

Low Voltage Battery Disconnect



Homebrew

Automatic Battery Shutoff For Medium Power DC Loads

G. Forrest Cook

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Lead acid and NiCd batteries will last a long time if they are operated within the proper charge and discharge voltages. A charge controller circuit is a necessity for preventing battery over-charge. Conversely, a low voltage disconnect circuit (LVD) prevents excessive battery discharge. By using a combination of both circuits it is possible to keep the battery operating within the proper range.

This article describes a low to medium power LVD which operates like a common on-off toggle switch. The circuit is very efficient, consuming a mere 8 milliamperes while running and essentially no power when off. The LVD was designed to use commonly available parts. The prototype was built entirely from junk-box parts.

Theory

The heart of the LVD is the power MOSFET transistor, Q1. Transistor Q1 operates as a switch in the positive line of the external circuitry. Switching of the positive side of the circuit allows for a common negative ground between the battery and the load which aids in many applications, especially automotive ones. To achieve this "high side" switching, it is necessary to generate a gate drive voltage that is higher than the supply voltage. This is accomplished by a voltage tripler circuit. Op-Amp U1b generates a 5 KHz square wave. This is fed into the diode/capacitor ladder circuit which successively boosts the voltage to about 3 times the peak voltage of the square wave.

This signal is then used to gate on the power MOSFET. Resistor R5 is used to discharge the gate circuit when the LVD is shut off, allowing the MOSFET to turn off.

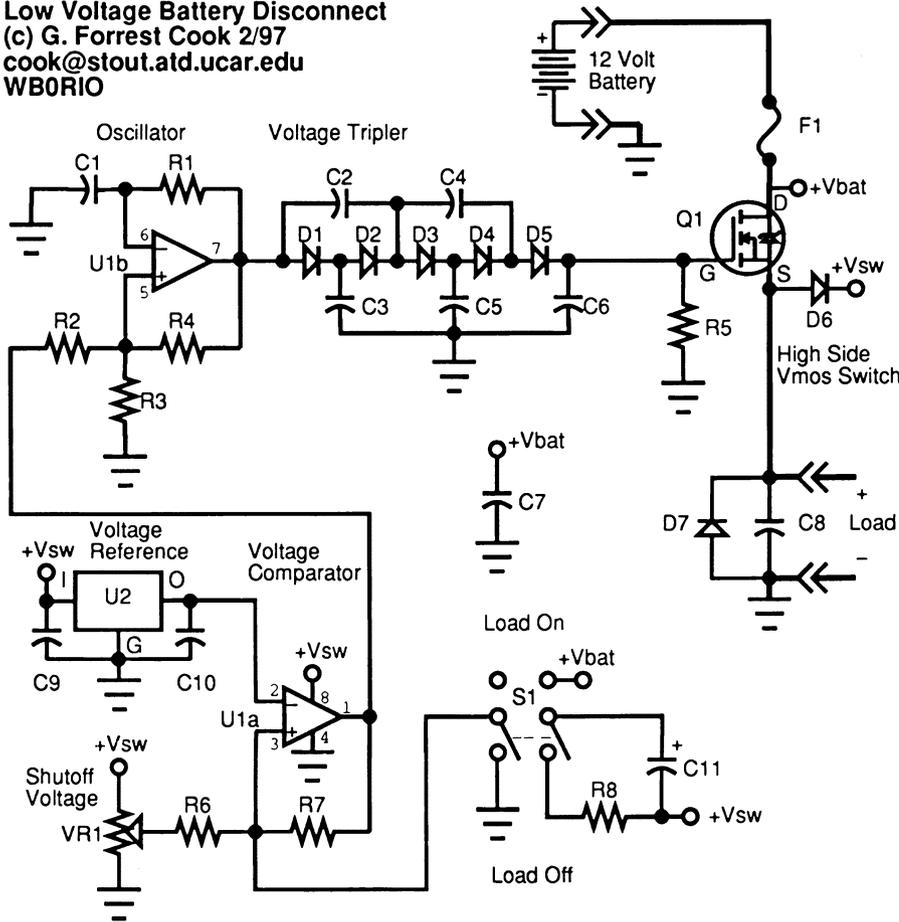
The voltage comparator circuit consists of U2, a standard 5 Volt regulator which is used as a voltage reference, U1a wired as a comparator, and VR1, a voltage divider to provide a set point for the low voltage shutoff. When the battery voltage is above the threshold U1a provides a positive output which is used to create a bias level via the R2/R3 voltage divider, that allows the U1b oscillator to run. When the battery voltage drops below the set point the output of U1a goes to zero and the U1b oscillator shuts off, causing the voltage tripler and MOSFET to shut down. Resistor R7 gives the comparator circuit some hysteresis to prevent comparator oscillation near the shutoff voltage. The circuit is analogous to a solid-state latching relay in that it shuts its own power off when the MOSFET turns off. This is achieved with diode D6 and the on-off switch. When the circuit is switched on capacitor C11 acts like a momentary short-circuit, pulling the op-amp Vcc line up to the battery voltage. The whole circuit fires up long enough to turn the MOSFET on, after which operating current flows through the MOSFET and diode D6.

When the switch is shut off the comparator is forced off by shorting pin 3 to ground. This turns off the MOSFET. Resistor R6 prevents switch S1 from shorting the VCC directly to ground when potentiometer VR1 is set to VCC. Capacitor C11 is discharged through the other half of the switch and current limiting resistor R8. Discharge of the capacitor is required for circuit start-up the next time the switch is turned on. Diode D7 is used to protect the MOSFET from negative spikes generated by motors or other inductive loads. Capacitors C7, C8, C9, and C10 provide filtering in various parts of the circuit.

Fuse F1 protects the circuit from overload and should be a fast blow fuse that is rated at about 80 percent of the maximum current that Q1 can handle. Numerous MOSFET transistors can be used for Q1. Parts selection is based on cost and maximum current. The IRFZ34 MOSFET is rated at 30 Amps continuous current and should be used for switching heavy loads. A lower power MOSFET such as an IRF520 may be used for up to 8 Amp loads. A heat sink and thermally conductive grease should be used on the MOSFET unless the load current is always kept under a few amps.

An alternate method of switching the circuit on and off is to replace the DPDT switch S1 with a pair of momentary push buttons for separate on-off controls. The "on" push button connects between the Q1 Drain and the D6 cathode. The "off" push button connects between U1A and ground. If push buttons are used, capacitor C11 and resistor R8 may be left out of the circuit.

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Remember to switch the circuit off and back on while adjusting, it will not turn on by itself.

Construction

I built the prototype circuit on perforated circuit board using point to point wiring. Teflon insulation over tinned bare wire is my personal favorite method for making prototypes since the teflon can withstand a lot of abuse without melting. Wire-wrap or other methods could also be used for construction. Be sure to use thick wires for the current carrying part of the circuit. In the prototype I built the circuit into an aluminum box and used computer DB25 connectors for the input and output connectors.

Use

Simply connect the circuit between the battery and the load and use it like a switch. If the battery sags below the set value the circuit will shut off. After the battery is charged up again the circuit can be switched off and back on. The circuit works well with a 12 V car tail light and a gel-cell battery.

Alignment

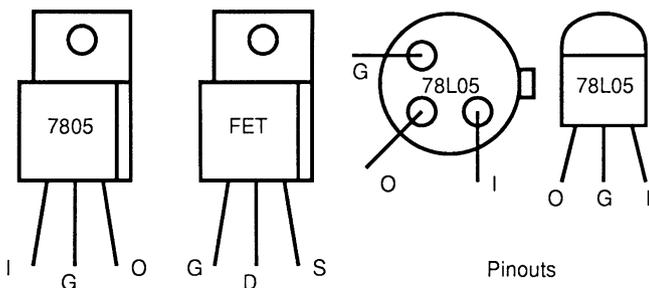
Alignment is straightforward, the equipment required is a variable voltage power supply and a load such as a small 12 V light bulb. Connect the power supply to the battery input terminals and the light bulb to the load output terminals. Set potentiometer VR1 to the midpoint and the variable voltage supply to 13 Volts. Turn the circuit on and the light should go on. If it does not, adjust VR1 towards ground and switch the LVD off and back on. Repeat until the light stays on. Then slowly turn the variable power supply voltage down until the light goes out. This is the LVD set point. Adjust VR1 until the shutoff voltage is where you want it to be, I usually set it to 11 Volts for gel-cell batteries.

Battery Capacity Meter

An interesting application for this circuit could be as a component in a battery capacity meter. For the load

LVD Parts List

U1:	1458 dual op-amp
U2:	78L05, 78M05, or 7805 5 Volt regulator
Q1:	IRFZ34 or IRF520
D1-D6:	1N4148 switching diode
D7:	1N4001 1 A diode
F1:	Automotive fuse (see text)
S1:	DPDT toggle switch
C1:	0.001 µF ceramic disk capacitor
C2-C6:	0.01 µF ceramic disk capacitor
C7-C10:	0.1 µF ceramic disk capacitor
C11:	22 µF, 16 V electrolytic capacitor
R1-R4:	100k 1/4 W resistor
R5,R7:	1M 1/4 W resistor
R6:	1K 1/4 W resistor
R8:	22 ohm 1/4 W resistor
VR1:	100K trimmer pot, 10 turn variety preferred



wire a high wattage resistor in parallel with a 12 Volt mechanical clock. Set the clock to 12:00 and charge the battery up. Select a load resistor that gives the desired discharge current. To make a clock that runs on 12 V I used a 1.5 V travel alarm clock with the voltage dropping circuit shown in figure 2. Discharge the battery via the LVD and measure the hours that it ran after the LVD has shut off. This circuit is very useful for sorting through a set of marginal batteries and gives an indication of the useful power that the battery can provide.

Access

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