Lead-acid Battery Protector

Prevent deep discharge

Lead acid batteries come in several different forms and are quite trouble-free. OK, so they don't like to be overcharged, but the charger unit can take care of that. What they really don't like is when their cell voltage drops so low that the battery enters a deep-discharge state. To avoid this situation we need the help of some electronics; that's where the protector comes in.

By **Jochen Brüll**
(Germany)

Lead-acid batteries are not only used in cars and other types of vehicles; they also are a good choice for powering equipment in remote locations where plugging an adapter into a wall outlet is not an option. In these situations it's important to arrange some protection for the battery to ensure it doesn't get irreversibly damaged by becoming completely discharged. Besides designing some method of battery charging it's also necessary to implement some protective circuit to automatically disconnect the load when the battery voltage approaches its deep discharge level. That's where the protector circuit comes in.

Applications

The author has a wide experience diagnosing EMC problems and finds the interference-free environment surrounding an analog circuit preferable to the barrage of RF noise produced by sensitive microcontroller designs. **Figure 1** shows the circuit of the protector and there isn't a single digital component in sight (if you ignore S1!). The protection circuit sits between the battery and load, powered by the battery, and protects the battery by disconnecting the load when the individual cell voltage falls below 1.8 V. For long-term battery health its much better to disconnect any load before the battery gets to this state. Apart from this feature the protector also limits switch-on surge current supplied to the load.

In its form described here it would typically be useful in a battery powered remote sensing application. Using two series-connected 12 V 1.2 Ah lead-acid batteries the author has already been using the protector for six years without a hitch. With the components given in the circuit diagram, it is suitable for applications drawing a continuous current up to 400 mA.

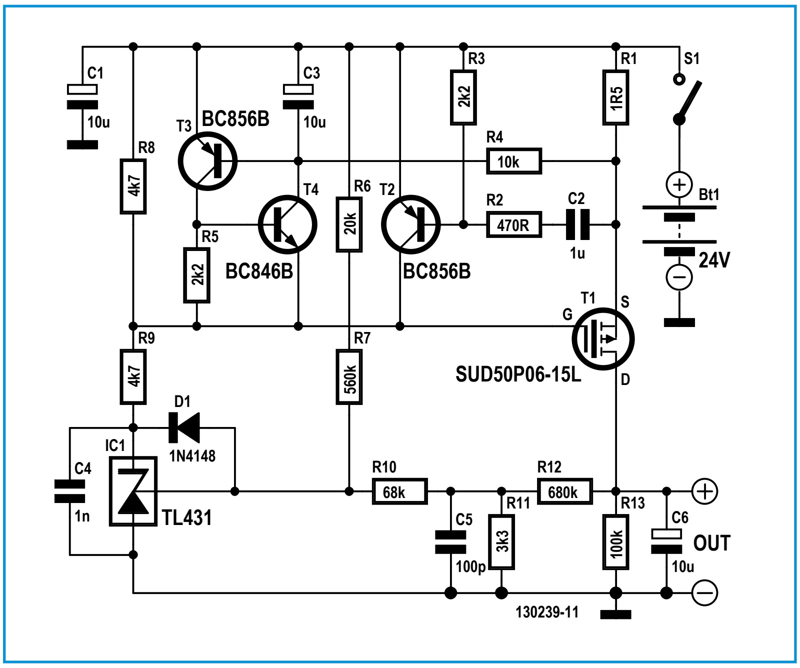

Figure 1.
The battery protector circuit is purely analog.

With switch S1 closed (normal operation) and no load connected, T1 is conducting because the unconventionally configured IC1 has sufficient battery voltage at its cathode to conduct. This pulls the gate of T1 to ground via R9 to provide voltage at the output.

Switch-on surge limiting

The majority of equipment designed to operate from 24 V will derive their supply from a switch-mode adapter unit. Usually there will be a reservoir capacitor with a value of a few mF at the equipment input which causes a large inrush of current from the external adapter at turn on. With battery operation this current flow can cause a momentary dip in the battery's terminal voltage and trigger the cell deep-discharge detector. An inrush reduction mechanism is included in the circuit to prevent false triggering. The current limiting feature has two mechanisms:

- At switch on a current surge flows through T1 and R1. The voltage drop across R1 makes T2 conduct for the first hundred microseconds which makes the gate of T1 positive, limiting the load current to less than 600 mA. T1 and T2 operate during this time as a current source. During this switch-on period the capacitor in the load circuit will charge up and current falls to a value below 400 mA.

- The second mechanism detects when too much current is drawn by the load. Load current through R1 produces a voltage drop stored on C3 via R4. When too much current flows, the voltage increases to the point where T3 conducts. T3 and T4 are configured as a thyristor so when T3 switches T4 conducts and shorts the gate of T1 to the supply rail. The load is thus turned off and remains off until the supply is cycled by S1. The time taken for the overload circuit to trigger depends on load current. At 650 mA it triggers after approximately 0.6 s, at 6 amps it takes around 30 ms.

Deep discharge protection

As we already mentioned lead acid batteries should not be used when the cell voltage has fallen to its deep discharge voltage. To promote long battery life it makes sense to disconnect the battery when there is still some charge remaining. Using 12 cells to give a nominal 24 V this lower threshold V_B is set to 22 V. This ensures the battery will not be discharged below 1.83 V per cell.
The protection mechanism functions like this: when the battery voltage V_B falls below 22 V the voltage on the REF input of IC1 (produced by the resistor network R6 + R7 and R10 + R11) falls below the 2.5 V reference voltage so current flow into the cathode of IC1 and through R9 stops. The gate of T1 is now pulled up to V_B via resistor R8 which turns off T1.

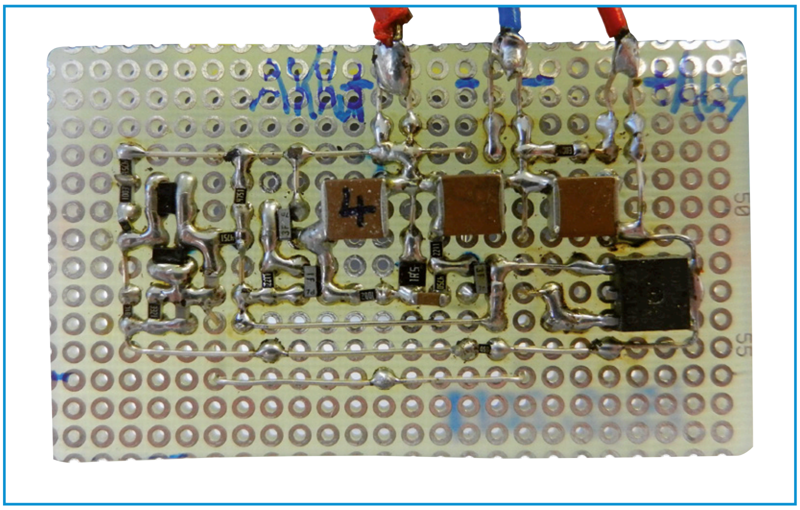

Figure 2.
Construction on a piece of .1″ pitch stripboard using SMD components.

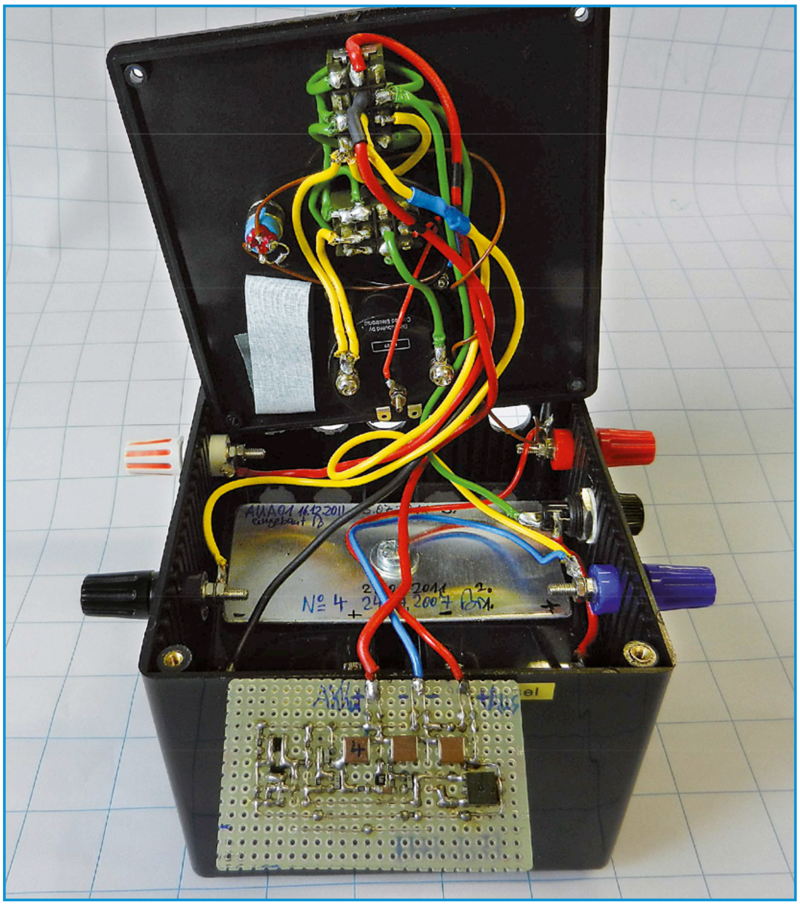

Figure 3.
It all fits in a project box.

The battery level V_B rises slightly when the load switches out of the circuit. Resistor R12 introduces a 1 V hysteresis to the trigger level so that this voltage rise does not cause the circuit to cycle on and off as it reaches the switching point. The load can only be switched on again when the battery has been recharged and its output voltage is >23 V.

Construction

The circuit can be built using conventional thru-hole (leaded) components soldered on a square of perf board. For the prototype (**Figure 2**) the author used a piece of stripboard and SMD components. The complete circuit fits neatly into a small project box (**Figure 3**) together with a switchable Amps/Volts meter mounted in the lid. The finished unit is compact (**Figure 4**) and can be easily connected between the battery and load.

The components are all standard items, if you plan to substitute an equivalent type of MOSFET for T1 note that it is a P-type with its source lead connected to R1. The values of resistors R6, R7 and R10 should all have a tolerance of 1 %. To make the circuit suitable for 12 V operation it will be necessary to change some resistor values so that: R6 = 33 kΩ, R7 = 220 kΩ and R9 = 2.2 kΩ. Transistor T1 is used as a switch here so it doesn't need any heatsink. A current of 6 A results in just 400 mW dissipated by the transistor and this only lasts for 30 ms. A 0.5-watt resistor will be okay for R1.

(130239)

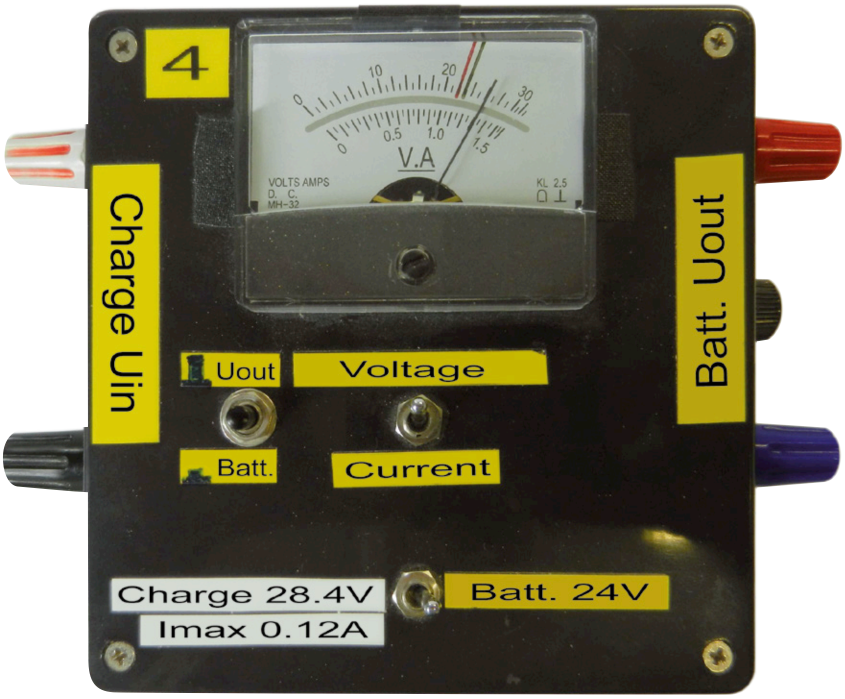

Figure 4.
The finished protector prototype.