DCC Impulses Column

by Bruce Petrarca

photos by the author, unless otherwise specified

Let's go from theory to circuit, step by step.

After my March 2013 Staying' Alive column (http://model-railroad-hobbyist.com/magazine/mrh-2013-03-mar/di_staying-alive), I got an e-mail from a fellow model railroader about adding a battery to his camera car to keep the video from dropping out with track power disruptions. He provided me with a complicated circuit with two adjustable voltage regulators and a bunch of capacitors and resistors.

I took on designing a simple module to charge the battery and power the camera using DCC track power. The battery will take over running the camera when track power is interrupted. There are lots of needs in DCC model railroading for such a circuit. They can provide power for coach lights or other lighting details, on-board sound modules, etc. That's why I decided on making it a column.

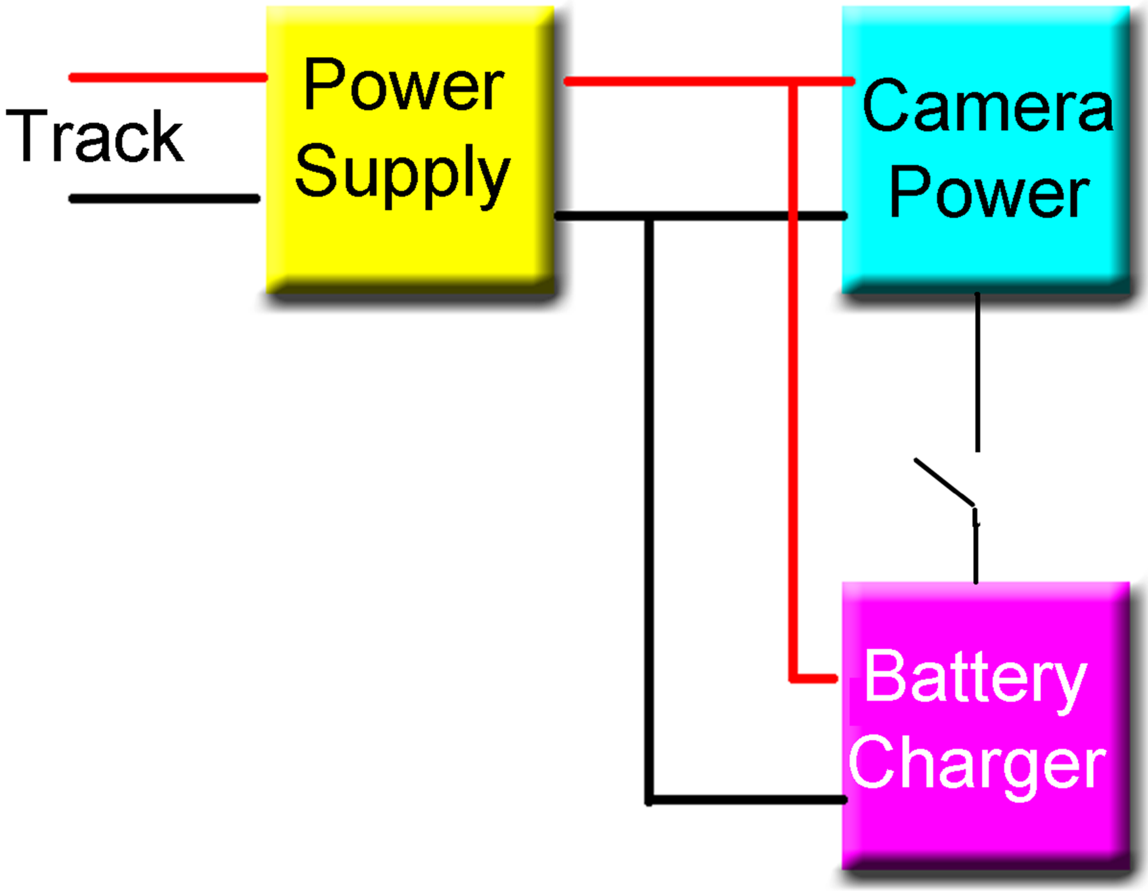
Building such a device is a simple project, once you have a design. So, I broke the circuit down into functional bocks and designed each block, using Ohm's Law. A walk through the design may help folks unravel some of the "mystery" of electronics.

Functional Blocks

There are three functions that this circuit needs to perform, as shown in figure 1.

- Power supply

- Camera power
- Battery charger



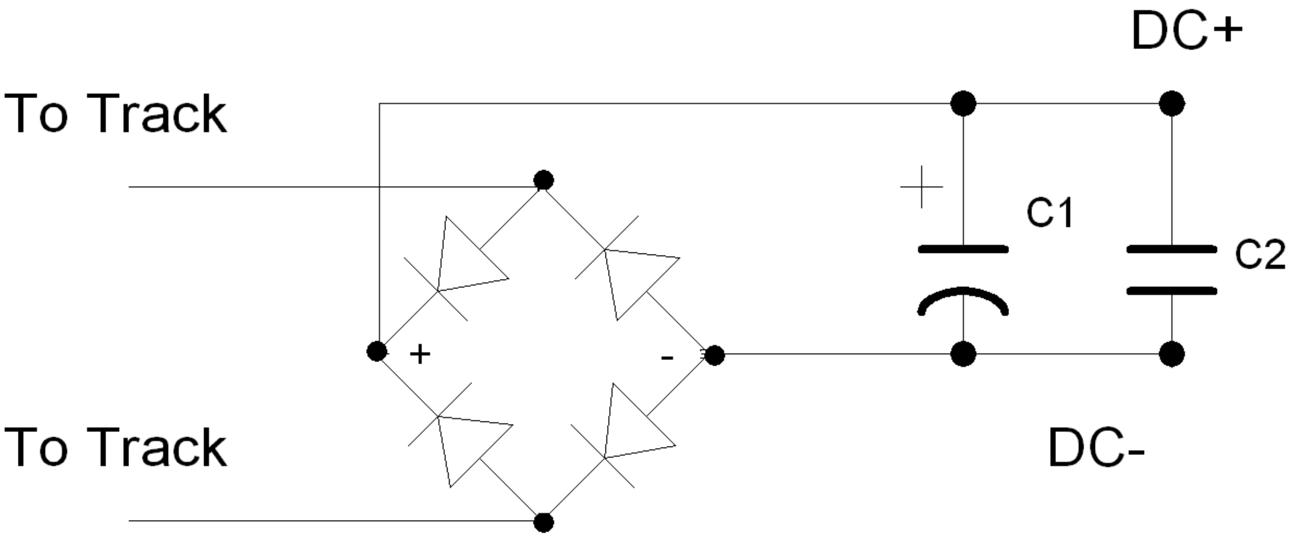
1: Block diagram

So, let's look at each function by itself and understand how to select each component.

Power Supply

This will turn the track DCC into a DC voltage. The DC voltage will be slightly less than what the track DCC voltage is set to. The schematic is shown in figure 2.

The heart of this function is the **bridge rectifier** – the four diodes near the middle of figure 2. It stacks all of the positive DCC pulses on one side and all the negative ones on the other side. It can come as a module with four terminals on it (2 inputs, one + and one - output) or can be made from four discrete diodes. Generally, I recommend the module, for small size and ease of construction (3).



2: Power supply schematic

Rectifiers have two primary specifications, voltage and current.

The rated voltage is properly known as Peak Inverse (reverse) Voltage (PIV) and is the maximum voltage that the rectifier is designed to withstand backwards across the diode. Back to my water analogy from my December 2012 (http://model-railroad-hobbyist.com/magazine/mrh-2012-12-dec/di_basic-electronics-for-dcc) ***Basic Electronics*** column. PIV is the maximum pressure that the check valve will withstand when the water is trying to flow against the closed valve.

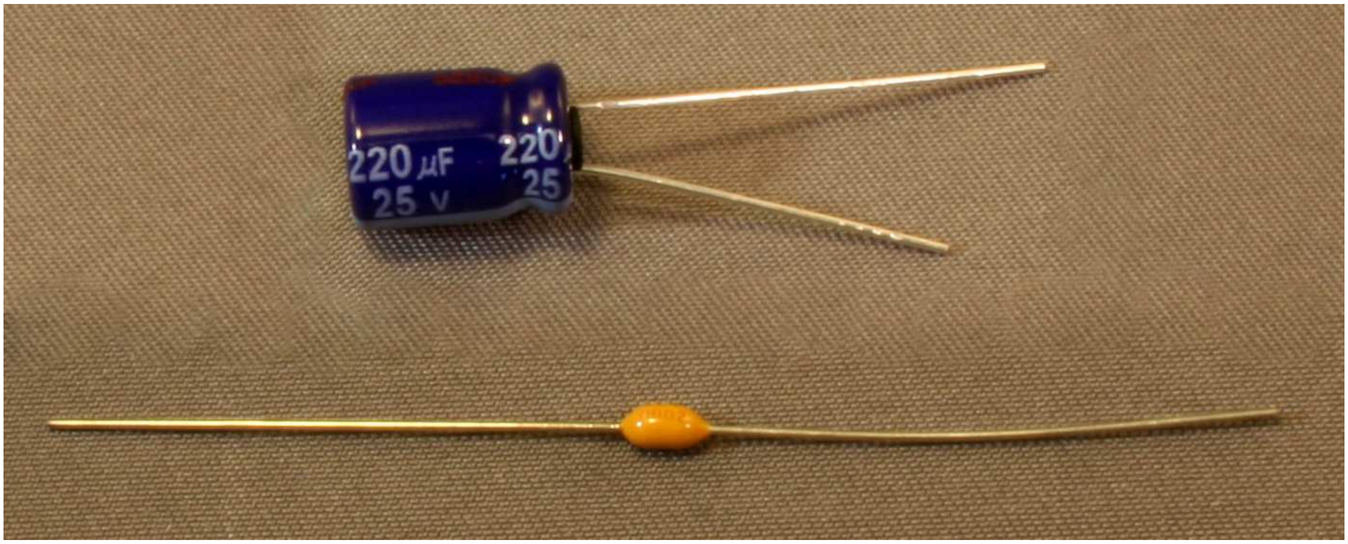
3: Bridge rectifier module vs. discrete diodes

Rectifiers are usually rated at 50 volts or higher. Since this exceeds the maximum DCC voltage, most any will work just fine, voltage wise.

The sum of all the current drawn through the rectifier should be less than the rating on the rectifier. One amp is about the minimum current rating for a rectifier and works in the vast majority of DCC uses. In the case of this circuit, there will be about ⅛ amp being drawn through the rectifier, so a 1-amp unit will be fine.

There are two capacitors in this circuit.

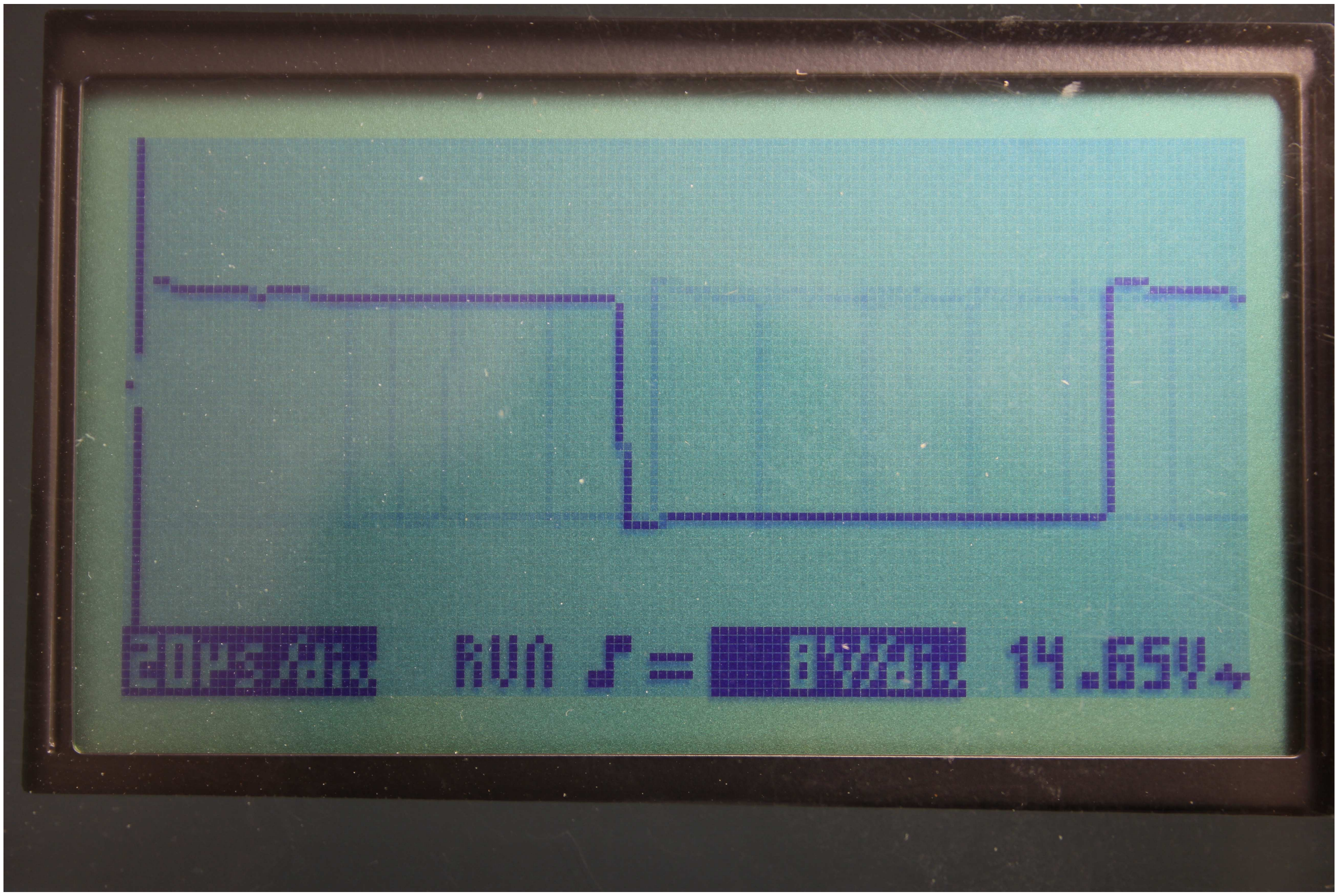
The filter capacitor (C1) is an electrolytic (polarized) unit. Its function is to store the pulses passed by the rectifier. It makes DC out of the pulses of DCC that have been directed by the bridge rectifier. 10 µF is enough to smooth out the pulses. A 25-volt rating will work with all DCC track voltages up to 20 volts. If you are in garden railroading or using track voltages up to the 27-volt DCC maximum, use a 35-volt capacitor for safe operation.



4: Capacitors used in this circuit: electrolytic (top) and ceramic (bottom). The electrolytic capacitor shown is a much larger value than what this circuit needs.

The other capacitor (C2) is there to remove any spikes left due to asymmetry in the DCC signal. This should be a small mica or ceramic capacitor. The electrolytic capacitor doesn't filter these small spikes, so the addition of a spike suppressor capacitor in parallel will help you have clean DC for sensitive electronics like the camera. A frequent value is 0.1 µF at 50 volts. This could be anywhere from 0.01 µF to 0.5 µF, as long as the rated voltage is above 35 volts.

Figure 5 shows the oscilloscope display reading the DCC signal being applied to the power supply whose circuit is in figure 2. Note that the oscilloscope reads the peak-to-peak DCC voltage as 14.65 volts. When this photo was taken, the output voltage was measured at 13.57 volts DC. This is why I use a 1-volt difference between DCC track voltage and DC output voltage as a "rule of thumb".



5: DCC input waveform to power supply – 14.65 volts "track voltage"

Okay, now we have a DC power supply (very much like what is in a DCC decoder). While that is necessary, it doesn't do what we came here for. Let's get on with designing the circuits that do what we really want.

Camera Power

I'm going to assume a DCC track voltage of 15 volts throughout this example. As you saw above, the DC power supply will put out about one volt less than the DCC input. I'm going to use 14.3 volts in my calculations. First, let's supply power to the camera.

In order to design this circuit, we need to know how much voltage and current the camera needs. Since it was designed to use a 9-volt battery, the quickest way to get this data is to connect it to one. The camera owner connected a conventional battery through an RRAmpmeter to the battery. He read 8.6 volts at 0.12 amps.

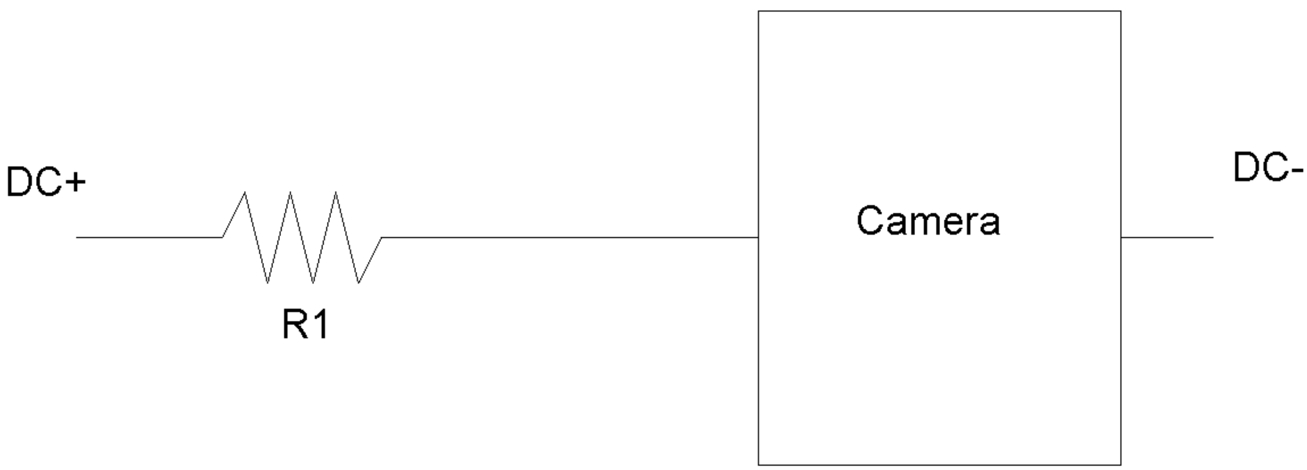
We'll use those numbers to figure out what value of resistor (R1) to use to connect the camera to our power supply. The purpose of this resistor is to drop the voltage down to what the camera wants when the camera is drawing its operating current.

First, we figure out how much voltage we need to drop across the resistor. The camera seems happy at 8.6 volts and the power supply will deliver 14.3 volts. Thus, the resistor needs to drop 5.7 volts (14.3 volts – 8.6 volts).

Ohm's law is R = E / I (Resistance in ohms = Volts / Amps). Let's plug in what we know: 5.7 volts and 0.12 amps.

$$R1 = E / I = 5.7 / 0.12 = 47.5 \text{ ohms}$$

You can't go to the store and buy a 47.5-ohm resistor. Resistors come in standard values and 47 ohms is the closest value. It will result in a slightly larger voltage for the camera, but well within normal design parameters.



6: Camera power supply circuit diagram

Resistors are also rated in watts (how much power they will dissipate). Let's see how much power (in watts) will be being put into the resistor.

Another formula is P = E x I (Power in watts = Volts x Amps). If we plug our numbers in, we get:

$$P = E \times I = 5.7 \times 0.12 = 0.684 \text{ watts}$$

Okay, if we put 0.684 watts into the resistor, it must be rated to handle at least that amount. A standard value larger than 0.684 is 1 watt.

Warning: this is quite a bit of power and the resistor will get warm – not hot. Make sure that it is located so that it won't touch plastic items: a shell or plastic tape.

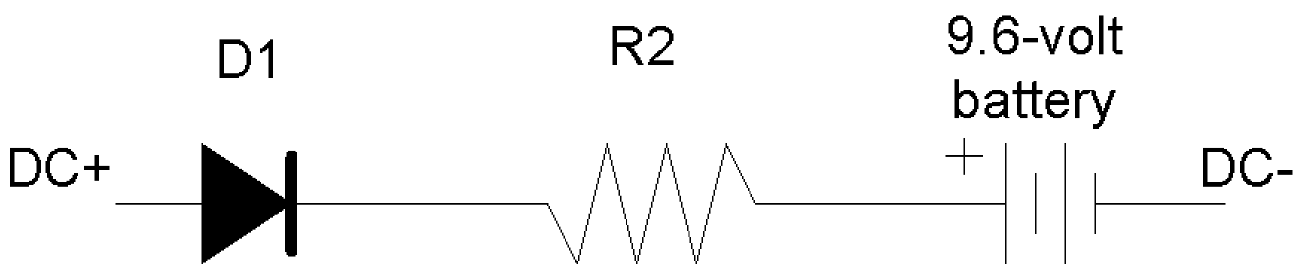
Next we need to build a battery charger.

Battery Charger

To safely charge the battery, we need to know how much voltage we must drop between the DC power supply and the battery and what current we can safely run through the battery for extended periods of time.

The camera owner selected a PowerEx 9.6 volt NiMh battery with a capacity rating of 230 mAH. This means that the battery will supply 9.6 volts when fully charged and will deliver 230 mA (0.23 Amps) for an hour. Thus, a fully charged battery will run the camera for almost two hours (0.23 / 0.12 = 1.92).

These sorts of batteries will accept a charge current of 0.1 C forever without damage. Okay, what's C? Not the speed of light, as in the theory of relativity. C stands for the **Capacity** of the battery. So, a 230-mAH battery will stand 23 mA (0.023 Amps) or less of charge current on an ongoing basis. So, we design the circuit to supply this current to the battery.



7: Battery charger circuit diagram

There is a diode between the DC power supply and the resistor connected to the battery. This is a check valve to keep the battery voltage from feeding back into the power supply. As I said before, this diode will drop 0.7 volts, so that reduces the voltage across the resistor.

Let's calculate the voltage across the resistor. The DC supply provides 14.3 volts. The battery charges to 9.6 volts and the diode will drop 0.7 volts. So, the voltage across the resistor when the battery is fully charged, but under load, will be:

14.3 volts – 0.7 volts – 9.6 volts = 4 volts

Now that we know the voltage and current, we can calculate the resistance and power:

R2 = E / I = 4 / 0.023 = 173 ohms

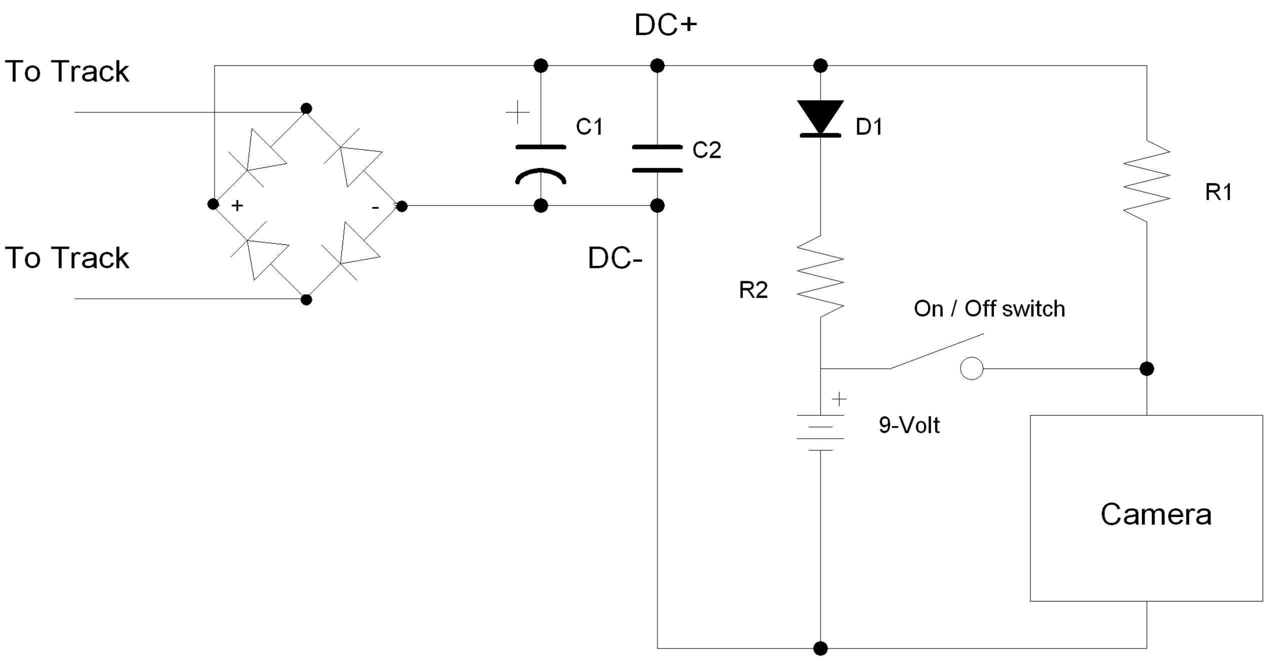
P = E x I = 4 x 0.023 = 0.1 watts

A standard resistor close to this is 180 ohms rated at least ⅛ watt (¼ watt is very common). The slightly larger resistor will reduce the on-going charge current, which is safer for the battery.

A very common diode for this circuit is the 1N4001, rated at 1 amp and 50 volts. The 1N400x series are all rated at 1 amp, with the last number increasing with higher voltage ratings. Thus, a higher rating, such as 1N4007 will work just fine.

Bringing it all together

Okay, we now have each module designed. We need a switch to disconnect the battery from the camera, to keep the camera from discharging the battery when no track voltage is present. Bringing this all together, we get the complete circuit diagram.



8: Complete circuit diagram

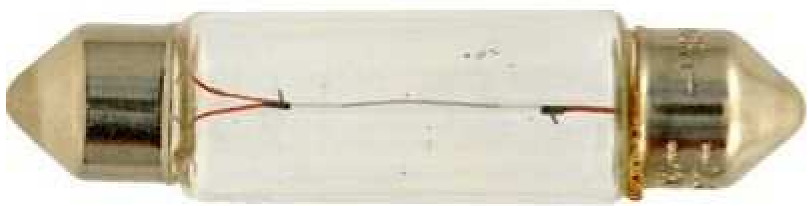
If you liked this column, please click on the Reader Feedback link here and rate it **awesome**. Please join in the conversation that invariably develops there about the topics presented in the column. Share your experiences. Thanks.

Until next month, I wish you green boards.

From Mr. DCC's workbench

Another DCC Tester

In a recent post, my friend Marcus Aumann talked about using a dome light bulb for HO track testing. It is designed for 13.8 volt auto systems and the contacts are just perfect to pick up HO (or On30) track (9).



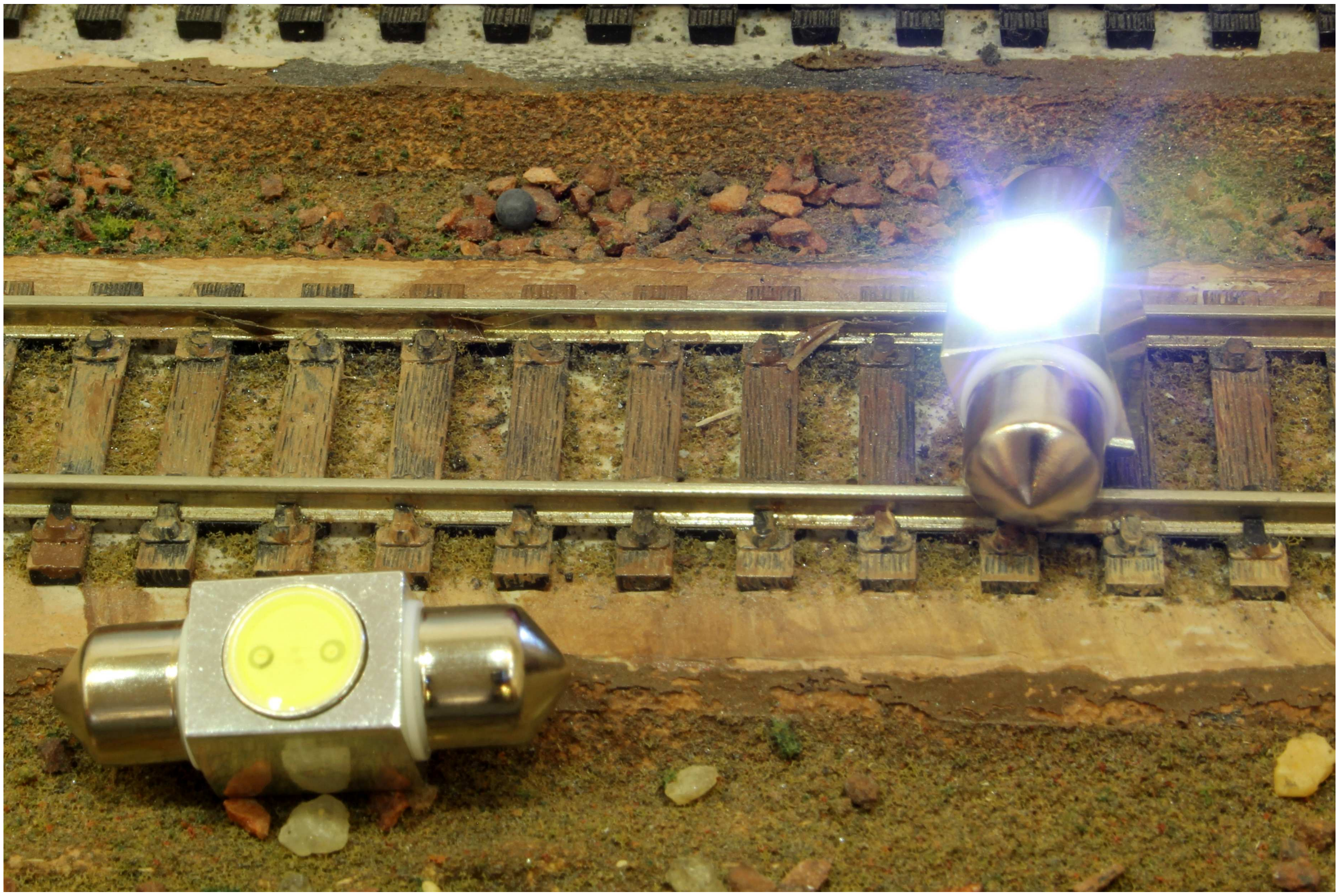
9: Dome light bulb

I thought about this for a bit. I see good and bad things with this approach.

It draws about one amp, which can be good or bad, depending upon what sort of testing you are doing. If you are looking to verify voltage on the rails, it is a bit much. If you are looking to see that the system can handle the load of a locomotive, it is beneficial.

The current it draws makes it get hot quickly: burned fingers.

So, looked online and found the LED replacement bulbs. They don't draw a lot of current, but stay cool. They are intrinsically more rugged than a filament bulb. And, I found a package of 10 on eBay for $9.99 with free postage.



10: LED dome light testing HO track plus one off track for comparison

Anybody want to buy a few LED bulbs? I have about 8 more than I'll probably ever use!