FROM THE ELEKTOR LAB...

(by Pierre Kersemakers)

Battery monitor

Batteries are crucial for making electrical energy 'portable'. Without batteries, our lives would look very different; not only would cell phones and MP3-players be outside of the realm of possibilities, but also something as ordinary as starting a car by simply turning the ignition key. Admittedly, in theory you could start a car by pushing it or driving it down a slope, but it'll take a lot of muscle to jumpstart a massive four-wheel-drive SUV in the winter, especially when the oil is cold and viscous. Preventing a nightmare scenario like this is a good enough reason to continually check and maintain your batteries. To reduce the amount of effort it takes to gain this battery-security, you can automate the surveillance process with this little
i-TRIXX circuit.

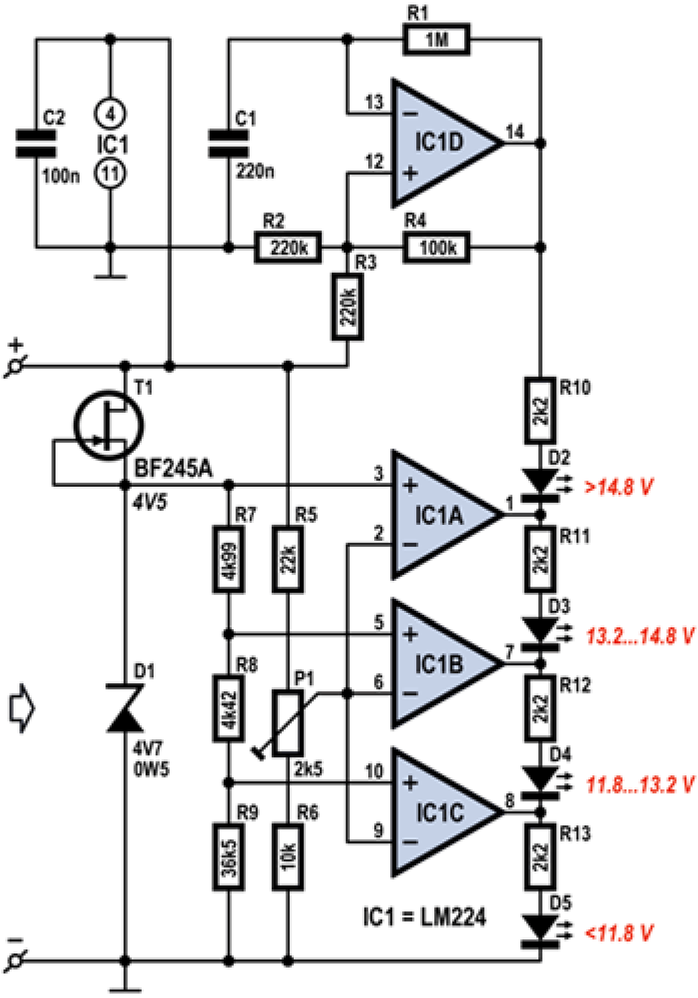
Our battery monitor is suitable for checking up on lead-acid batteries with a nominal voltage of 12 V. These batteries can be in one of four different situations at any given time, depending on the voltage over their terminals:

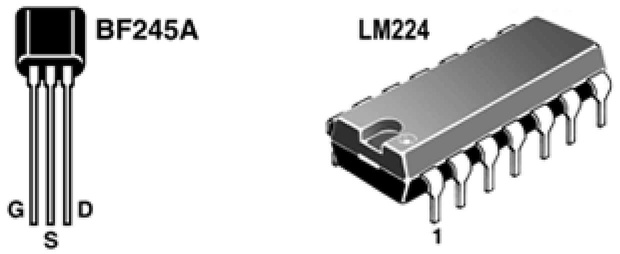
- $V_{battery}$ < 11.8 V: The battery is practically empty
- 11.8 V < $V_{battery}$ < 13.2 V: Normal condition (still charge left)
- 13.2 V < $V_{battery}$ < 14.8 V: The battery is being charged
- $V_{battery}$ > 14.8 V: Danger! The charging voltage is too high

So, what we need is a circuit which can state (preferably in a visual manner) in which of the four ranges the battery voltage is located. It seems obvious to use a comparator circuit to achieve this.

Reference voltage

As the word 'comparator' might already have implied, we will need a reference voltage to compare the battery voltage with. This reference, which will be derived from the battery's voltage, should be as constant as possible, independent of what the voltage of the source is. We can achieve this using a 4.7 V zenerdiode (D1 in the circuit diagram). To make the reference voltage less dependant on the current which passes through the zenerdiode, we'll drive the current using a simple JFET current source (T1). This way, we acquire a stable reference voltage of approximately 4.6 V. This is slightly lower than expected, although the discrepancy can be explained by the current running through the zenerdiode in our circuit being lower than the current specified by the supplier.





We'll use a simple quadruple opamp chip for the four comparators (IC1A..IC1C). The output turns high (i.e. equal to the supply voltage) as soon as the voltage on the plus input is even slightly higher than the voltage on the minus input, and low if the minus input is higher than the plus input, due to the extremely high amplification factor of a non-inverting opamp. This property lets an opamp mimic a comparator.

Because we (purposely) chose regular opamps instead of 'real' comparators (which are usually equipped with open collector outputs), we can control *four* LEDs with just *three* opamps, as shown in the table.

output IC1A	output IC1B	output IC1C	LED	colour	meaning
low	low	low	D2 flashes	red	danger
high	low	low	D3 on	yellow	charging
high	high	high	D4 on	green	normal
alto	alto	alto	D5 on	red	empty

Voltage dividers

The red LED D2 should light up when the battery voltage is higher than 14.8 V, which corresponds with a too high charging voltage. Charging with such voltages can lead to irreversible damage to the battery and the formation of an explosive gas, so it is wise to keep the red LED dark as much as possible. To allow the circuit to detect such overvoltages, we'll need to convert the battery voltage to a level which can be compared to the reference voltage. By feeding the battery voltage through a potential divider, we can derive an input voltage (U_{in}) which is equal to the reference voltage (U_{ref}) of 4.6 V. The voltage divider consists of the components R5, P1 and R6.

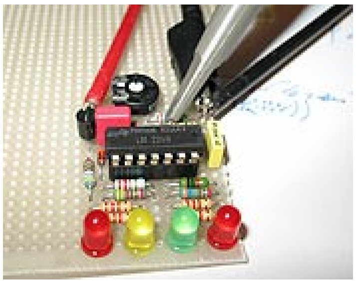
To make understanding the circuit easier, you can ignore P1 for the time being, since it's only necessary for the calibration of the circuit. After choosing the standard value of 10 kΩ for R6, the required value of R5 is easily calculated using the potential divider rule. In theory, R5 should have a resistance of 22.17 kΩ, although in practice 22 kΩ will suffice. This results in a theoretical input voltage of 4.625 V (10 / (22 + 10) x 14.8 V). The thresholds for the two other comparators will therefore be 4.125 V (10 / 32 x 13.2 V) and 3.6875 V (10 / 32 x 11.8 V).

The next step is to convert the reference voltage U_{ref} with a second voltage divider, which consists of the resistors R7 through R9, to the threshold voltages for IC1B and IC1C. These voltages need to match the previously calculated voltages as precisely as possible. The easiest way to accomplish this is to assume a current of 0,1 mA flowing through R7..R9. This results in a total resistance of 46 kΩ. The voltage drop over R7 needs to be 0.5 V (4.625 V - 4.125 V), therefore requiring a resistance of 5 kΩ. The closest E96 number (!) is 4.99 kΩ.

Using the same method, we calculated the values of R8 and R9 to be 4.42 kΩ and 36.5 kΩ (also E96 values). Try calculating it for yourself!

To limit the power consumption of our circuit, we chose to use low current LEDs. When using a 13 V power source, the current flow amounts to approximately 7 mA, which amounts to a current usage of 5 Ah each month. No decent car battery will have any trouble supplying the current.

FlashLED



The LM224-IC, which is used in the circuit, contains four opamps. The comparator circuit only requires three, which leaves one to spare. And, of course, in true i-TRIXX spirit, it won't remain unused.

The remaining opamp (IC1D in the diagram) is part of a simple oscillator, which produces a square wave of about 2 Hz (f = 2.4 x R1 x C1), when using the same components as we have. This oscillator insures that the battery won't go unnoticed when it truly resides in danger by making sure the LED D2 will not only light up, but flash frantically to attract attention. Note that the oscillator doesn't influence any of the other LEDs.

Construction & calibration

As you may have become used to from us here at i-TRIXX, this circuit is easily built on a piece of prototyping board. If you work neatly, you shouldn't encounter any problems.

Properly calibrating the circuit does require an adjustable (lab) power supply unit though. Connect the PSU to the plus and minus terminals of the circuit and set the voltage to 14.8 V. Now turn P1 until the LED D2 starts flashing. Make sure you didn't turn too far by turning P1 back a tiny little amount after D2 lit up. If the range of P1 isn't high enough, don't hesitate to use a potentiometer with a higher value.

After that, adjust the power supply to 13.2 V and 11.8 V and check if the other LEDs light up at approximately the correct voltage. Now the circuit is ready to be built into a casing and used! Happy hacking!