Testing Capacitors:

How to Measure Capacitor Leakage Current

How do you test power supply and coupling capacitors?

Back to Eric's DIY Theater Projects

SAFETY FIRST! General advice for old, tube radios:

So, you find yourself the proud new owner of some not-quite-so-new tube radio or amplifier and you have made the choice to try to bring it back to life. **NEVER!** plug in an old tube radio or amplifier that you found in the garage/attic/flea market/wherever without first performing a careful and thorough electrical inspection (details below). Many people want to plug it in "just to see if it works" or "just to try things out." NO, NO, NO! This is a **MONUMENTALLY BAD IDEA!**

DO NOT PLUG IT IN! This is the single worst thing in the world to do with antique electronics! If you are lucky (and few of us truly are), all it will do is hummmmmmm. If you are not lucky (yes, this probably means you), a rush of electricity after decades of sitting around and deteriorating is likely to kill old capacitors, creating cascading failures that can blow a rectifier tube, destroy other downstream components, or start a fire... A shorted rectifier can permanently destroy an irreplaceable vintage power transformer or power supply inductors. A typical power transformer for a tube radio produces about 700 Volts! Dried, cracked, and missing insulation from old wires can come into contact with the metal chassis and can electrocute you!

The BEST practice for dealing with old tube radios is to **CUT OFF THE POWER CORD** right away! First, it probably needs to be replaced anyhow, and second, this keeps anyone else from plugging it in until you've been able perform a thorough inspection.

Safety Protocol for YOU:

First, there is a protocol to follow for testing tube radios/amps that needs to be followed BEFORE you plug the power cord into the wall. Failure to follow protocol risks destroying old equipment, starting a fire, or killing yourself. A tube radio power supply harbors LETHAL voltages, often in the range of 200-400v. This voltage can be present EVEN WHEN THE POWER CORD IS UNPLUGGED. This voltage CAN KILL YOU. There are a few basic safety rules that apply here:

1) REMOVE ALL jewelry. ALL of it! NO rings, NO necklaces, NO bracelets, NO danglies, NO nothing that will accidentally conduct electricity!

2) UNPLUG THE DEVICE AND DISCHARGE ALL CAPACITORS. This is typically achieved by using a specially made (by you) insulated wire with insulated alligator clips at either end and a 10k-100k power resistor rated at 1 to 3 watts in the middle. USING ONE HAND ONLY, clip one end of the wire to one side of the capacitor. Using that SAME HAND again, clip the other end of the wire to the other side of the capacitor. Let it sit there for a few seconds and then move on to the next cap. Do this for EVERY cap in the device. Use ONE HAND ONLY! Keep the other hand behind your back AT ALL TIMES. Exposing yourself to high voltage that spans both hands (and your HEART in the middle) is just asking for an ambulance ride! Tube amp power supplies make excellent defibrillators. A properly beating heart does not respond well to being defibrillated! You've been warned... Also, you'll find many people online just say "short the cap with a screwdriver." NEVER DO THIS! This is potentially damaging to the screwdriver, to the equipment you are testing, AND TO YOU. Depending on voltage and capacitance levels involved, you are potentially dealing with an arc welder. This much power can literally blow off the tip of your screwdriver. If this flying chunk of screwdriver tip hits you or someone else in the eye, you have a major problem. DON'T BE DUMB!

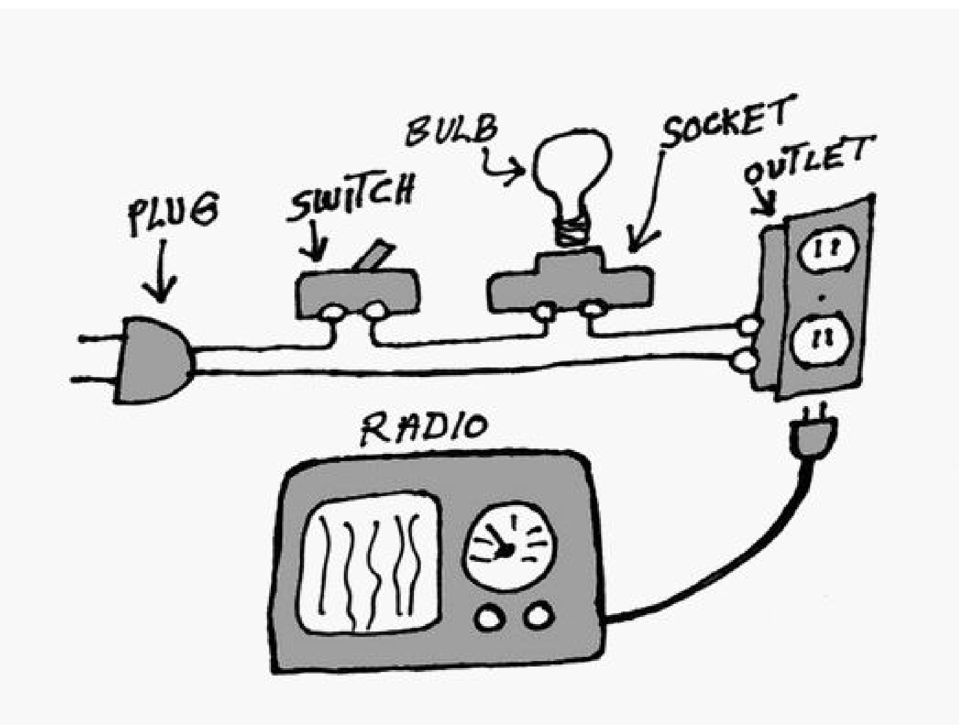
Safety Protocol for your RADIO:

DO NOT PLUG IN YOUR RADIO! No matter how tempted you are to "try things out" or "see if it still works" or whatever else, DON'T DO IT! You need to carefully and methodically inspect your tube gear FIRST so that you prevent doing even more damage than time alone has caused. Here is my short protocol for things you want to inspect first. A much more detailed and thorough protocol can be found here: [Trouble Shooting Antique Equipment](#).

1) You will need to remove the metal chassis that contains the electronics from its wooden cabinet so you have access to the electronics. Once the chassis is freed, take lots of pictures - up close, in focus, well lit pictures from different angles. Photograph each tube and each connector. Make notes on how things are wired and connected to each other. Note colors of wires, positions of wires. Label all of the tubes with masking tape BEFORE you remove them. Draw a diagram of the chassis and label where each tube goes. Now remove the tubes, get yourself a old bath towel and lay it down on the table. Turn the chassis upside down on the towel and take lots of pictures of the underside before you touch/disturb anything. Use good lighting, make close up images that show details of where wires travel and what they connect to. Only then should you begin to poke further into the chassis. Your notes and images will become an invaluable resource when you start removing and replacing things. If you have an air compressor, this might be an excellent time to use it to clear out some of the old dust/dirt/debris. As always, use a bit of care not to dislodge weak/brittle wires or other structures. It might be best to blow some air across the chassis before your compressor hits maximum pressure to aviod unintended damage. 100 PSI is NOT your friend in this situation...

2) Inspect the power transformer with your ohm meter. Check the primary for resistance - justs measure across the prongs on the AC plug (make sure the radio is switched 'on'). It should measure somewhere in the 1-10 ohm range and not be open (mega-ohms of resistance). Check each of the secondaries for resistance. They, too, should not be open, nor should they be a dead short. These will typically measure tens, hundreds, or thousands of ohms. Check to make sure multiple secondaries are still isolated from one another. You should find mega-ohms of resistance (or infinite resistance) between secondary windings. If these measurements check out, your transformer should be good.

Alternatively, you can use a dim-bulb tester to check the health of your power transformer. It is important to use a regular TUNGSTEN filament bulb - no CFLs or LEDs! Tungsten has a large PTC – positive temperature coefficient of resistance, so the voltage dropped across the light bulb falls off rapidly as the current through it drops. For a small tube radio, start with a 60-100w bulb. A 60w bulb will limit the current to 0.5A (60w divided by 120v). For a radio with more than 6-7 tubes in it, use a 100w bulb. A properly functioning radio/amp will make the bulb glow somewhat brightly at first as the power supply transformer in energized and the capacitors charge and then should diminish to a dull red to orange glow. A short circuit in your radio will only make the bulb shine at full brillance -but with no burning insulation or metal melting arcs in your radio!

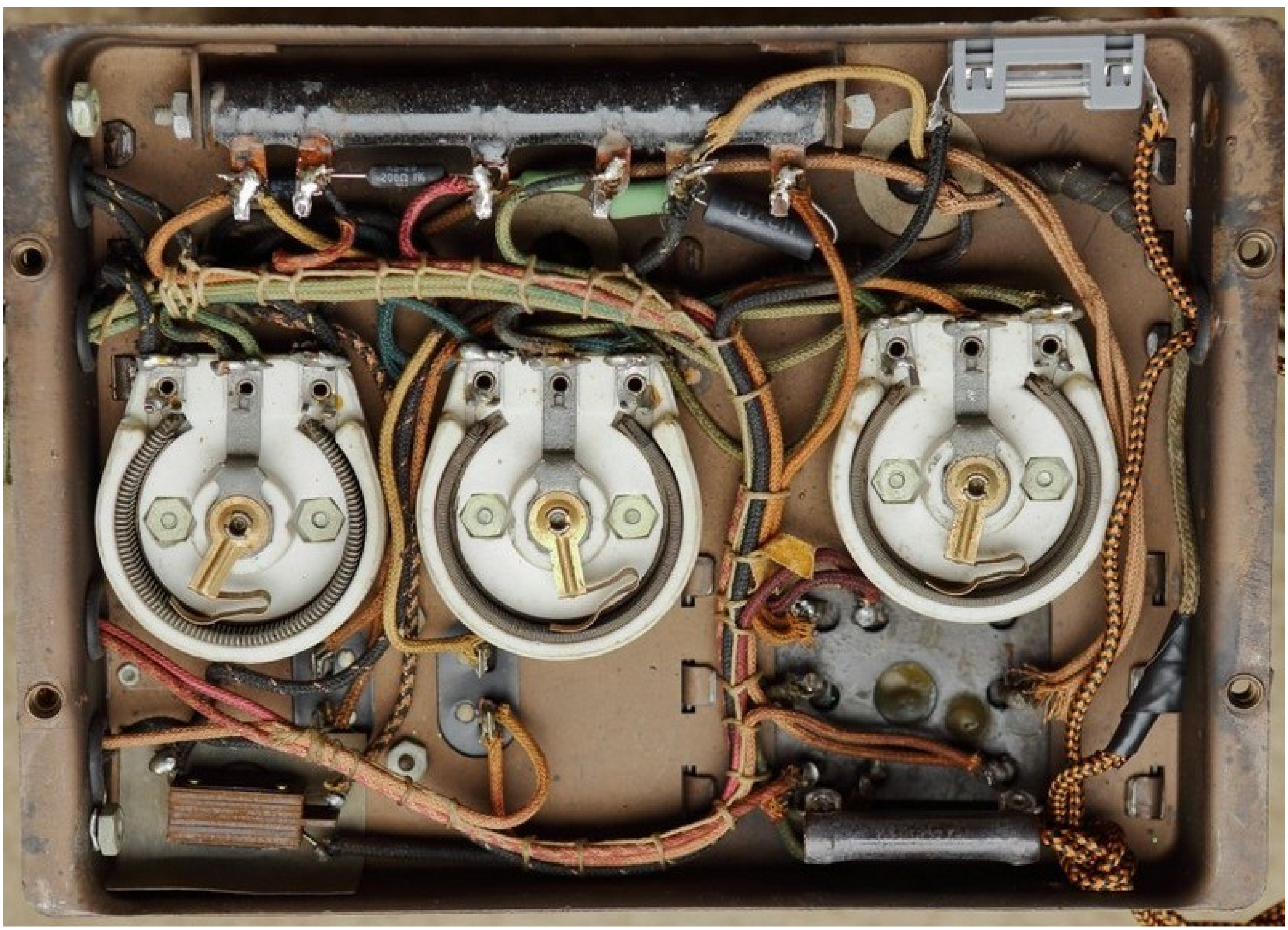


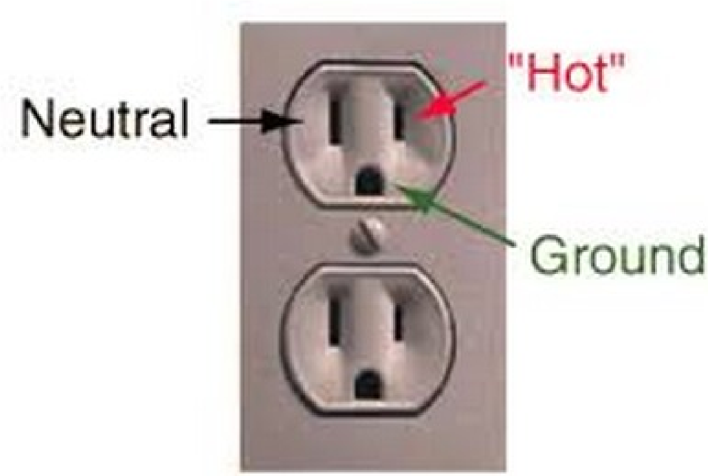
This protocol comes from Leigh from the [AntiqueRadios forum](#):

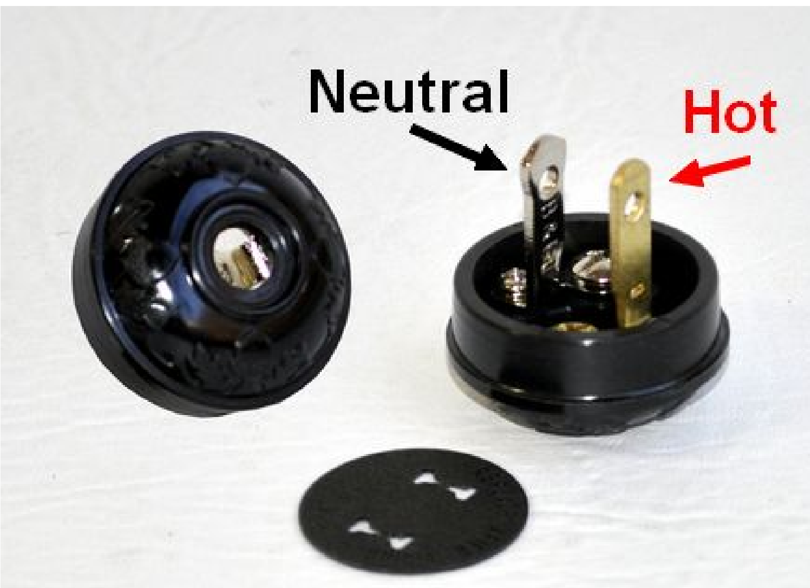
One test would be to remove all tubes, then power up with your [dim bulb tester](#). Searching the web for "dim bulb tester" will reveal many examples. They all work the same way - a light bulb is placed in series with your radio to protect the radio's transformer from a shorted condition. The bulb might come up very briefly but should settle down to dark or almost dark. If it shows any significant brightness you have a shorted transformer or circuitry connected to the transformer. At that point you would need to disconnect all secondary wires, then try again. If the bulb still comes on, the transformer is bad. If not, trace the loose secondary wires to find the problem.

If everything looks good at this point, re-install all tubes except the rectifier. Bring it up again on the dim bulb bester. The bulb will light, hopefully not too bright. You should be able to measure less than about 5-6v AC at the heater (larger diameter) pins for the rectifier and several hundred volts AC across the two remaining (smaller diameter) pins. Measure the voltage at the transformer primary. Calculate the percentage (for example: 60v measured / 120v = 50%). Apply that factor to your nominal filament voltages. Then measure those filament voltages. If any are not close to your calculated value, that points to a possible problem.

3) This is probably a good time to make your first modification to your old piece of gear: add a polarized AC plug and add a safety fuse. Old AC power cords have plugs with two blades that are the same size so you can plug it into the AC wall outlet either way. This is a bit dangerous with old gear, so replacing the plug with a new polarized plug is a good first step. Then, follow the power cord back into the chassis and add a fuse to the "hot" wire. Do this somewhere AFTER the cord strain relief (where the cord physically enters the chassis) and BEFORE the power line hits the power switch and transformer. The power flow sequence should be: AC power cord, fuse, switch, transformer. You can use any type of fuse holder here, depending on how "original" you want to keep things looking under the hood. The image below shows a grey fuse holder that I attached to the chassis in the top right hand corner of the power supply for my Radiola-17. The power cord is new and enters from the bottom right of the image. I made a knot in the cord just inside the hole it travels through to keep the cord from getting pulled and coming lose. Then, I cut the "hot" wire and added a safety fuse. Typically, a 1A slow-blow fuse will be fine. When in doubt, start with a smaller fuse first, say 0.5A. I would not recommend going above a 1A fuse unless you have a rather large radio. Refer to the metal plate that is usually riveted to the chassis for the actual power consumption of your radio.







When attaching a new power cord to your new outlet plug, the ends of the wire need to be tied with and "Underwriter's Knot" to prevent strain on the cord from pulling the wires loose from the screw terminals on the blades of the plug.

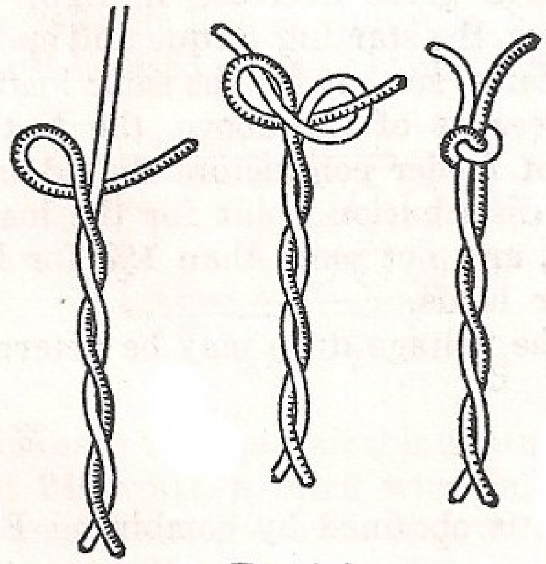
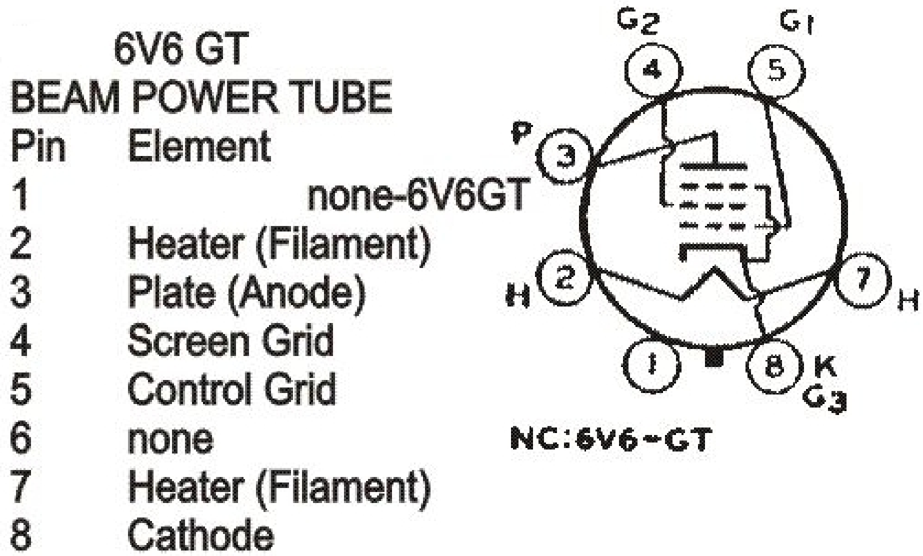


FIG. 3-5

Underwriter's Knot.—The portion of a cord extending within a socket, plug, or fitting should be installed so that any stress imposed on it will not be transmitted to joints or binding screws. This condition is fulfilled by tying an underwriter's knot at the end of the cord, as shown in Fig. 3-5. Such a knot can stand considerable stress without injury to the insulation.

4) Check each of the tubes for resistance. Identify what type of tube you have, the numbers are usually stamped in silver on the glass envelope, either on the top or the side. You might need to wipe the tube with a damp paper towel to remove the dust and grime before you can read anything stamped on the outside. Sometimes you need to hold the tube at an angle to reflect the light from a lamp. Look here at [Frank's Electron Tube Database]() or Goolge the tube number and find a data sheet for it. This will help you identify the pins and their function. Start with the heater/filament pins - these are typially the pins that are connected to one another in the tube diagram. With a four-pin tube, the heater pins are typically the fatter two pins. In the tube pinout diagram below, pins 2 and 7 are the heater. They are labelled as such with an "H" and you can see in the diagram that they are the only two pins that have a physical connection to one another.

Test the heater pins with your ohm meter for resistance. Conductivity between the heater pins should reveal a small resistance - typically under 10 ohms. Make sure there are no other shorts across any of the remaining pins. Test the remaining pins in pairs, all combinations, one pair at a time with your meter. If any other pair of pins besides the heater pins show connectivity, you probably have a shorted tube that needs to be replaced. If you want to do more thorough testing, you'll need a tube tester - a vintage one that probably also needs to be restored... Using your ohm meter for now is probably sufficient.



5) Inspect the power supply capacitors. You can perform one or two tests with your typical inexpensive Digital Multi Meter, and you can perform a few more if you have an expensive DMM. but NO digital multi meter (unless you've dropped a few grand on a digital capacitance bridge tester/meter) is equipped to help you test what really needs to be tested in antique tube radios and amps: do any of your capacitors "leak"? This is a simple test: caps are supposed to allow AC to pass and are supposed to block DC from passing. If DC passes through your cap, you have a leaky cap. The ONLY way to test for this is to remove the cap from the circuit, apply a working voltage (200+ volts DC) to your cap and see if any of the current leaks through. Here is where we get to the heart of the story and my new box pictured at the top of this page. See below for how to build a capacitor leakage meter.

In case you missed it the first time through, here is an EXCELLENT detailed writeup for how to thoroughly inspect a tube-based power supply BEFORE applying AC power. Be sure to read Max Robinson's write up about Trouble Shooting Antique Equipment. The first one third of this page is very detailed and definitely worth a read to help keep you from screwing things up even worse than they are already likely to be from the simple passage of time.

Once you've verified the proper functionality of each capacitor (and replaced them accordingly), you are probably most of the way toward making your radio work...

So, How Do You Test Capacitors?

The instructions that follow are intended for the measurement of high-voltage power supply capacitors and interstage coupling capacitors in tube-based radios and amplifiers. Tiny electrolytic capacitors that populate circuit boards in today's modern solid state (no tubes) amplifiers, CD players, satellite receivers, etc. are typically not worth measuring or testing. If your modern audio equipment has recently stopped working and is more than 10-15 years old, your first order of business is simply to REPLACE ALL OF THE ELECTROLYTIC CAPACITORS in the power supply (first step) and potentially in the rest of the circuit (second step, after the first step didn't solve your problem). See here for additional details.

OK, so what is the big deal here? If you've poked around my web site, you might have seen my write up on how to repair some typical problems with modern electronic devices. On this page, I recommend sweeping replacement of capacitors without much effort to test them. The rationale here is simple: New caps for modern gear fit standard form factors for size, are inexpensive, readily available, and generally easy to replace. With this winning combination, there is nearly nothing to lose from simply replacing all of the caps on the circuit board, so long as you work carefully and don't make silly mistakes or damage something in the process. When you replace capacitors on a circuit board, it is often difficult to tell that you've done anything at all to the board.

But things are different with tube-based audio gear. If you are restoring an antique radio or amplifier, there is often a desire to keep things looking as original as possible. The older your gear is, the less "standard" parts become. While new "equivalent" parts most likely exist, they certainly don't look the same or they may not fit into the physical space you have because they are a different size or shape. Thus, simple and wholesale replacement may not be a viable option with antique electronics. Thus, it is useful to have a better understanding of what shape the original parts are in. Similarly, if you are building a new tube amplifier and using NOS (New Old Stock) capacitors in your power supply or as interstage coupling caps, you need to make sure these caps function properly. An interstage coupling cap that leaks will spell disaster for your (likely expensive) output tubes!

Capacitors feature a number of attributes that can be measured - nearly all of which require you to remove at least one leg of the capacitor from the circuit in order to properly measure it. Some meters will allow you to test caps "in circuit" but it is typically best to carefully unsolder at least one leg and measure a cap outside of the influence of other components it is connected to. Sometimes, removing the tubes sufficiently isolates the capacitors you are interested in testing. Sometimes not, so you'll have to check the schematic carefully. Alternatively, follow the actual wires that are connected to the cap in question and see where they lead to be sure about this. Each radio/amp will be different.

1. Measuring Capacitance:

This is a first step in checking capacitors and nearly any $30 digital multi meter (DMM) can do this. Typically, a capacitor that is more than 20% off of its specified value (either high or low) has had a hard life and should be replaced.

2. Measuring Dissipation Factor (DF):

Some DMMs will provide dissipation information while they are measuring capacitance, but this is not the norm for a $30 DMM - you are typically talking about a meter that costs closer to $100 at this point. Dissipation Factor (as indicated by "D" or "DF" on your meter) measures the loss rate of energy stored in the capacitor and is often conveyed as a percentage. DF readings of less than 0.5% are typical, but can be as high as 1% to 2% in some capacitors. Lower is better when it comes to measuring dissipation. This measure is related to ESR (below). Here is a chart that I pilfered from Conrad's web site that provides some analysis of Dissipation Factor:

"What value do you use as a cutoff to determine that a cap is bad? If you have a datasheet for the part, it should give some limits. If you can get a datasheet for a similar class of part it should serve as a useful estimate. Hopefully it will specify a maximum dissipation factor, usually measured at 120 Hz. Here's the chart for a general purpose Rubycon YK series general purpose radial that's typical of most general purpose caps:

Rated Voltage	6.3	10	16	25	35	50	63	100	160	200	250	350	400	450
DF	0.26	0.22	0.18	0.16	0.14	0.12	0.10	0.08	0.20	0.20	0.20	0.20	0.20	0.20

There is a note at the bottom of the table: *'When nominal capacitance is over 1000 uF, tan θ shall be added 0.02 to the listed value with increase of every 1000 uF.'* So let's say you have a 4700 uF 50 volt cap. The base dissipation factor for 50v is 0.12 from the chart above and because it's larger than 1000 uF there's an adder of 0.08, giving you 0.20 (I rounded the value to 5000 uF). Now, the end-of-life dissipation factor is 2X, so the cap can be considered bad if the dissipation factor measures over 0.40 @ 120 Hz."

When you start getting into more expensive meters, the meter should specify at what frequency specific readings are made. Better meters will allow you to change the frequency at which readings are made. My meter allows testing at 120Hz (2x mains frequency of 60Hz) and 1kHz (typical frequency for audio-related purposes). Even better meters will provide a wider variety of frequencies for testing.

3. Measuring Equivelant Series Resistance (ESR):

This measure is related to DF (above), but is a separate calcuation performed by meters and is also not typical for a $30 DMM. Some meters will display either DF or ESR, or both. An ideal capacitor is just that - a capacitor that displays no other electrical properties. In the real world, however, ideal capacitors don't exist - a capacitor always exhibits some resistance in addition to its capacitance. Determining ESR is not as simple as measuring the resistance across a capacitor with the resistance function of your DMM, though. ESR is a much more complex entity that depends on a number of other factors.

ESR typically increases with capacitance and with the frequency of the signal that passes through the capacitor being tested. This is why simply measuring the resistance across a cap with the typical DMM (that makes measurements with a single and unspecified frequency) will not provide useful information for you. ESR also increases over time (normal aging - with or without use), as a result of high temperature (tube gear gets hot), and with large ripple currents (high-voltage or high-current power supplies commonly found in Class A amplifiers). When the ESR of a capacitor increases, it causes circuits to misbehave and can lead to the failure of other components downstream in the circuit.

But here is the interesting part: a cap with tragically high ESR (lower numbers are better - see chart below) won't be revealed by simply measuring its capacitance with an inexpensive DMM. Thus, it is possible to have a bad cap whose capacitance measurement on a cheap DMM matches the label on the cap - in this case, you'd never know the cap was bad unless you made further measurements. Darn sneaky little buggers!

Capacitor Type:	22 uF	100 uF	Freq. measured: Hz
Std. aluminum	7-30ohm	2-7ohm	120
Low-ESR aluminum	1-5ohm	0.3-1.6ohm	100k
Solid aluminum	0.2-0.3ohm		500
Sanyo OS-CON	0.04-0.07ohm	0.03-0.06ohm	100k
Std. solid tantalum	1.1-2.5ohm	0.9-1.5ohm	100k
Low-ESR tantalum	0.2-1ohm	0.08-0.4ohm	100k
Wet-foil tantalum	2.5-3.5ohm	1.8-3.9ohm	not stated
Stacked-foil film	<.015ohm		100k
Ceramic	<.015ohm		100k

The discussion above concerning capacitor testing is rather high-level summary information. If you thirst for a greater understanding of capacitors and the various tests that can be performed on them, I recommend reading Samuel Goldwasser's excellent writeup on capacitors.

4. Measuring Leakage Current:

Here is where things get interesting, especially for high-voltage capacitors that exist in tube electronics. Let's presume you've made each of the three measurements that I described above and each of your caps passed with flying colors. There could still be a tragic and fatal flaw with a capacitor that mandates it be replaced: it leaks. None of the previously described tests will identify this problem. In fact, **THIS CRITICAL PROBLEM CANNOT BE IDENTIFIED WITH ANY DMM!** Measuring the leakage current of a capacitor means you need to apply the full working DC voltage to the capacitor and measure how much of it "leaks" across to the other side. It is important that this test be conducted at the voltage rating of the cap or the working voltage that the cap will see in the functioning circuit. Many repair people will recount experiences of troubleshooting electronics with caps that measure good at low voltage (5-15v) only to fail (by leaking current) when exposed to 50v, 100v, or more. This is the reason why a 9v battery-operated DMM cannot perform this test.

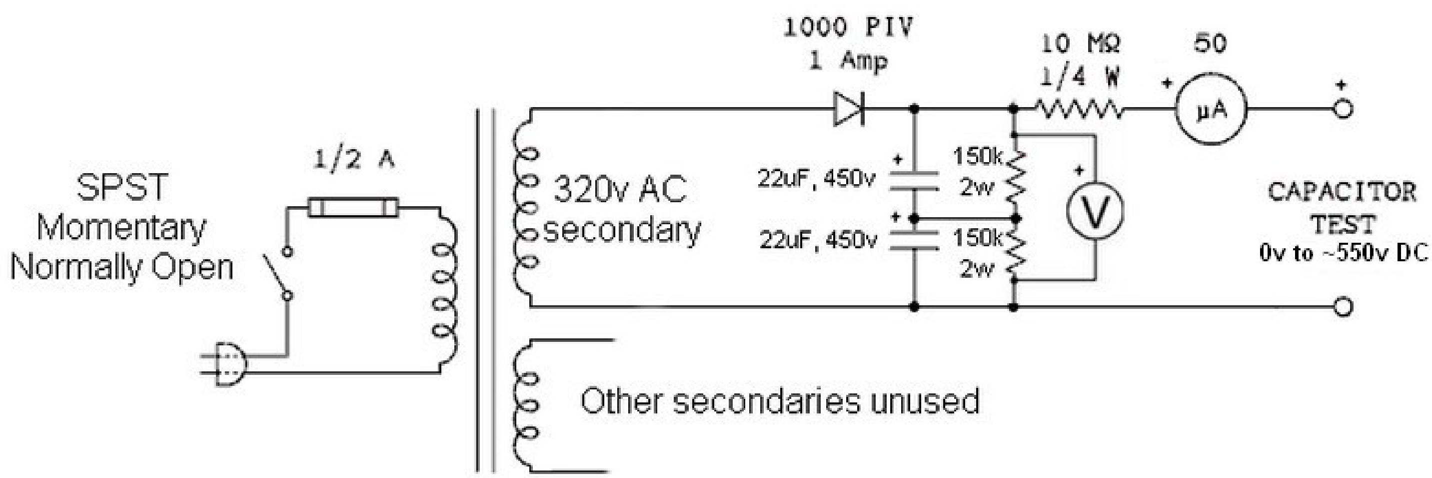
This test is important for power supply capacitors, but is **ABSOLUTELY CRITICAL** for signal capacitors, especially for interstage coupling capacitors in tube radios and amplifiers. Remember, capacitors are supposed to allow alternating currents (music signals) to pass through, but are supposed to COMPLETELY BLOCK direct current (DC power supplies, plate voltages, grid voltages, etc). If DC gets through a cap, it can easily lead to burned out resistors (easy repair), blown tubes (potentially expensive repair), burned out filter chokes (sometimes impossible to repair/replace), and burned out power transformers (sometimes impossible to repair/replace). This is another good reason to install a protective mains fuse in your tube gear - it prevents damage to you and your gear when you've got leaky caps and other undiagnosed problems.

You basically have two options for directly measuring leakage current in capacitors. The first is a tube-based capacitor tester. These devices are old and no longer made, so you need to hunt for one on E-Bay, at flea markets, or at Ham/radio fests. Search E-Bay for "Capacitor Checker" or "Capacitor Tester" and you'll likely turn up a number of them. Some are more expensive than others and many will need some form of maintenance (a new "magic eye" tube, new wires, new reference caps, calibration, etc, etc) due to their age. This path represents something of a mixed bag for those with already limited skills in diagnosing and repairing old electronics. This leads us to the second option:

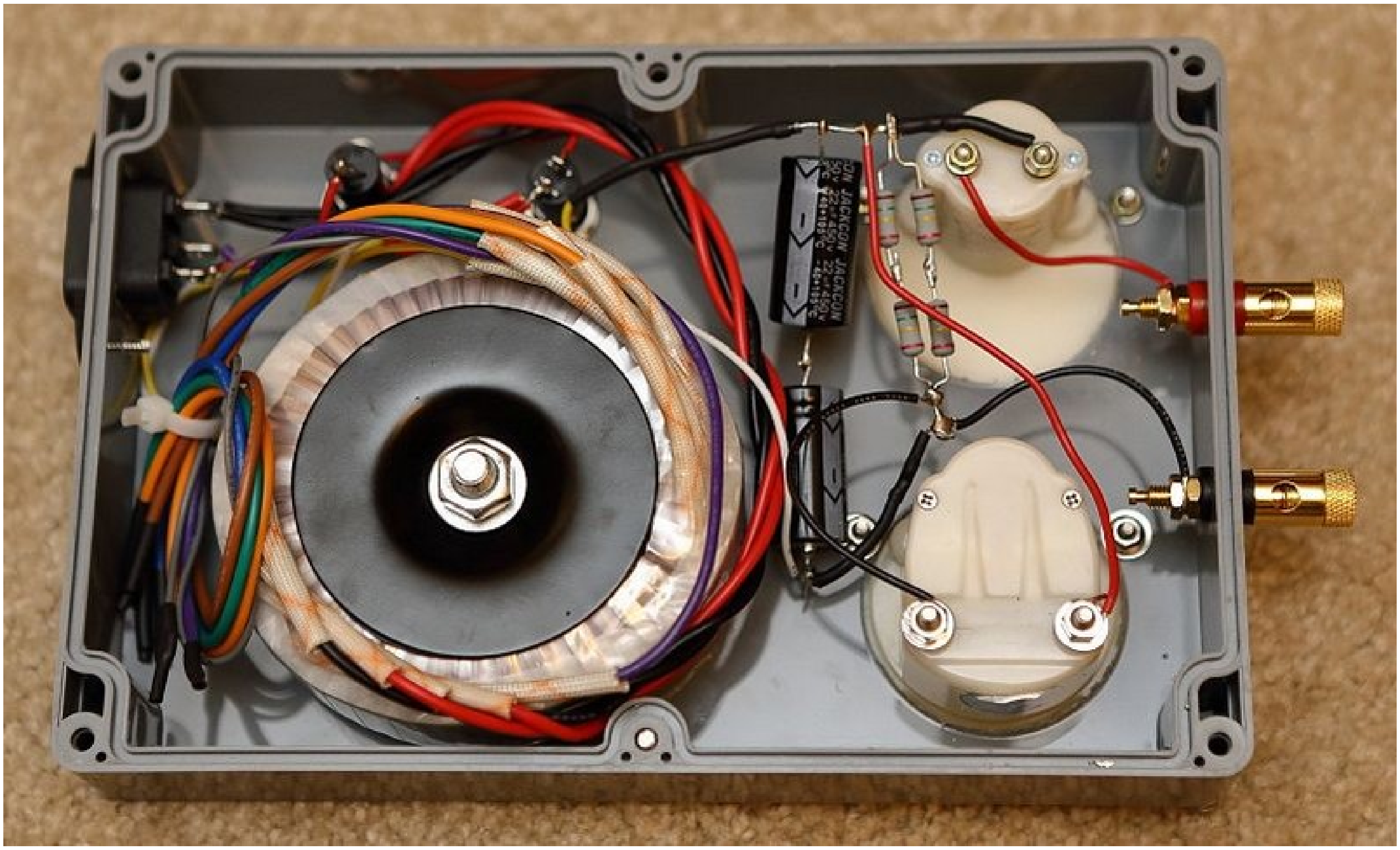
Building Your Own Capacitor Leakage Meter:

When people on the antique radio forums first asked me if I'd checked my vintage radio's power supply caps for leakage, I had no idea what they were asking me to do. I did a few searches that didn't turn up very much at all and my troubleshooting process ground to a halt. One day, though, I stumbled across Max Robinson's incredible web page. One of the articles he's written is A Simple Way to Test Capacitors. This page includes some description, instructions, and a handy schematic for how to build your very own modern capacitor leakage meter. I started with his schematic and made a few modifications to it. First, I did not include the rotary switch and associated power resistors (used for measuring and reforming electrolytic capacitors). Second, I added an internal volt meter to indicate the voltage being applied to the capacitor under test. Finally, I used a momentary push button instead of the original SPST toggle switch. The image below shows the internals of my new capacitor leakage meter.

There are many devices / schematics / videos floating around the Internet that provide a binary "leaky" or "not leaky" indication for capacitors: some show a flickering neon bulb, others will light up a small bulb. I prefer this method where you can vary and control the test voltage and obtain an exact reading of just how much your capacitors leak, if at all. While this device costs more to build than some others do (this one cost me $65), it provides excellent control and precision. I started with Max's schematic, made a few tweaks, and ended with this:



And here is my actual implementation:



Instead of the 140-0-140 center-tapped transformer that Max recommended, I used an Antek AS-05T320 50VA transformer which has 320V, 300V, and 6.3V secondaries. This change has two advantages: first, my toroid was less expensive than a comparable Hammond center tapped transformer, and second, it provides a higher test voltage making it more useful for 300B tube amps. Many coupling caps used in these modern tube amps need to withstand 600Vdc or so. I wired the transformer to an EIC power entry module shown in the upper left of the image. The primary is wired through a 0.5A fuse and a normally open, momentary push button switch. Only two secondary wires are used (the 320v tap); I clipped the bare ends from the remaining secondary wires, covered them in heat shrink tubing, and bundled them together so they'd stay out of the way and not cause problems (lower left corner of image). There is a 1N4007 (1A 1000v) diode (though it is hard to see because it is covered in heat shrink) just before the positive leg of the caps at the top of the image. The two caps in series are each rated 22uF at 450v, resulting in a "single" 11uF cap with a capacity of 900v DC. The bleeder resistor array is made from 4 x 150k 2w resistors arranged in parallel then series configuration for a net of 150k. The maximum output of this power supply with my variac is about 550vDC, so each half of the bleeder resistor array sees a maximum of about 275v. To calculate the maximum power dissipation of the bleeder resistors, square the maximum voltage (275v) and divide by the resistance of each resistor (150k): 275^2/150,000 works out to just about 0.504w maximum dissipation for each resistor. Since each resistor is rated at 2w, we're in good shape!

Not shown in the image above: it is a good idea to connect the centerpoint of the two caps to the center point of the two adjacent bleeder resistors. This voltage divider insures that the two caps share voltage equally - a measure that prevents exceeding the voltage rating of either cap for improved safety and longevity. Without this connection, one of the caps may tend to hog the voltage due to mismatches, etc.

The 10M resistor that comes before the 50uA meter (uppermost meter in image above) is also covered in heat shrink so it is not directly visible. Finally, the 500 volt DC meter (bottom meter) is wired across the bleeder resistor array. The power output is simply a pair of speaker binding posts that were in my parts box. It is critical that the voltage output is isloated from your box if you've used a metal project box! So, for a grand total of about $65 and a little bit of assembly time, I have a brand new capacitor leak tester. To use it, I plug the EIC power cord into my variac so I have continuously variable voltage from 0 to 550vDC (instead of the original fixed 200v and 400v test points). The momentary pushbutton switch is for safety and makes sure that the box is never left unattended in a power-up state. Once you let go of the push button, the transformer is powered down and the bleeder resistors discharge both the internal caps and the external capacitor under test within a few seconds. While the external cap is discharging, the ammeter will deflect into the negative region and will return to the zero point when the external cap is fully discharged.

Add a few labels to the outside of the box and it's ready to go.

Important Safety Precautions:

Before using your nifty new box to test old caps, BE SURE TO WEAR SAFETY GLASSES! Old caps have been known to fail in spectacular fashion - think 4th of July! Capacitor explosions are very noisy, can be bright, and can damage your hearing or eyesight. Burns may occur. Small parts and pieces may fly away at high speed. You get the idea... In general, caution is ALWAYS warranted in situations that deal with lethal voltages!

Using Your New Meter:

Using your new meter is simple. Just connect the cap you want to test to the screw terminals with a pair of insulated alligator clips, plug the meter into your variac (dialed down to zero first), hold the power button down, and slowly bring up the voltage. A fuse rated at 0.5A is sufficient if you always start with the variac set to minium voltage and increase from there. If the variac is set high and you push the button, the inrush of current necessary to charge the caps to high voltage will likely blow the fuse. I ate up a few fuses before I figured this out... A 1A fuse would probably eliminate this behavior, but it's not any big deal. As you increase the voltage across the cap, you'll see the ammeter rise as the cap draws current to charge. When you have reached the desired test voltage and the caps is no longer charing, the ammeter should begin to decline toward zero over time - things should become stable after several RC time constants. One RC time constant is the product of the circuit resistance in ohms (10M in this case) and the size of your capacitor in farads. With small caps (say, 0.1uF) used for interstage coupling in tube amps, one RC time constant equals about 10 seconds, thus you are looking at 20-40 seconds for things to stabalize as the cap charges. For larger tube power supply caps (3-10uF) it may take 1-2 minutes to determine the minimum amount of leakage current. You'll get the feel for it once you test a few caps.

When the test is over, release the push button. This removes power from the transformer and the capacitor you are testing (as well as the two internal caps) will begin to discharge through the bleeder resistors in your box. The ammeter will deflect into the negative region as the caps discharge. This, too, will take several RC time constants, which could be a few minutes depending on the size of the cap you are testing. You will know that all of the caps are safely discharged when the ammeter reads zero again. Go ahead and disconnect your external cap now.

Interpreting The Results:

So, what can you learn by using your new capacitor leakage meter? Here is Max's response when I asked him: "How much leakage is too much?"

The paper in oil capacitors that were used in radio power supplies in the 1930s can tolerate some leakage - maybe as much as 40 microamps. For any capacitor that is used as a coupling capacitor (for example: interstage coupling of a more modern tube amplifier), if you can measure ANY LEAKAGE CURRENT AT ALL with this meter, it is TOO MUCH. Discard the cap and look elsewhere for a replacement.

So, there you have it. You, too, can build and use your very own capacitor leakage current meter.

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