I_o + R_5 \times I_{ch2}$, therefore, $R_4 = (V_5 - R_5 \times I_{ch2}) / I_o$ with $I_o = 1.4\text{mA}$

$$R4 = 53.6\Omega$$

$V_{ref} = V_I \times R_{15} / (R_{14} + R_{15})$ with $V_I = 2.5V$ and $R_{14} + R_{15} \sim 20k\Omega$

$$R_{15} = R_{14} = 10k\Omega$$

Figure 5 : Precise Output Voltage Control

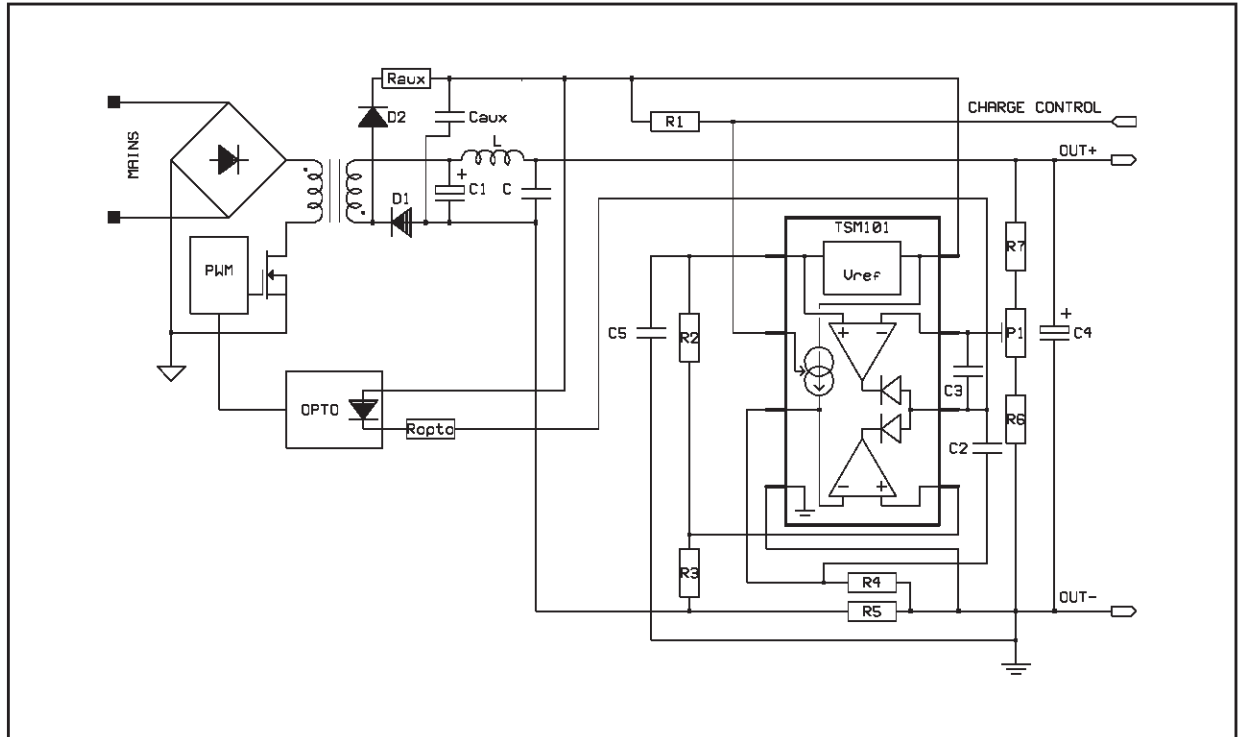
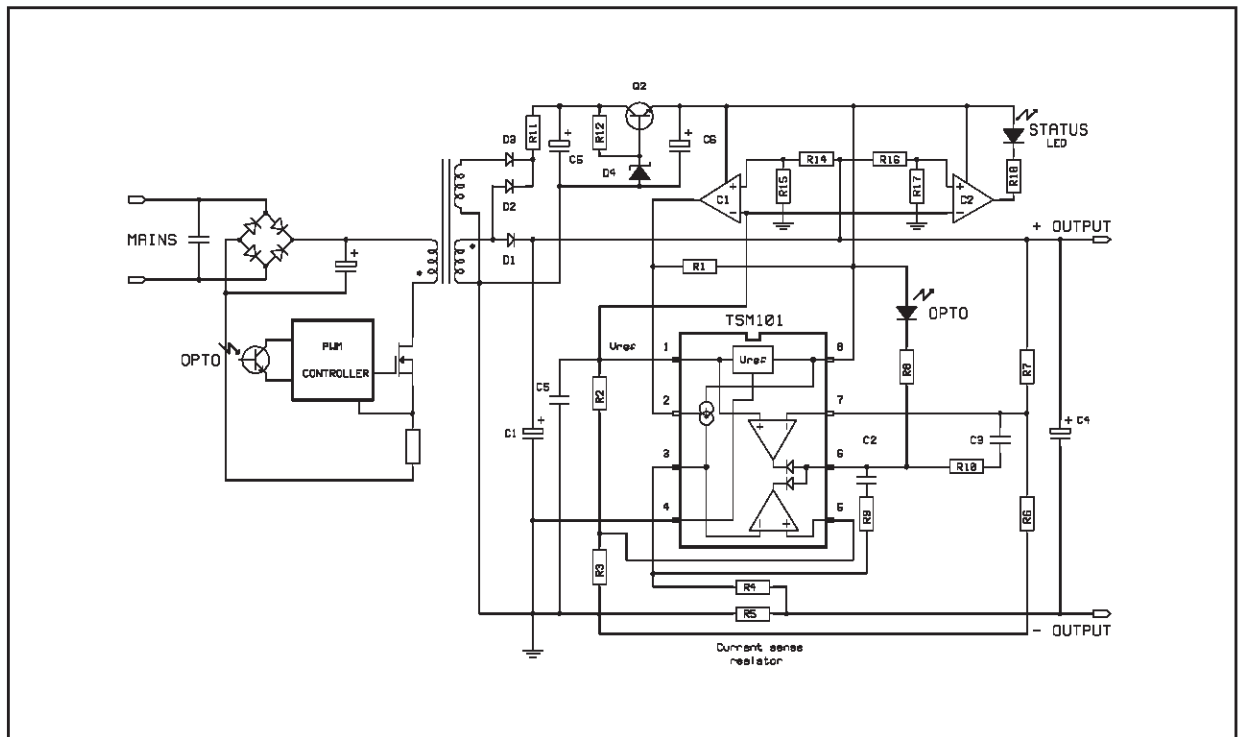


Figure 6 : Optimized Charging Conditions



AN1283 - APPLICATION NOTE

EVALUATION - TECHNICAL NOTE

TSM101 integrates in the same 8 pin DIP or SO package

- ☐ one 1.24V precision voltage reference
- ☐ two operational amplifiers
- ☐ two diodes which impose a NOR function on the outputs of the operational amplifiers
- ☐ one current source which can be activated/inhibited thanks to an external pin.

An immediate way to take advantage of the high integration and reliability of TSM101 is to use it as a voltage and current controller on power supplies secondary. The application note AN896 describes precisely how to use TSM101 in an SMPS battery charger.

The TSM101 Evaluation Board is adaptable to any power supply or battery charger (SMPS or linear) as a voltage and current controller with minimal constraints from the user.

HOW TO USE THE TSM101 EVALUATION BOARD ?

The generic Electrical Schematic is shown on figure 1. It represents an incomplete SMPS power supply where the primary side is simplified.

The “IN+” and “IN-” power inputs of the evaluation board should be connected directly to the power lines of the power supply secondary.

The “Vcc” input of the evaluation board should be connected to the auxiliary supply line.

In the case of an SMPS power supply, the “Reg” output of the evaluation board should be connected to the Optocoupler input to regulate the PWM block in the primary side. In the case of a linear power supply, the “Reg” output should be connected to the base of the darlington to regulate the power output.

A diode might be needed on the output of the evaluation board in the case of a battery charger application to avoid the discharge of the battery when the charger is not connected.

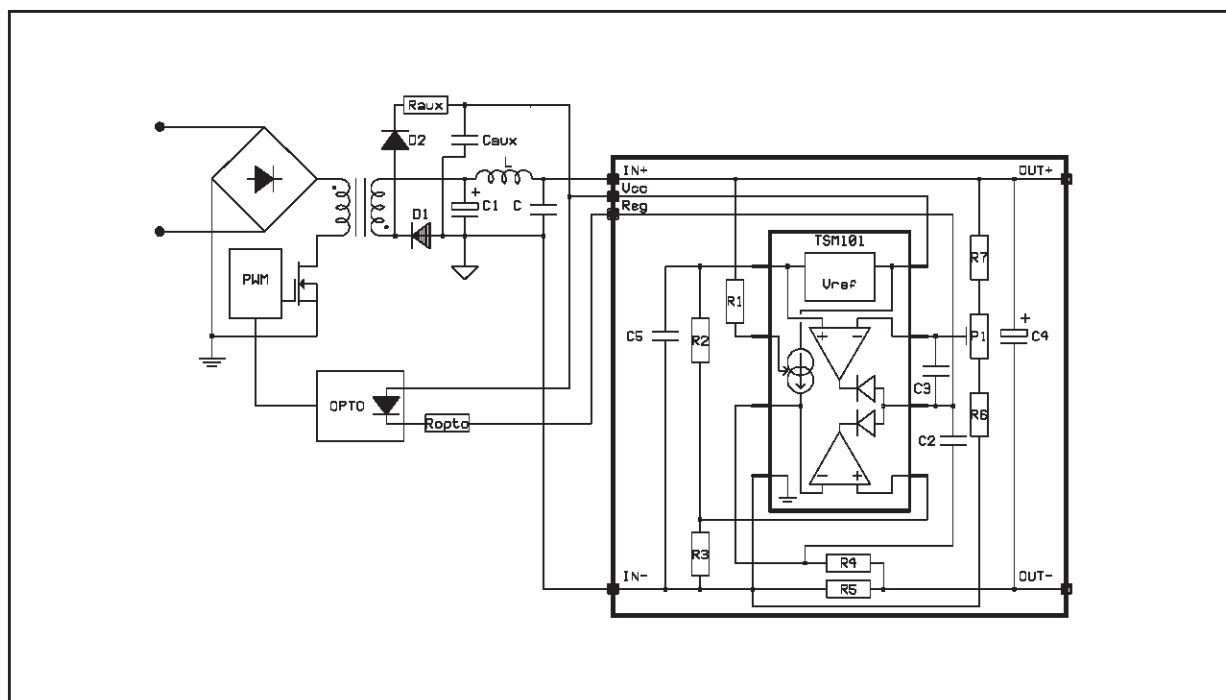
COMPONENTS CALCULATIONS

The voltage control is given by the choice of the resistor bridge R6/R7 (and the trimmer P1) due to equation 1 :

$$\square V_{ref} = \frac{R6}{(R6+R7)} \times V_{out} \quad eq1$$

where $V_{ref} = 1.24V$

Figure 1



The **current control** is given by the choice of the voltage drop through the sense resistor R5 (to be linked to the nominal current of the application) and by the value of the sense resistor itself.

For medium currents (< 1A), a good value for the voltage drop through R5 can be $V_{sense} = 200\text{mV}$ (dissipation < 200mW).

The resistor bridge R2/R3 should be chosen following equation 2 :

$$\square V_{sense} = R3/(R2+R3) \times V_{ref} \quad \text{eq2}$$

The total value of the resistor bridge should be in the range of the kW in order to ensure a proper charge for the voltage reference (in the range of the mA).

To set the current limit, the sense resistor R5 should be chosen following equation 3 :

$$\square I_{lim} = V_{sense}/R5 \quad \text{eq3}$$

The internal current generator (Isce) can be used to offset the current limitation with a lower value.

This current generator is activated by connecting pin 2 to ground. It is inhibited if pin 2 is connected to the positive rail via the pull up resistor R1.

The current offset is given by the choice of the resistor R4.

If I_{lim1} is the current limit calculated in the previous paragraph, and I_{lim2} is the current limit that is to be set when pin 2 is connected to ground, R4 should be chosen following equation 4 :

$$\square R4 = (V_{sense} - I_{lim2} \times R5)/I_{sce} \quad \text{eq4}$$

where $I_{sce} = 1.4\text{mA}$

C4 and C5 are bypass capacitors used to smoothen the regulated outputs.

C2 and C3 are capacitors used for high frequency compensation.

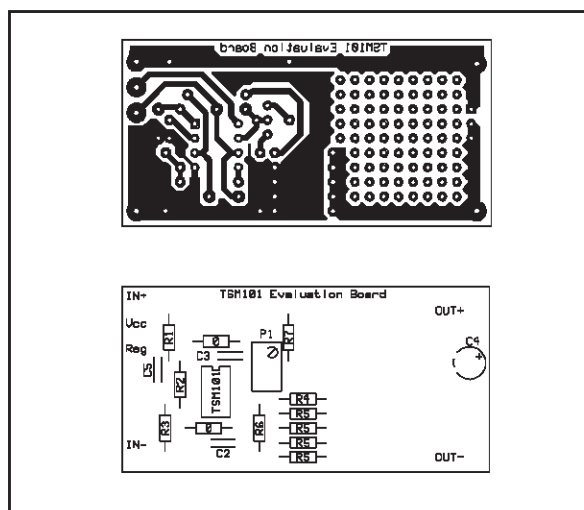
EXAMPLES OF COMPONENT LISTS

Table 1 summarizes a few examples of component lists to generate quickly 15V/700mA/200mA, 12V/1A/500mA or 8.2V/200mA/100mA voltage and current regulations.

Table 1

Voltage/ Current Control	15V 700mA 200mA	12V 1A 500mA	8.2V 200mA 100mA
R1	10k Ω	10k Ω	10k Ω
R2	1.2k Ω	1.2k Ω	1.2k Ω
R3	220 Ω	220 Ω	220 Ω
R4	100 Ω	68 Ω	68 Ω
R5	1.2 Ω x4	0.8 Ω x4	1 Ω x4
R6	1k Ω	1k Ω	1k Ω
R7	12k Ω	8.2k Ω	5.6k Ω
P1	100 Ω	100 Ω	100 Ω
2 straps	0 Ω	0 Ω	0 Ω
C2	100nF	100nF	100nF
C3	100nF	100nF	100nF
C4	10 μ F	22 μ F	4.7 μ F
C5	100nF	100nF	100nF

Figure 2



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