Model Railroad Hobbyist |

DCC IMPULSES
column

BRUCE PETRARCA MMR

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The truth about capacitors in DCC

I wrote about basic electronics in my December 2012 column. There I discussed capacitors briefly. Recent traffic on the web shows that it may be time for more in-depth information about these pesky little devices.

What is a capacitor?

A capacitor [1] is basically a pair of conductive plates separated by an insulator. As such, it can couple varying voltages (AC) from one lead to the other while blocking constant (DC) voltages. It can also store energy in the form of an electrical field.

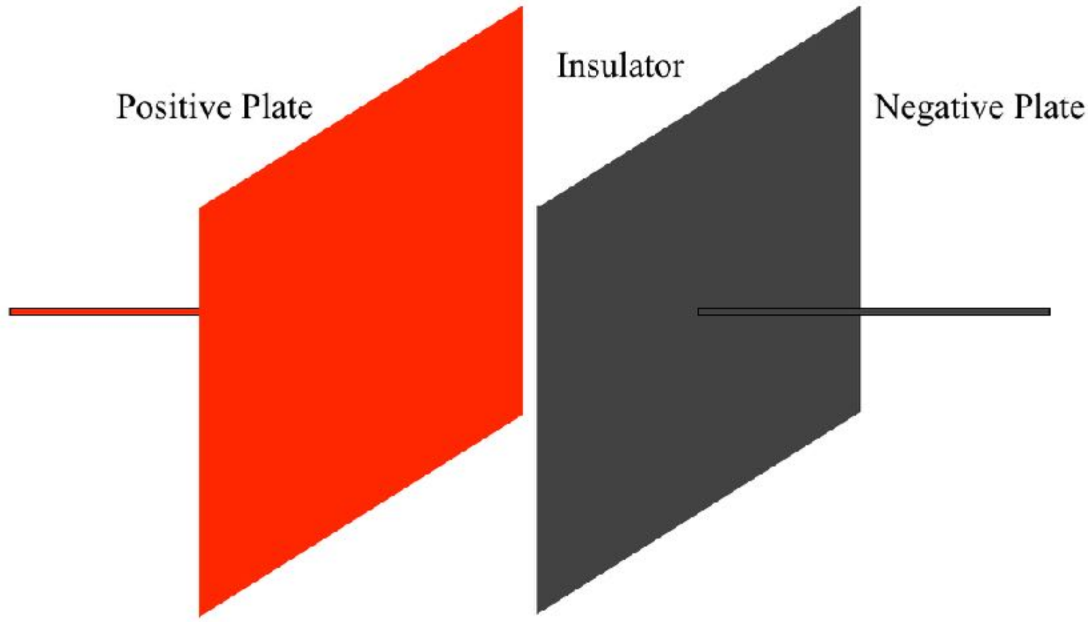
The insulator may be one of many things, such as air, ceramic, polypropylene, mica, or an electrolytic solution in a semi-liquid form. Capacitors are most frequently classified by their insulating medium.

Capacitors are rated with two important numbers: capacitance and working voltage. Capacitance is measured in farads (F) or fractions of a farad, frequently microfarads (a millionth of a farad, abbreviated µF or uF or MFD).

Most capacitors are not polarized, meaning that it doesn't matter which way you hook them up. That said, electrolytic and super-caps are polarity sensitive and if you hook them up incorrectly they may leak nasty fluid or explode.

For safety, it is best that the capacitor be rated for 150% or more of the maximum expected voltage, including spikes or transients. A capacitor with a higher voltage rating than specified or calculated will work just fine; it just will take up more room and possibly cost a bit more.

1. A capacitor is basically two plates separated by an insulator.
Bruce Petrarca diagram

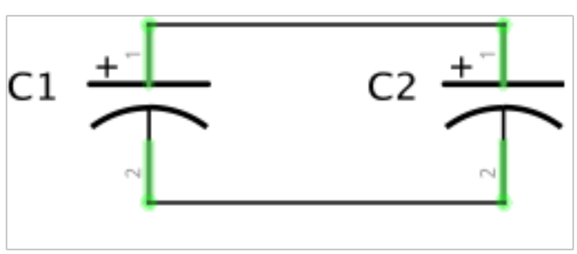


Do not remove the wrapping found on polarized capacitors, such as electrolytic or super-caps. The case is frequently the negative plate of the capacitor and is actively connected to the circuit. Removing the wrapping may lead to a short within your loco.

What do I get if I connect two or more capacitors together?

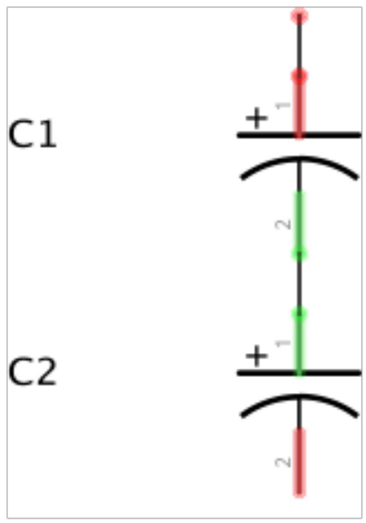
If you connect them in parallel [2], the capacitance will be the sum of all of the capacitors and the voltage rating of the group will be that of the lowest capacitor connected.

2. Parallel connected capacitors. ***Bruce Petrarca diagram***



If you connect them in series [3], the voltage rating will be the sum of the voltage ratings and the capacitance will be reduced. There is a complicated formula to calculate the resulting capacitance. However, if all connected capacitors have the same value, the result is simplified: with two connected, ½ the capacitance; three are ⅓, etc.

3. Series connected capacitors. ***Bruce Petrarca diagram***



Okay. Let's look at some model railroading applications for capacitors and how they affect folks who are working with DCC.

Energy storage

Energy storage capacitors allow your loco to run, or the microprocessor in the decoder to keep thinking when the power drops out, such as due to dead rails, dead frogs, or dirt or discontinuities.

They frequently have been polarized electrolytic units [4]; 100 to 10,000 µF; frequently rated 25 (indoor) or 35 volts (garden) for DCC applications.

In smaller scales, some folks are willing to work with surface mount capacitors [5] in order to make things fit in the available space or spaces. I recommend 20 volt capacitors as the minimum to use with DCC. While this technically violates the NMRA standards for DCC (track voltage as high as 22 volts), most folks in the smaller scales limit their track voltage to 16 volts or less. Thus, there is still a slim safety margin but less than the 150% I mentioned earlier.

4. Electrolytic capacitors are polarized, requiring attention to detail when connecting them. This radial lead design designates the negative lead by the stripe. ***digikey.com photo of their part number 1189-1733-ND, used by permission***

5. Surface Mount Device (SMD) 100 µF 20 volt electrolytic capacitor. The negative lead is indicated by the band on the upper left side in this photo. ***Bruce Petrarca photo***

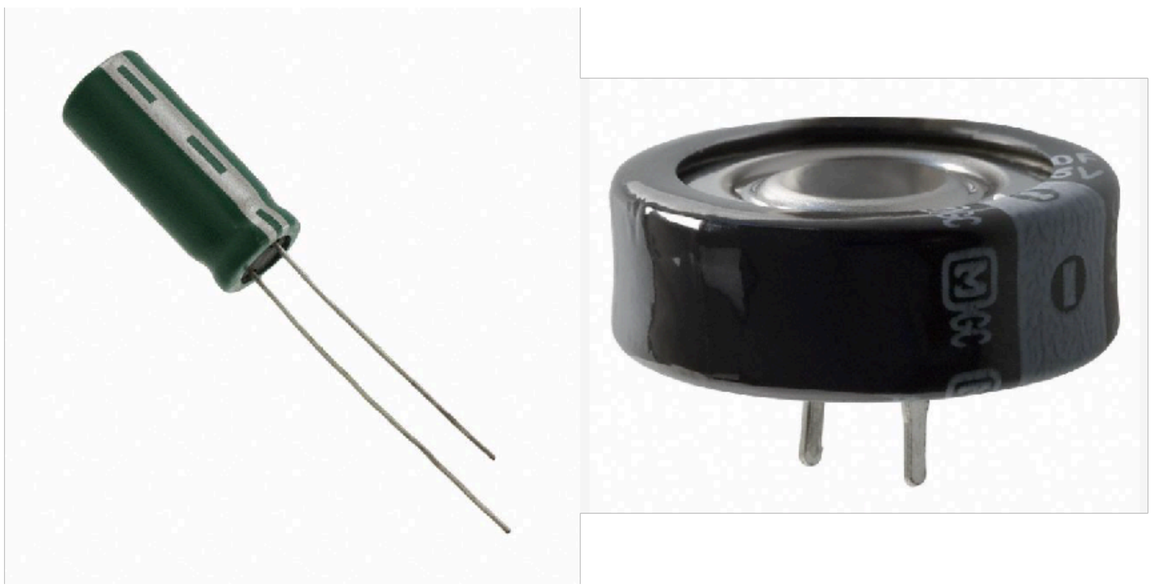
Be sure to insulate the contacts to avoid shorting out the power supply of your decoder. Heat-shrink tubing, Kapton tape or even the liquid electrical tape products will do.

Decoder manufacturers (and some hobbyists) build modules out of super capacitors to store more charge than is possible using electrolytic units. Three 1-farad 5.5 volt capacitors in series will be about 330,000 µF (1,000,000 µF / 3). Remember, the voltage ratings add, so the resultant stack will have a voltage rating of 16.5 (5.5 x 3) volts. This is a bit low to connect directly to a DCC decoder, which is why I recommend additional protection.

There are two versions of a super-cap.

One is designed to keep memory chips functional during power outages. They have what is called a high Internal Resistance (IR), as in tens of ohms. This is similar to the Equivalent Series Resistance (ESR). But IR is measured at DC and ESR is measured with AC, frequently 1 kHz. This means that they are not able to deliver more than a few mA of current, barely enough to keep a microprocessor functioning and certainly not enough to run a motor. Low IR units are frequently "coin" units, such as shown on the right in figure [6]. They are usually less expensive than low IR units.

6. Super capacitors have very large storage capabilities but are very limited in the voltage that they can withstand. The negative lead is indicated by the stripe. Most model railroading uses will need a low IR unit; see text. The unit on the left is a low IR model. The "coin" versions as shown on the right tend to be high IR units and, therefore, not usable for model railroading purposes.
digikey.com photos combined by Bruce Petrarca, used with permission



To make an energy storage module for model railroading, one will need super-caps that have an IR less than ½ Ω (500 milliohms); the lower the better. These caps may not be available through eBay, surplus stores or other low-cost retailers. I recommend Mouser (mouser.com) or Digi-Key (digikey.com), at least as a starting point.

Absent a specification for IR, the ESR number will give you an idea of the capabilities of the capacitor. For example a unit with an ESR of 70 Ω is unlikely to have an IR under ½ Ω.

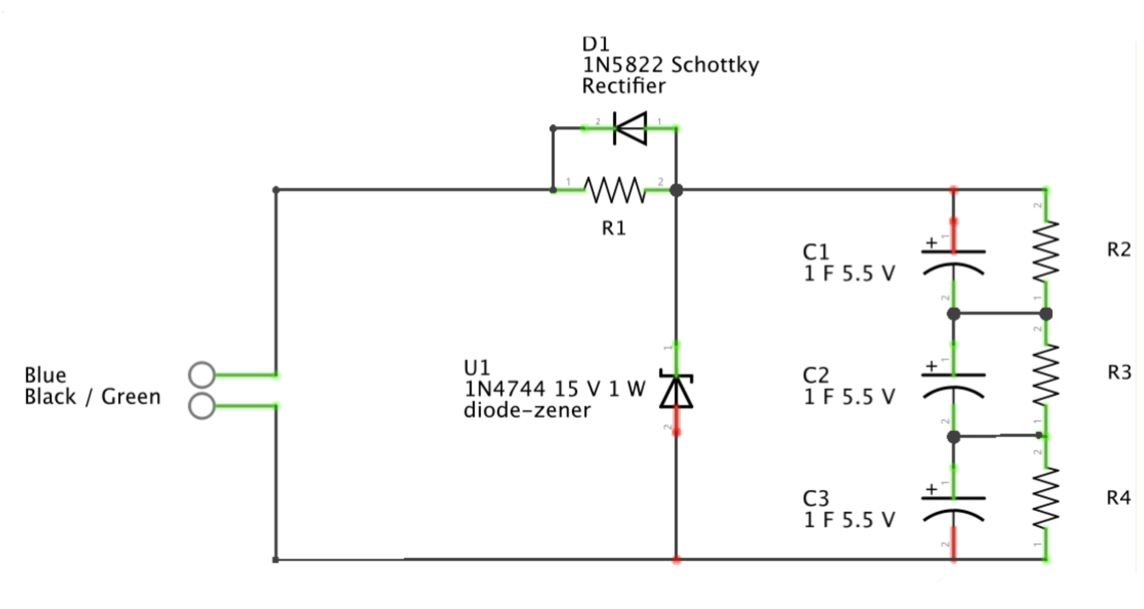
Since the lowest cost versions usually do not have the low IR needed to keep a motor running, I recommend you inquire or test before you purchase large quantities of a super-cap to roll your own energy storage modules. Also, don't blindly accept a different part number than the one you selected. I recommend negotiating a return clause before you purchase large quantities.

If you are building your own module, find a safe circuit to follow. I've drawn up a circuit [7] that I believe includes all these elements. Use this as a starting point for your own design.

Safety to me includes a small resistor (called R1 in [7]) series connected with the stack of capacitors and a 15-volt zener diode across the entire stack. This keeps the applied voltage from exceeding the rating of the capacitors. Also, I recommend a large value resistor (R2 to R4 in [7]) in parallel with each capacitor, distributing the applied voltage evenly across all capacitors. A discharge diode (regular or Schottky) in series with the small resistor (R1) will bypass the resistor when the module is supplying power to the decoder.

While my circuit is based on 5.5 volt capacitors, there are lower voltage super-caps available, down to 2.5 volts. I recommend enough in series to get the total voltage rating at or above 16.5 volts. Remember, the more you put in series, the more the IR will add up.

7. A generic circuit diagram of what I consider a safe design for a home-made energy storage module. I haven't calculated values for the components nor tested such a circuit. That's why it is incomplete. *Bruce Petrarca diagram*



I haven't built or tested any of these circuits, so I cannot thoroughly recommend them. Unless someone is needing lots of these modules, I find that purchasing them is a better route than purchasing the components to build them. Also, if the circuit diagram or any of the terms in the last few paragraphs aren't easily understood by you, I recommend you leave the fabrication of these modules to the professionals.

DCC manufacturers label these devices with their own monikers: Keep-Alive, CurrentKeeper, Power Xtender, or No Halt, for example.

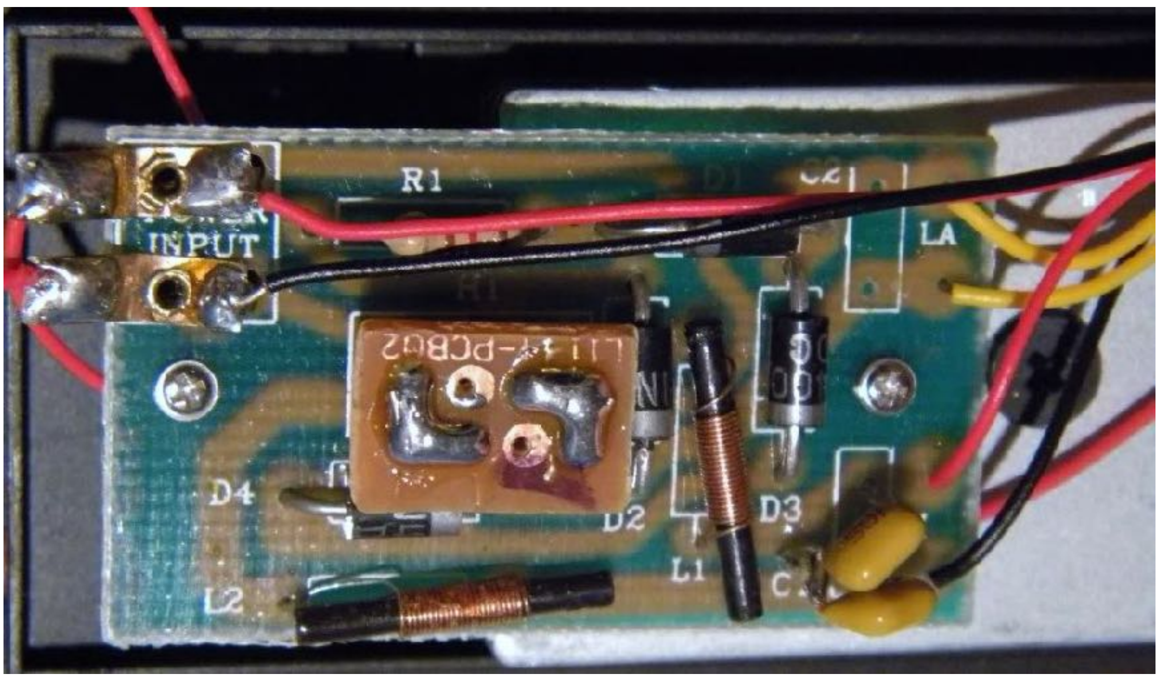
Noise suppression

There are two cases where ceramic capacitors [8] enter into the realm of DCC installations. In both case they are suppressing noise.

8. Ceramic capacitors have capacities up to about 1 μF (1 micro-Farad). They are frequently used in model railroading to remove noise or RF interference (RFI). This unit is rated 0.1 μF at 50 volts. *Bruce Petrarca photo*

The boards [9] in early Bachmann DCC-ready locos (mostly HO) are designed to keep the motor noise away from the track when the loco is run without a decoder. Two coils of wire wrapped on small ferrite rods (inductors) plus a ceramic capacitor or two help these locos meet the requirements for minimal Radio Frequency Interference (RFI) when a decoder is not installed.

9. Early Bachmann board showing the (yellow) capacitors for RFI reduction in the lower right. These capacitors can confuse decoders which use Back EMF (BEMF) to control the motion of the locos. When a decoder is installed, using the 8-pin plug in the middle of the board, the ceramic capacitors can be safely cut off the board. Or, the entire circuit board can be removed and the decoder wired directly to the rails, motor and lights.



For the most reliable DCC operation, the capacitors should be removed from the circuit when a DCC decoder is installed. This can be accomplished by removing the Bachmann board entirely or by cutting the capacitors off the board when plugging a decoder in.

Speaker isolation

In some decoder designs, a capacitor is used to couple the sound to the speaker from an amplifier. Many early sound decoders (SoundTraxx DSD and DSX series, for example) had this component external to the decoder for flexibility of installation.

SoundTraxx supplied non-polarized electrolytic capacitors rated at 33 µF and 16 volts with their decoders. This special style of electrolytic capacitor doesn’t care which way it is connected. They are larger and more expensive than a polarized electrolytic capacitor with the same ratings. This type of capacitor looks [11] just like an electrolytic, except there is no band indicating the negative lead.

11. A non-polarized version of an electrolytic capacitor will be needed to decouple the amplifier in the decoder from the speaker in early SoundTraxx decoders. Note: there are no polarity-defining markings. ***digikey.com* *photo, used with permission***

This capacitor is connected between the decoder and the speaker. It protects the circuitry and the speaker by keeping the DC voltage that exists on the speaker output from connecting through to the speaker. The design of the amplifier in these decoders limits the DC voltage on the speaker terminals to half of the power supply (track) voltage. Thus the 16-volt rating will maintain the 150% safety margin with track settings up to about 22 volts.

Newer amplifier designs either don't need this capacitor or it is built into the board. I included this short explanation of this older technology for legacy sake.

Hopefully these tips and comments will give you some more insight into these multi-faceted electronic components. Please share your ideas with us all. Just click on the Reader Feedback icon at the beginning or the end of the column. While you are there, I encourage you to rate the column. "Awesome" is always appreciated. Thanks.

Until next month, I wish you green boards in all your endeavors.

