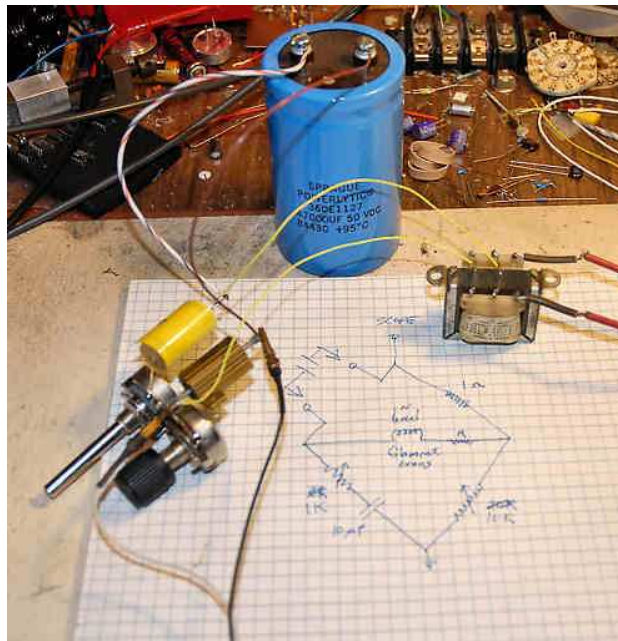


## Build a Basic Capacitance Bridge

There are various ways to measure capacitance and many plans for digital capacitance meters on the net. Those circuits fill the need to confirm value, but they usually lack the ability to measure dissipation factor (DF). Measuring DF is critical in determining the health of electrolytics and also for choosing the best cap for a given application. Oddly, there is very little information on building what I believe is the best tool for the job- the traditional bridge circuit.

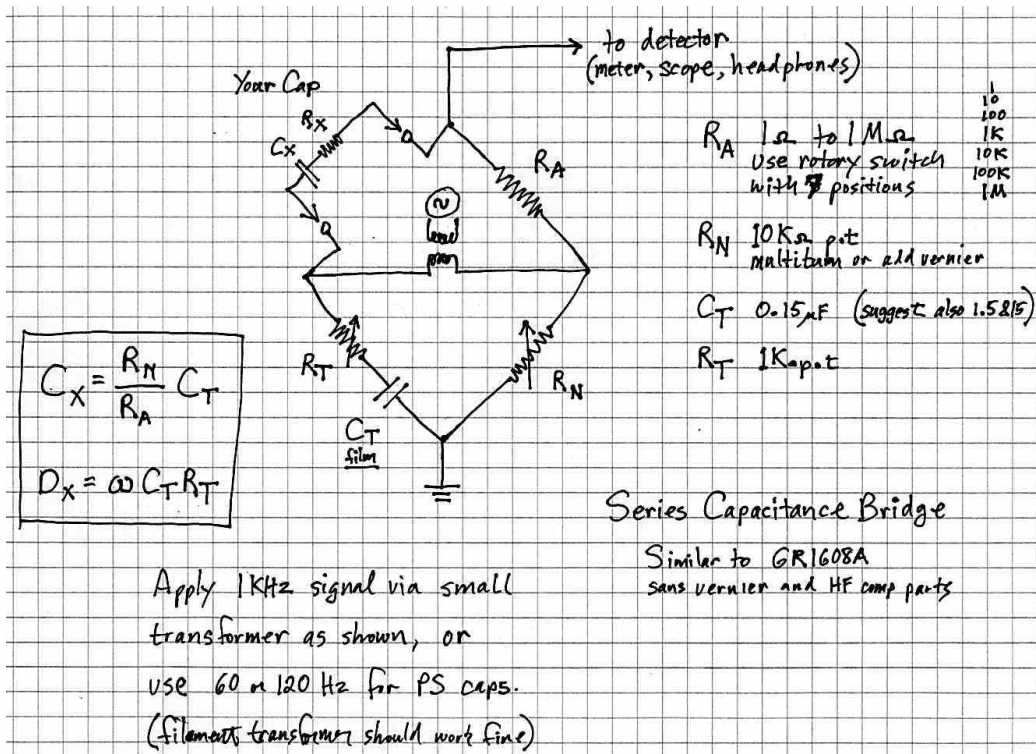
Bridges are extremely simple, having just a few passive parts. You'll also need a signal source which can be as easy as a filament transformer, and some way to see the level of the output signal like a DVM or oscilloscope.

Since I don't know what's in your junk box I can't predict what the final product will look like. If you're in a hurry to measure something, you might just tack together a couple pots, resistor and a capacitor, and have at it. Here a large electrolytic is being tested using the tack-it-together-on-the-bench method:



Crude as it appears here, the bridge technique is extremely accurate. The classic General Radio Corp. bridges like the ubiquitous GR 1650-B portable bridge were good to 1%. They used a large diameter pot with adjustable linearity and a large dial. The larger bench top GR 1608-A was good to 0.1%. It used a similar arrangement, but with a more complex divider so the entire burden of accuracy wasn't on the pot. It's just a matter of how well you can read the resistance, and the accuracy of your small reference film capacitor. Most good DVMs today will read resistance to about 0.1%, and 1% film caps are commonly and cheaply available. Electrolytics don't have close tolerances, so sub-percent accuracy in the bridge isn't really necessary, though it's achievable if you want it. Even if the absolute accuracy isn't sub-percent, you can easily match parts to far better than that, say for audio applications.

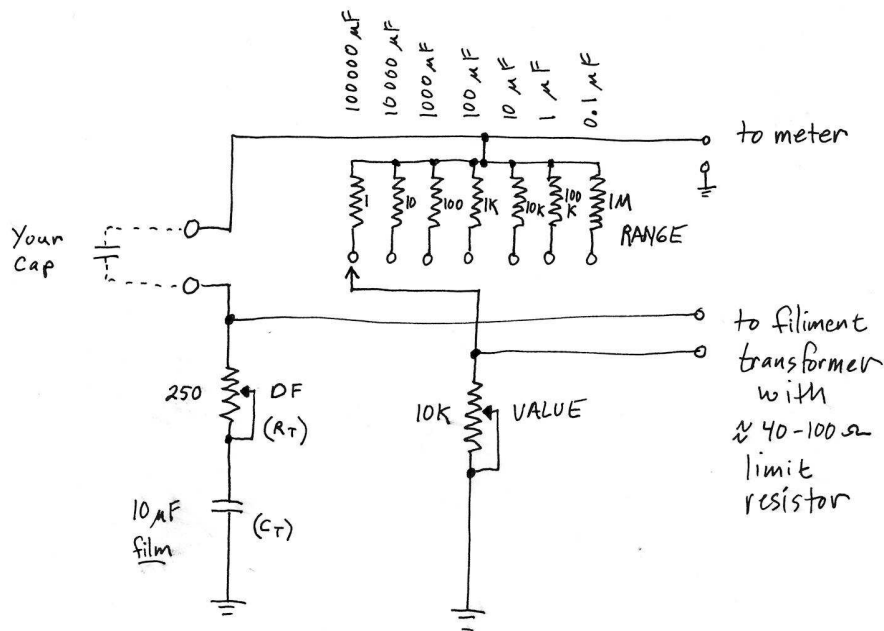
For reference, here's one of the 1608 circuits with slightly different pot values:



The signal source will usually be a low frequency for large capacitors, lest the resistor values be impractical. A 6.3 vac filament transformer is ideal. They usually have good frequency response, so you can also apply a higher frequency from a signal generator if desired. In either case, the transformer is necessary if you want to use a ground referenced detector (meter or scope) as shown above.

The reference capacitor ( $C_t$ ) in the GR 1608-A is 0.15uF. That was chosen so practical values of resistors would cover the ranges they were interested in, but the maximum it could measure was 1100 uF, not all that large. The GR 1617 was of similar design, but could measure far higher due to using 0.1 and 0.01 ohm resistors in its divider. We can avoid stray resistance and accuracy problems by increasing the value of the reference cap and using higher value resistors

Here's a slightly different circuit, with the switching shown and values optimized for testing larger value caps:



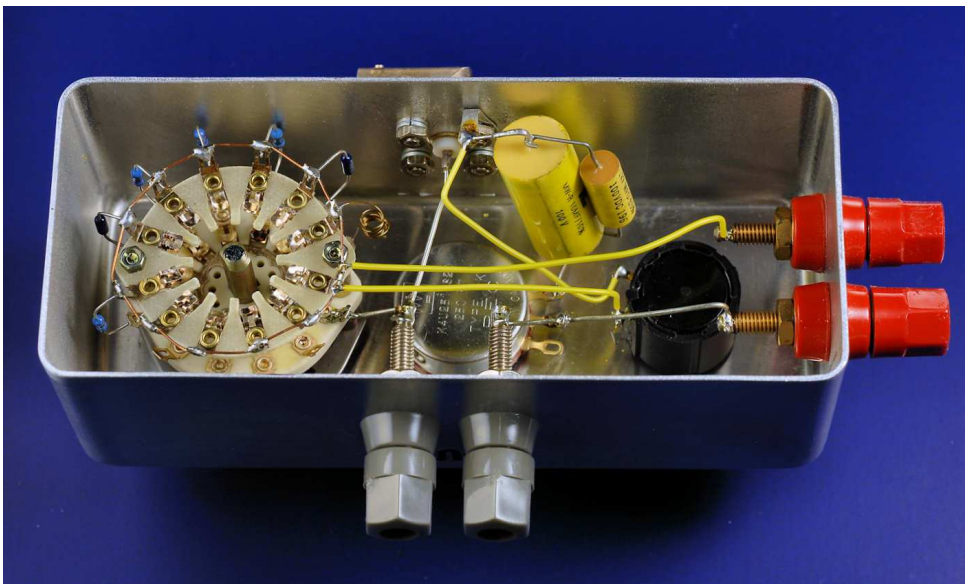
$$DF = 2 * \pi * F * C_T * R_T \quad C = \frac{VALUE}{RANGE} * C_T$$

You could use another switch and have two or more reference caps if you wanted to measure both tiny and mammoth caps, though you'd need two scales on the dissipation factor dial. Remember that the formulas are in farads and ohms. If this is just a quick measurement project, it's sufficient to measure the settings of the pots with your DVM. If you want to make a well-presented instrument, you'll need to make a dial or possibly use a multi turn pot with a commercial dial. If you make your own dial, it can be marked out in capacitance times the setting of the range switch. Be sure to include a current limiting resistor (not shown) in one lead of the filament transformer. This will protect the lower values of the range resistors which would otherwise see the full transformer voltage—remember, the cap under test will look like a short circuit at 60 hz so the 6.3 vac could appear across the 1 ohm range resistor.  $P = V^2/R$ , so that would be close to 40 watts! Thus, a 40 ohm 1 watt limit resistor is necessary.

Here's the above circuit stuffed into a small aluminum box:



And the inside:



I elected not to include the transformer and limit resistor in the box to give me more flexibility in what I use. The red terminals are the signal input, which *must* be floating. The gray terminals are the capacitor to be tested and the BNC is the output to the meter.

### So, how do you use this thing?

1. Apply an isolated signal (use the filament transformer) of about 6.3 vac at 60 hz to the input terminals.
2. Attach the device-under-test (DUT) to the test terminals.
3. Set the range switch to your best guess on the value.
4. Set the DF control a bit off zero.
5. Look at the signal output with a scope or a sensitive ac meter. Some old bridges even used headphones, but they were higher impedance back then.
6. Adjust the capacitance knob for the *minimum* signal.
7. Adjust the DF knob for the *minimum* signal.
8. Go back and forth a few times- you should get a sharp null where there is little question of what the knob settings should be. Keep increasing the scope or meter sensitivity- the detectors used with commercial bridges have high gain.
9. If the unit isn't calibrated yet, disconnect everything and measure the resistance of the two pots with your DVM.
10. Apply the formulas to get the capacitance and DF.

Once you've done this a couple times it becomes second nature and you'll be able to quickly balance any bridge. Using the DVM and formulas, you can mark a dial so it reads out directly.

### Hints & Notes

1. If the capacitor is completely unknown it can be a bit tedious to find the correct range and settings. Try to start with a good guess based on size or application.
2. Large value caps can be hard to balance in the form of "sliding balance". It may be necessary to make a small random offset of C or DF, and then adjust the other control for minimum signal. Repeat until a pattern is found that moves you towards the desired deep null.
3. If the capacitor is really bad, the capacitance may actually read high but the DF will also be high or even off scale. High DF is bad!
4. Download my "Handy Formulas" for many more conversions, or my impedance conversion utility, both at <http://www.conradhoffman.com>
5. If you get the idea to use a Variac with this, DON'T. A Variac isn't isolated. The circuit will be destroyed and you could be electrocuted. Signals must be low voltage, current limited and fully transformer isolated. It is ok to use a Variac on the line side of the filament transformer to reduce the voltage if desired.
6. If you ac couple the detector, it's possible to measure electrolytic capacitors under their full operating bias. That's beyond the scope of this brief write-up, but if it's of interest, email me at [choffman@conradhoffman.com](mailto:choffman@conradhoffman.com)

Enjoy,  
C. Hoffman  
4/13/09