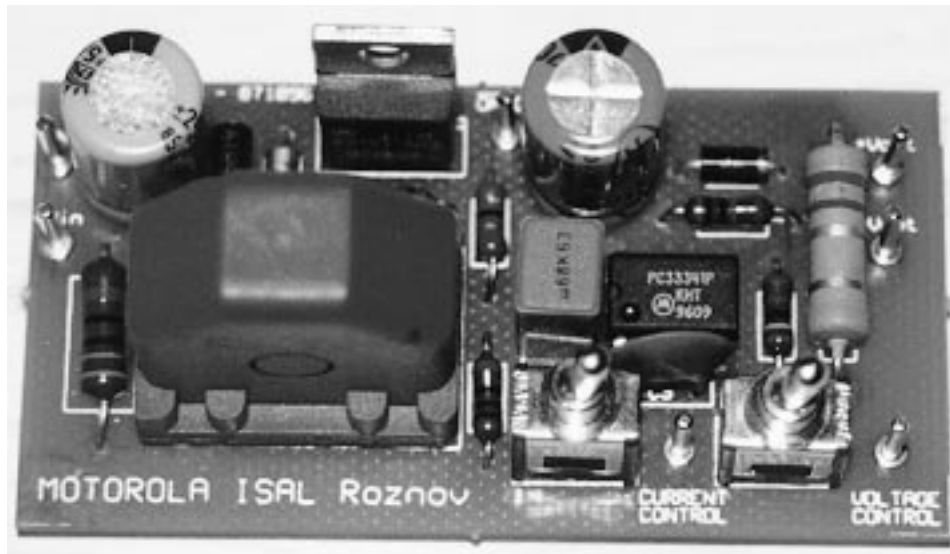**MOTOROLA**

Low Cost 1.0 A Current Source For Battery Chargers

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Figure 1. Low Cost Current Source for Battery Chargers Demonstration Board

This paper describes two designs of low cost current sources for battery charger applications based on the LM2575–ADJ switching step–down converter and the MC33341 regulator control circuit.

INTRODUCTION

This design is a highly cost effective 1.0 A current source for battery chargers with a rectangular constant–current, constant–voltage charging characteristic. This feature assures a basic protection against overcharge whose results can range from minor damage to catastrophic failure of the whole system.

This circuit was designed to implement additional charge control based either on the microcontroller or on any other charging control unit in the system that operates from NiCd or NiMH batteries. The MC33341 and this board may be used in a wide variety of applications. All functions needed are performed by just two integrated circuits and a small number of external components. This allows a very compact printed circuit board design and a very cost effective solution.

The LM2575–ADJ Easy Switch™ step down converter allows the system to operate from 8.0 to 40 Vdc, thus allowing direct operation from both 12 and 24 V board voltages used in the automotive industry. In comparison with linear topologies of battery chargers, this circuit provides much better efficiency, especially over a wide input voltage range.

General Description

Today's most popular rechargeable battery type is NiCd. When overcharged, this type of battery experiences increasing pressure inside the cell. This can cause opening of the cell's vent and release of oxygen. This has a detrimental affect on the battery, although it may still retain some useful capacity. When NiMH batteries are overcharged, they also increase their internal pressure and release some hydrogen, an extremely explosive gas.

The schematic diagram is shown in Figure 2. It is a 1.0 A (maximum) "dumb" battery charger that uses the LM2575–ADJ switching converter to step down the input dc voltage, together with the MC33341, which regulates the charging current flowing into the battery. The switching regulator has high efficiency over a wide input voltage range, which allows this design to be universal. Both 12 and 24 V car batteries as well as cheap, poorly regulated, wall adaptors can be used.

The term "dumb" battery charger means that it offers only some basic protective features and the main protective and control functions are maintained by a μP based main control unit inside the PC or the control function of a cellular phone. This concept allows a very compact and cost effective design.

Various charge techniques have to be used to accommodate both NiCd and NiMH type batteries. Both NiCd and NiMH batteries can be charged at a high current rate

('c' rate) up until the charge limit is reached. After that, the battery has to be charged by a much lower current at the so called 'trickle charge' rate. Trickle charging is a continuous low current charging rate that keeps the battery fully charged.

While NiCd batteries have a recommended trickle charge rate of about c/10, for NiMH type it is not recommended to exceed a charging rate of c/40.

Some battery manufacturers recommend, for their chemistry, pulse charging instead of continuous current charging. This feature can be accomplished by use of the ON/OFF pin of the LM2575.

Circuit Operation

Circuit operation is as follows. When a discharged battery is connected to the charger, the circuit operates as a constant current source. The LM2575–ADJ buck regulator is used to step down an unregulated dc input voltage. This regulator is capable of providing up to 1.0 A of charging current.The amount of charging current flowing into the battery is controlled by the MC33341 regulation control circuit. This IC is used to control the feedback loop in either constant–current or constant–voltage mode with automatic crossover. The MC33341 features the unique ability to perform both high–side and low–side current sensing, each with either internally fixed or externally adjustable threshold level. This feature makes this circuit very universal and ideally suited for use in connection with a microcontroller based intelligent control systems.

In the circuit shown in Figure 2, the MC33341 control circuit is configured for high–side current sensing. The voltage drop across the sense resistor RS provides a voltage that is proportional to the charging current. The current regulation threshold V_{sen} can be adjusted externally (switch S1 in position "2") in the range of 0 V to 200 mV with respect to Pin 4 of U2. When the switch S1 is in position "1", the current regulation threshold level is set internally to 200 mV. Then the regulated current can be calculated as follows:

$$I_{reg} = \frac{V_{sen}}{RS} = \frac{0.2}{RS}$$

Resistor R3 is required in those applications where a high peak level of reverse current is possible, if the source outputs are shorted and the diode D2 is not used. The resistor value should be chosen to limit the input current of the internal V_{CC} clamp diode to less than 20 mA. Excessively large values for R3 will degrade the current sensing accuracy. Resistor R3 value can be calculated from the following expression:

$$R3 = \frac{I_{pkRS} - 0.6}{0.02}$$

where I_{pkRS} is a peak current flowing through the sense resistor RS.

Once the battery voltage reaches a predetermined level, the MC33341 begins to regulate in the constant–voltage mode and the charger starts to regulate the voltage across the battery. This voltage is monitored by Pin 5 of U2, the

Figure 2. Low Cost Switching Regulator Performs Constant–Current/Constant–Voltage 3 Cell Charging Function
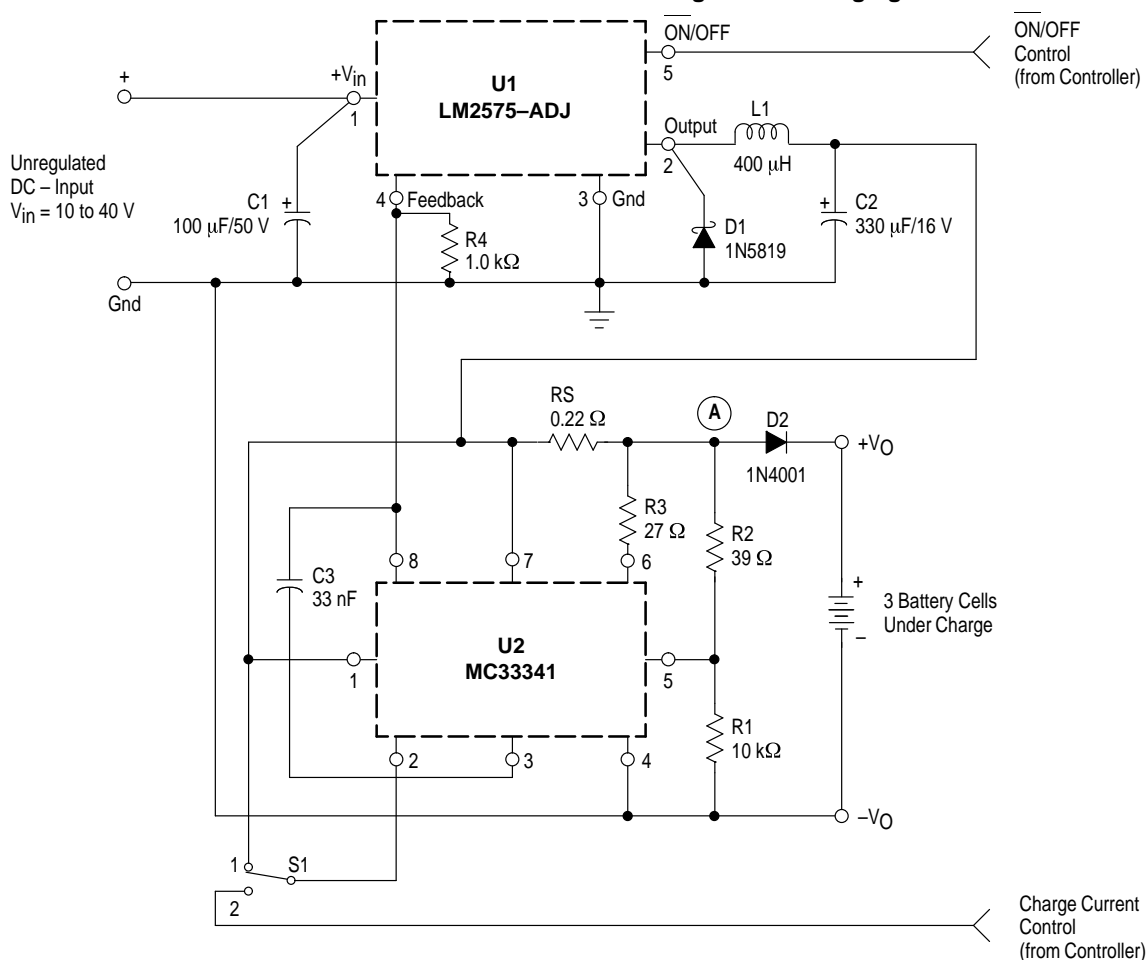
non–inverting input of the transconductance amplifier inside the MC33341. This voltage is divided by resistor divider R1, R2 to the 1.2 V internally fixed level V_{th}. By this arrangement the battery charger output voltage threshold can be set. Moreover, in the low–side current sensing configuration (refer to Figure 3) this threshold level can be externally adjusted over a range of 0 to 1.2 V with respect to the U2 ground at Pin 4. The maximum battery charger output voltage V_{reg} (the voltage at the point A with respect to Pin 4 of U2) can be calculated as follows:

$$V_{reg} = V_{th} \left(\frac{R2}{R1} + 1 \right) = 1.2 \left(\frac{R2}{R1} + 1 \right)$$

The current control loop is closed by connecting Pin 8 of U2 directly to the feedback input of the LM2575 (Pin 4 of U1). Under normal working conditions this pin is held at 1.23 V, resistor R4 is added to convert the MC33341 output current to this voltage. The diode D2 protects the batteries against discharge through U2 when the power source U1 is switched off. For the 1N4001 diode, used in this design, the typical forward voltage drop is 0.9 V. This value must be added to the voltage of three fully charged battery cells in series when the output voltage threshold level is chosen. Capacitor C3 is used for frequency compensation of an internal transconductance amplifier.

The circuit shown in Figure 2 provides high efficiency battery charging with protection against short circuit accomplished by the LM2575 internal current limiting. Because it is possible to set the output voltage threshold by a simple resistor divider, various types of battery cells, as well as various number of cells, can be charged. Nonetheless, this circuit has some limitations. In the high–side current sensing configuration, shown in Figure 2, the V_{CC} Pin 7 of the MC33341 is connected to the output of the power supply circuit. Such a configuration offers the advantage of a common return path for both ICs, the LM2575–ADJ and the MC33341, but it has also a drawback. The low limit of the MC33341 supply voltage is 1.9 V. That implies that charging

of a single 1.2 V cell may not be possible (depending on the voltage drop on D2, if used). Also the current limit in the case of fully discharged cells or shorted output is given only by the internal current limiting of the LM2575, as mentioned above. This drawback can be solved by using the circuit shown in Figure 3.

Improved Battery Charger

This circuit is very similar to the previous one. It uses the same source IC, the LM2575 and also the same charger control IC, the MC33341 but now in the low–side current sensing configuration.

The second difference is a different connection of the V_{CC} pin of U2 which is the supply voltage pin of the MC33341. Now this V_{CC} pin is connected directly to the unregulated dc input voltage through the supply current limiting resistor R5 and resistor R6. The use of the coupling capacitor C4 is essential to assure a stable operation of the whole system. C4 transfers the ac part of the LM2575 output voltage (or the LM2575 output ripple voltage) through the MC33341 V_{CC} Pin 7 and output Pin 8 into the feedback Pin 4 of the LM2575. The way the LM2575 operates makes this connection necessary. Since the maximum allowable supply voltage of the MC33341 is 18 V, the Zener diode D3 has to be used to clamp the supply voltage of the MC33341 to its operating limit when the input voltage exceeds that value. Use of such an arrangement assures that the charging control circuit U2 will always have a supply voltage high enough, even under short circuit conditions at the output of the battery charger. Switch S1 can be used the same way as in the previous design. Switch S2 is used to alter the output voltage threshold. When S2 is in position "1", the voltage threshold on Pin 5 is set internally to 1.2 V and consequently the output voltage threshold can be set only by the resistor divider R1, R2. Switching S2 to position "2" allows an external control of the Pin 5 voltage threshold V_{th} in the range of 0 V to 1.2 V. This feature contributes to the universality of this battery charger.

Figure 3. Low Cost Switching Regulator Performs Constant–Current/Constant–Voltage 3 Cell Charging Function. Version with Full Short–Circuit Regulation Control Capability.
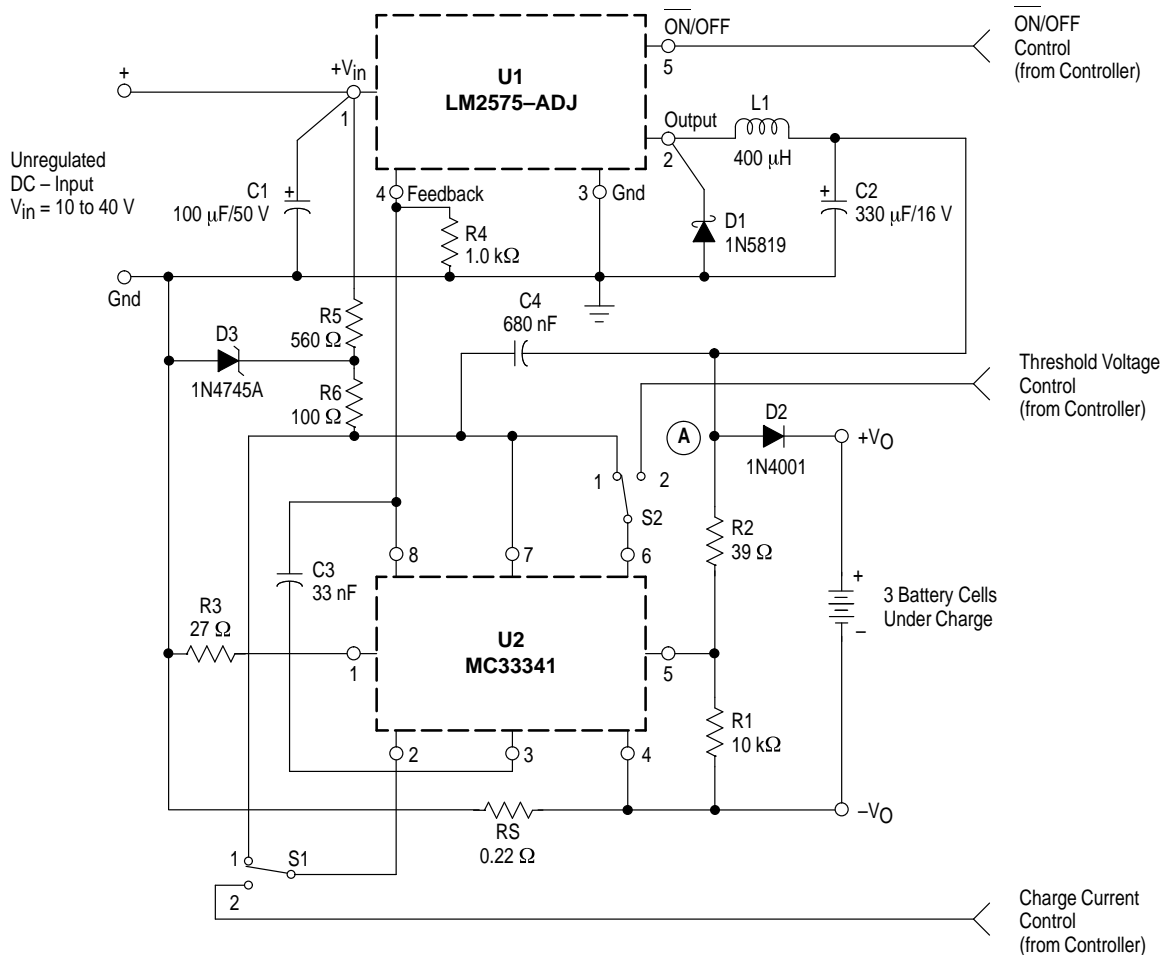

Figure 4. Constant–Voltage/Constant–Current Charging Characteristic of the Improved Current Source for Battery Chargers
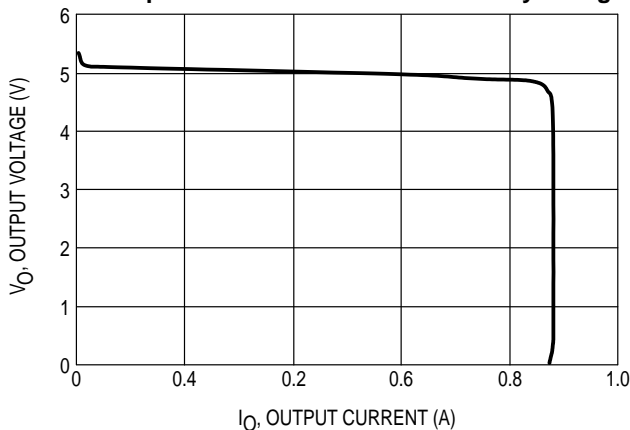

Figure 4 shows the V/I charging characteristic of the improved circuit (see schematic in Figure 3). The small voltage drop in the beginning of the V/I characteristic is caused by dynamic resistance of the diode D2. This phenomenon can be eliminated either by reconnection of the resistor R2 from the point "A" to the cathode of the diode D2,

or this diode might be replaced by shorting wire. Both actions would cause also another effect on the V/I characteristic of this circuit. When the output voltage drops below approximately 1.2 V, the output current will fall down accordingly, thus creating a typical "foldback" V/I characteristic.

Table 1. Parts List (Refer to the Circuit Shown in Figure 2)

Component	Quantity	Value/Rating	Description
R1	1	10 kΩ, 1/4 W	Resistor
R2	1	39 kΩ, 1/4 W	Resistor
R3	1	27 Ω, 1/4 W	Resistor
R4	1	1.0 kΩ, 1/4 W	Resistor
RS	1	0.22 Ω, 1/2 W	Resistor
C1	1	100 µF, 50 V	Capacitor Electrolytic
C2	1	330 µF, 16 V	Capacitor Electrolytic
C3	1	33 nF	Capacitor Ceramic
D1	1	1.0 A, 40 V	Schottky Diode, 1N5819
D2	1	1.0 A, 100 V	Diode, 1N4001
S1	1	–	Switch
L1	1	400 µH, 1.6 A	Inductor, 77 458 BV
U1	1	–	IC, LM2575–ADJ
U2	1	–	IC, MC33341

NOTES: 1. Inductor L1: Inductance Pins 4, 6. Manufacturer: TECH 39 Power Electronic,
Tel. +33/1–4115–1681, Fax +33/1–4409–5051.
2. All tolerances ±10%, unless otherwise specified.
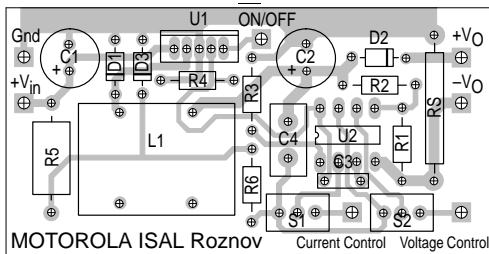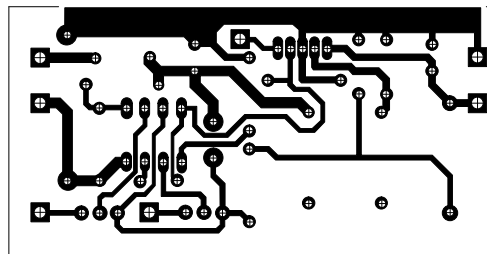
Figure 5. PCB Layout Component Side
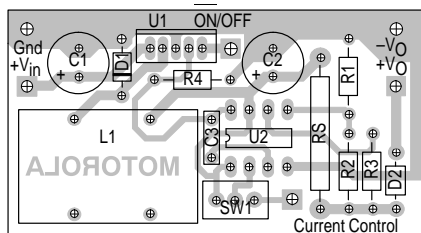
Figure 6. PCB Layout Copper Side
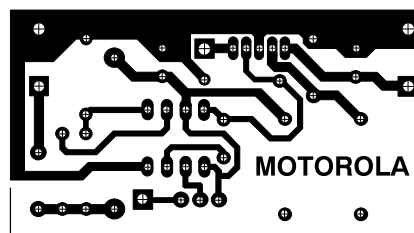
Performance of the Sample Design (Refer to the Circuit Shown in Figure 2)

Input voltage range . . . . 8.0 to 40 Vdc
Battery charging current . . . . 0.88 A
Open output voltage . . . . 5.45 V
Power converter efficiency . . . . . 77%, V_{in} = 24 V

Table 2. Parts List (Refer to the Circuit Shown in Figure 3)

Component	Quantity	Value/Rating	Description
R1	1	10 kΩ, 1/4 W	Resistor
R2	1	39 kΩ, 1/4 W	Resistor
R3	1	27 Ω, 1/4 W	Resistor
R4	1	1.0 kΩ, 1/4 W	Resistor
R5	1	560 Ω, 1.0 W	Resistor
R6	1	100 Ω, 1/4 W	Resistor
RS	1	0.22 Ω, 1/2 W	Resistor
C1	1	100 µF, 50 V	Capacitor Electrolytic
C2	1	330 µF, 16 V	Capacitor Electrolytic
C3	1	33 nF	Capacitor Ceramic
C4	1	680 nF	Capacitor Ceramic
D1	1	1.0 A, 40 V	Schottky Diode, 1N5819
D2	1	1.0 A, 100 V	Diode, 1N4001
D3	1	16 V, 1.0 W	Zener Diode, 1N4745A
S1	1	–	Switch
S2	1	–	Switch
L1	1	400 µH, 1.6 A	Inductor, 77 458 BV
U1	1	–	IC, LM2575–ADJ
U2	1	–	IC, MC33341

NOTES: 1. Inductor L1: Inductance Pins 4, 6. Manufacturer: TECH 39 Power Electronic,
Tel. +33/1–4115–1681, Fax +33/1–4409–5051
2. All tolerances ±10%, unless otherwise specified.

Figure 7. PCB Layout Component Side

Figure 8. PCB Layout Copper Side

Performance of the Sample Design (Refer to the Circuit Shown in Figure 3)

Input voltage range . . . . 8.0 to 40 Vdc
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Post–Design Recommendation

In some cases, there is a need to compensate for a small voltage drop on the constant–voltage part of the V/I characteristic of this current source or to compensate a voltage drop across wires leading from the output of the current source to the charged battery. In that case, it is possible to add a resistor between Pin 5 of the MC33341 and the ground of the circuit shown in Figure 3.

Conclusion

The LM2575–ADJ step–down converter and the MC33341 regulator control circuit used in the battery charger applications offer a solution which is simple, highly efficient and cost effective. The two current sources for battery chargers described in this paper can operate directly from both 12 and 24 V board voltages with no change of the electrical connection. This fact makes these applications especially suitable for the automotive industry.

REFERENCES

1. LM2575 Data Sheet and Application Note; order from Motorola by LM2575/D.

2. MC33341 Data Sheet and Application Note; order from Motorola by MC33341/D.

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