'Technical Shorts'

by Gerry O'Hara, G8GUH

'Technical Shorts' is a series of (fairly) short articles prepared for the Eddystone User Group (EUG) website, each focussing on a technical issue of relevance in repairing, restoring or using Eddystone valve radios. However, much of the content is also applicable to non-Eddystone valve receivers. The articles are the author's personal opinion, based on his experience and are meant to be of interest or help to the novice or hobbyist – they are not meant to be a definitive or exhaustive treatise on the topic under discussion…. References are provided for those wishing to explore the subjects discussed in more depth. The author encourages feedback and discussion on any topic covered through the EUG forum.

Eddystone Cap Lore: Failure, Testing, Replacing and Fixing

Valved Eddystone radios contain several types of fixed capacitors (caps). After several decades of continuous or intermittent use or non-use/poor storage conditions, many of them may have become faulty; commonly losing capacity, or becoming 'leaky' (measurable resistance much lower than expected for a particular dielectric type), open or short circuit. This is not surprising – who would have thought, for example, in the late-1940's through mid-1950's that the S640's, S740's and S770R's then in operation in commercial or amateur use would still be in service in 2006? I would suspect that even high-quality radios such as the various Eddystone models, would have anticipated working lives of little more than a decade at best (not six decades or more!) – in my view it's quite remarkable that some of the components in these radios, manufactured using primitive materials such as oil-impregnated paper, cardboard, wax and rubber, often subject to high temperatures and voltages are still functional at all.

A selection of 'failed' caps removed from valve radios (alas, not all Eddystones…)

Capacitor Failure Modes

The problems that develop in caps are usually caused by the encapsulation and/or sealing materials having become unreliable over prolonged periods of time due to effects of heating/cooling, moisture or direct mechanical damage, resulting in changes to the electrical properties of the caps dielectric material. Alternatively, the dielectric may have become physically damaged, altered or weakened due to electrical or mechanical stress, perhaps due to failure of an associated circuit component, eg. resistor, applying a voltage above the caps rating, or open circuit, resulting from internal fusing, fatigue or detachment of the connecting leads.

Electrolytic and paper dielectric caps are (quite rightly) the favourite suspects for failure, with silver-mica and the more 'modern' plastic dielectrics (eg. polystyrene) being generally much more reliable and therefore often ignored when checking out a faulty set, at least initially. Indeed, many folks discount failure of silver-mica caps as a matter of course (these are usually restricted in use to RF and IF tuned circuits), however, even silver-mica caps are prone to occasional failure, usually a short circuit caused by 'silver migration' around the sides of the mica dielectric element – this effect has been noted many times in 'Lighthouse'. Incidentally, don't be fooled by older plastic-jacketed caps – these frequently contain a paper dielectric, not plastic, and they are just as prone to failure as the wax-coated paper type - the plastic often develops a hairline crack that lets moisture due to age or the effects of a local heating source. The infamous 'red Hunts' are this type (as found extensively as de-couplers in my 830/4, though, surprisingly, in my set these are mostly ok). Also, this type of paper dielectric cap was often used as a service replacement part during repair of tube radios from the 1940's through the 1960's (eg. the grey-jacketed 'Radiospares' ones marked, appropriately, with a little gremlin-like symbol) and by now these replacements often need to be replaced themselves.

Testing Caps and Those Prone to Failure

There are several techniques for testing capacitors, including resistance (leakage) testing, substitution and measurement techniques. My usual 'quick and dirty' test is made using an analogue ohmmeter on the x10,000 (or higher) scale following disconnecting one leg of the cap from the circuit. On cap values of 0.005uf and higher (or less if you have a very sensitive meter, eg. a VTVM), a 'kick' of the ohmmeter needle may be observed when connecting the meter test leads across the cap under test (bigger value caps should give a bigger 'kick'), the meter should then settle down to a very high resistance reading if the cap is ok (tens of megohms for paper types, hundreds of megohms for plastic and silver-mica dielectrics, and greater than a few hundred kilohms for electrolytics (note: observe correct polarity of multimeter test leads when testing electrolytics: their 'real' polarity on ohms ranges is often the reverse of that indicated by the meter connections). This check gives a qualitative 'feel' for the cap performance, however, this is under low voltage DC conditions only and the performance of the cap in 'real' circuit conditions, eg. higher DC voltage, presence of AC or ripple, may differ significantly, however, it can identify most really 'duff' caps very quickly. With a bit of practice, you can get an 'eye' for the capacitance value

from the size of the 'kick' (try comparing with known good caps of similar capacity). Having identified a suspect cap I then remove it and substitute with a known good one. If I want to check the effect of a replacement before soldering it into the circuit or wish to test the effect of changing the value, I built a little gadget fitted with spring-loaded 'speaker' connectors, banana plugs and a switch to allow rapid connection into the receiver, test meter and change-out of caps (or any other component with leads for that matter) – see photo. However, this set-up is only useful for low frequency circuits as the length of the leads will impact the caps performance in HF circuits (and even some IF circuits) due to their inductance. For HF and IF circuits therefore, just replace directly into the circuit, trying to keep similar lead lengths and dressing as per the original component. For checking purposes, the new component may be tack-soldered temporarily.

I also use a commercially-available and inexpensive digital multi-tester (Knight K-240C – see http://www.knightonline.com/meters-2.htm) - that has a capacitance measurement facility from a few pf to several thousand uf. I find this especially useful to confirm the actual values of caps that DC testing show as good, but their value markings may be obscured due to ageing or wear, or to measure the actual value of a critical replacement. Textbooks mention using capacitance bridges and sometimes these and older 'cap testers' are for sale on EBay, rallies and fleamarkets, but I haven't used a capacitance bridge since I was at school and old 'testers' are likely to be unreliable.

Graeme Wormald, G3GGL, describes a simple cap tester ('Condenser Zapper') in Lighthouse Vol. 34, page 8. I have not tried it but is well worth checking out (see also the 'cap reformer' device noted below).

Caps most prone to failure and common symptoms? – in my experience:

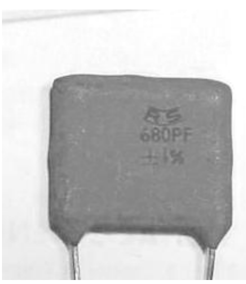
- electrolytics in power supply and audio stage cathode bypass circuits ('motorboating', hum, buzzing, distortion, incorrect frequency response) – the first audio stage cathode by-pass caps in my 830/4 were open circuit and this had the odd effect of not only introducing slight distortion, but also contributing to not being able to turn the audio down completely (although the main cause of this is the design of the 6AT6 valve);
- paper inter-stage coupling caps (output tube failure/overheating, distortion);
- paper screen de-couplers (no/low gain, distortion, spurious oscillation or instability);
- paper mains filter caps (blown fuses, low HT volts); and
- AGC de-couplers (this is a high-impedance circuit and even a very low leakage can have a significant impact on receiver gain, or, if the capacitance is incorrect, on the time constant of the AGC) – my S740 had an AGC de-coupler cap measuring just over 2 megohms resistance that pulled the AGC voltage down to less than half that when it was replaced by a new Mylar dielectric type.

Some folks advocate changing-out power supply smoothing, audio inter-stage and AGC de-coupler caps in old radios (>25 years) as a matter of course for ''peace of mind', whether there is a sign of a problem or not – this isn't a bad suggestion.

Selecting Replacement Capacitors

Replacement caps are usually selected from four different dielectric types, depending on the application. Although paper caps are still manufactured, and even sought-after for use in those 'audiophile' amplifiers for that genuine 'tube amp sound', I would not advocate their general use as replacements for old paper caps in radio circuitry (they are not generally available anyway).

Electrolytics: electrolytic capacitance values in Eddystone tube sets tend to be quite low for high-voltage types (eg. up to 50uf for power supply smoothing caps with working voltages up to 550v) and 10uf through 50uf for cathode de-couplers with working voltages of 25v through 50v). All these values are readily available from electronic component suppliers. For best performance and longevity in power supply applications, however, try to use 'high ripple' types – these can still be purchased, but be careful of 'new-old-stock' (NOS) units as these can be unusable (see section on testing and re-forming electrolytics below). Tantalum caps are available only in low voltage ratings (up to 30v or so) and therefore would only be applicable for cathode by-pass type applications. I personally have never used one outside solid-state circuitry: their small size is of no benefit in valve circuits.



Silver-mica: usually found in Eddystone RF and IF circuits due to their long-term stability and low temperature coefficient (values from a few pf to 1000pf) and may also be used as inter-stage couplers (up to 0.05uf – though at this value they are getting rather large!). The small value types are readily available from most electronic suppliers and should be used as direct replacement for failed or out-of-spec silver mica units. Where a particular capacitance value is critical, more than one cap may be used (usually several lesser-value ones in parallel: simply add the values) to attain the desired capacitance. Most silver mica caps intended for non-transmitter applications are rated at 500v DC working, but some miniature types are rated as low as 100v, so be careful.

Ceramic: these are not found in many tube sets until WWII and in Eddystone sets until the late-1950's, however they make excellent RF/IF HT, screen and cathode bypass caps (they have low inductance), or even inter-stage couplers, and may be readily used to replace paper caps in these applications – just ensure that the voltage rating is adequate for HT, screen and inter-stage use (250v through 1000v DC working types are common, but some, intended for solid-state applications are rated as low as 25v).

Plastic Film: these were not available until post-WWII, with the introduction of polystyrene caps – indeed, polystyrene caps, having good long-term stability and RF performance, are a still a good choice for RF/IF circuits, particularly for replacing larger silver mica values that may not be readily available – be careful where you place them though as they can be easily damaged by heat – eg. from a nearby resistor or tube. Polyester ('Mylar'), being suitable to fabricate into very thin films (hence relatively small capacitor size), is the most popular general purpose plastic dielectric type in use today and is a good choice to replace paper caps in by-pass and inter-stage coupling applications at RF, IF and AF – the popular 'orange drop' caps are this variety (630v DC working is a good choice for almost all applications). Metalized-film types of plastic dielectrics are smaller and are good performers but don't use where appreciable AC signal is present as they have limited current-carrying ability.

Focus on the Humble Electrolytic

Electrolytics are electrochemical devices: two aluminum foils separated by an insulating media (eg. paper), impregnated with a liquid electrolyte: the dielectric is actually a thin oxide coating formed on the anode foil by a chemical reaction when current flows. Compared with other cap types, the electrolytic tends to have a lower DC resistance (and therefore a higher leakage) and a higher internal inductance (the latter limiting high frequency performance), a higher manufactured tolerance and the capacitance value tends to drop with age. Low-temperature stability is poor, they can leak chemicals and even explode (usually if too high a voltage, reversed polarity voltage or the cap has not had voltage applied for some time): their saving grace is that a large capacitance can be built into a small space.

Not a candidate for re-forming – note the split in the rubber seal with electrolyte oozing out… yuk. One for the bin!

If an electrolytic cap has not been used for some time, the current leakage increases due to breakdown of the oxide layer. This increased current flow between the cathode and anode foils, through the electrolyte, can be sufficient to overheat the cap and destroy the component. Thus, when it is intended to use/re-use such a cap, precautions should be taken to avoid applying significant voltage until the oxide layer has been re-established and normal DC leakage levels attained. Thus, electrolytic caps that may test (using an ohmmeter) as being almost short-circuit can sometimes be 're-formed' with a little care and patience – the power supply smoothing caps in my S740 were in this category (I almost just changed them out, but not having direct replacements to hand I decided to try to re-form them: several hours later they were working just fine. Re-forming old electrolytics can be desirable, compared with replacing, eg. for authenticity (as in my S740), however, in many such caps the electrolyte has dried out due to poor sealing of the encapsulation and the oxide layer therefore cannot re-form (such a cap will often test open-circuit). If a direct replacement cannot be obtained, don't despair – simply disconnect the old one (even if it tests open circuit – don't be tempted to use the tags as connecting posts) and leave it in place if it is the can type to retain above-chassis aesthetics. Then simply wire in the replacement under the chassis. Perhaps one better – at least for appearance - is the 'cap in a cap' technique, where the can of the old cap is carefully cut open, the guts discarded and a new cap (or caps for multiple units) inserted or 'stuffed' inside and the can re-assembled – this is possible, even in cardboard or plastic-cased paper units, as modern caps tend to be smaller than their older counterparts. There are several articles on the internet about such 'cap stuffing' (see references) for both electrolytic and paper types, though I have never tried it myself.

The basic principal of re-forming an electrolytic is to monitor DC current flow through the cap as the applied voltage is gradually increased. The premise is that initially, even at low applied voltage, the leakage current will be high. If the cap has the ability to be reformed (sufficient electrolyte and no other damage), the leakage current will gradually fall for a particular applied voltage as the current flow through the electrolyte restores the oxide coating onto the anode. The applied voltage can then be increased in small steps, monitoring the leakage current until it drops again and so-on. The oxide layer forms at varying speeds, however, a timescale of hours is generally appropriate. Observing polarity, start by applying 5% of the rated voltage and increase in similar steps up to the rated voltage, not allowing the leakage current to exceed ~5mA. If the cap starts to heat significantly or the current draw does not decrease after a couple of hours on a particular step, discard the cap. The variable voltage for high-voltage units can be a receiver power supply fed to the cap under test via a milliameter and a 10 x 1 megohm resistance ladder/switch (or power the receiver with a variac and use that to vary the receiver HT voltage). Simon Robinson, M5POO (then G8POO), describes 'The EUG Capacitor Reformer and Tester; in Lighthouse Vol. 55, page 23 based on these principles.

Discharged…

One final and extremely important note: <u>always</u> exercise due caution when dealing with high voltages – <u>they can be lethal</u>! Also, note that caps can hold a high voltage for a long time after power has been removed from the circuit – be careful and ensure that they are discharged safely before handling.

Well, that is probably enough for a 'short' article on failure, testing, replacing and fixing capacitors (a sizeable book could probably be written on this subject). I hope readers will find one or two useful tips in it, or that it stimulates thought and curiosity, or for others to submit additional material, either as an article or a post on the EUG forum.

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References

- Electronic Components Handbook, TH Jones, 1978
- Radio Communications Handbook, RSGB (eg. 4th Ed, page 1.7)
- Radio Amateurs Handbook, ARRL (eg. 57th Ed. page 2.8)
- Restoration of Valved High Frequency Communications Receivers, Chris Parry, G8JFJ (http://www.vk2bv.org/radio/), page 52
- Various EUG Lighthouse articles, including:
  - Vol. 34, page 8 'Condenser Zapper' by Graeme Wormald, G3GGL
  - Vol. 55, page 23 'EUG Condenser Reformer and Tester' by Simon Robinson, M5POO
  - Vol. 73, page 13 'Eddystone Radio Repair for Beginners, Part 4' by Peter Lankshear
- Some web-based articles on checking, replacing and 're-stuffing' capacitors:
  - http://itsmegfb.tripod.com/id16.html
  - http://antiqueradio.org/recap.htm
  - http://radioatticarchives.com/features/shinn/restuffing-wax-paper-caps.htm
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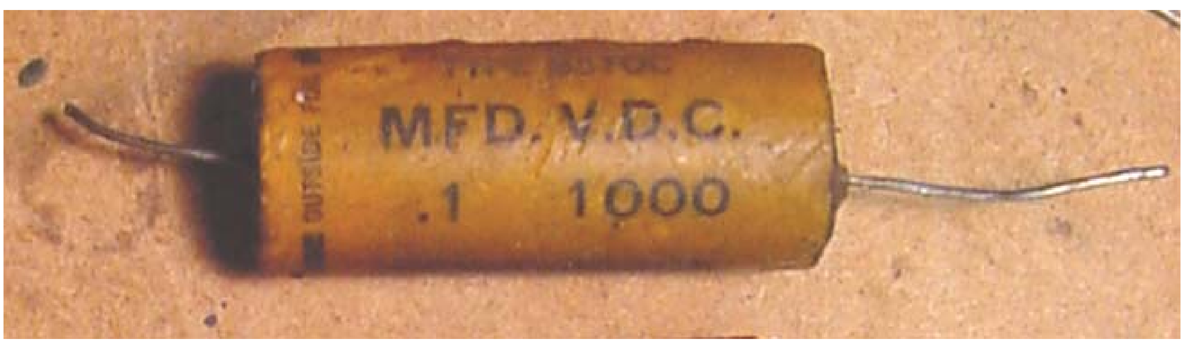

Would you place a thousand volts across this old fella? – I don't think I would….