'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.

The Humble Resistor

Resistors: perhaps the most humble of all the passive parts in your favourite Eddystone. They have the simple function of introducing electrical resistance into a circuit to produce desired voltage drops, act as elements in filter circuits etc. Fixed resistors are linear in operation – i.e. they follow ohms law and should be stable in value across their specified operating range of temperature, dissipation and voltage. They can be broadly subdivided

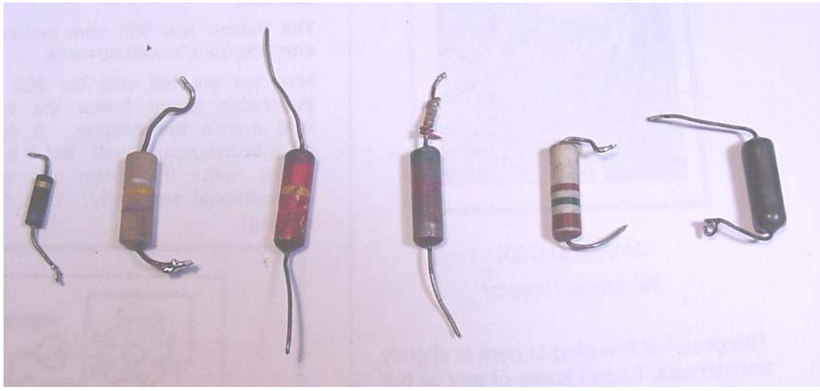
into fixed resistors, variable resistors (rheostats) and potentiometers (pots), the latter having three terminals, one connected to each end of the resistive element and the third movable along the element. Until I started restoring old valve radios, I thought for the most part that you simply selected the correct type and value of resistance, appropriate wattage, soldered it in and forgot about it. Since then, I have come to realize that things are not that simple: resistors have quirks, and although not as quirky as capacitors (caps), they must be checked out and treated with suspicion unless demonstrated otherwise. Like caps, many resistor types in common use in the 1930's through 1960's have, after several decades of continuous or intermittent use (or abuse) or non-use/poor storage conditions, become faulty; commonly significantly increasing in value, not just out of tolerance (commonly 20% in those days), but by more than 2 orders of magnitude! Even though valve circuits are usually very tolerant of resistor values, soldiering on remarkably well notwithstanding, such major changes can have significant impact on the performance of radio circuits – sometimes subtle, allowing operation but impacting specs, sometimes catastrophic, silencing the set or worse, blowing valves, caps or other components. Also, such deterioration is often accompanied by generation of noise – this effect can be most annoying, ranging from intermittent clicks, through variable or steady hiss, to a harsher sound like frying eggs… There can be scores of resistors lurking in that Eddystone on your bench (my 830/4 has over 100!) and it is therefore important to give them due consideration during a restoration or service. This Technical Short provides some insight into why resistors fail, which resistors tend to fail (and why), how to check them and considerations in the selection of suitable replacement types.

Another component that is a sort of resistor is the 'thermistor', this is a resistor that (deliberately) changes its resistance value with operating temperature (i.e. it is a non-linear device) – not to be confused with fixed value resistors that change their resistance value with temperature due to a malfunction… see discussion later in this article. These devices can have positive or negative characteristics (i.e. either increasing or decreasing resistance with increasing temperature), with the negative types being by far the most common (eg. type CZ1) – normally used in an AC/DC set to limit current surges through valve heaters and/or dial lamps at switch-on.

Resistor Failure Modes and Testing

The mode of failure of a resistor depends on four things: resistor type, construction material, operating stress and environmental conditions. Fixed resistors fall into three main categories: carbon composition (carbon powder mixed with a filler as the resistive element – very popular for all sub-2 watt resistors during the production years of Eddystone valve radios: their main benefits were availability, low cost and low inductance), wirewound ('Eureka' or similar high resistance wire wound around an insulating, heat resistant former, often porcelain or ceramic – these types were used for most 2 watt and higher dissipation resistors, especially in power supplies), and film types, where a thin layer of metal oxide, metal or carbon is deposited on an insulating former (these types were not in general use during the Eddystone valve radio years, but are now very common – advantages are better long-term stability than carbon composition types and closer tolerance, though some types can exhibit some inductance that can be an issue at higher frequencies).

Resistors are, superficially at least, rather straightforward to check, using the ohms ranges on either analogue or digital multimeters. However, just because a resistor checks out to be within tolerance under static, low voltage conditions of an ohmmeter check does not mean it will perform well in the actual circuit! Such a check will not identify a resistor that, due to some quirk of its construction, will act as a noise generator (hiss or crackle) or that may change its value (ie. acts as a thermistor), when its temperature increases due to dissipating power under load. The value-



Selection of 'failed' resistors removed from my Eddystone sets: five carbon composition types and one wirewound, 6w unit (right) changing phenomena is a little difficult to demonstrate, but measuring the voltage across the resistor in circuit under load from 'cold' to normal working temperature can sometimes identify this. 'Shocking' the suspect resistor with a blast of cold or hot air can also uncover a faulty unit whilst it is operating in its circuit - also try pushing the component with an insulated tool or squeezing it gently with insulated pliers. In my experience, if a resistor is suspect, then simply change it out – they are so cheap it may not be worth testing! Wirewound types can develop intermittent open circuits or abrupt changes in value (especially those types with adjustable taps).

Fault Symptoms and Resistors Prone to Failure

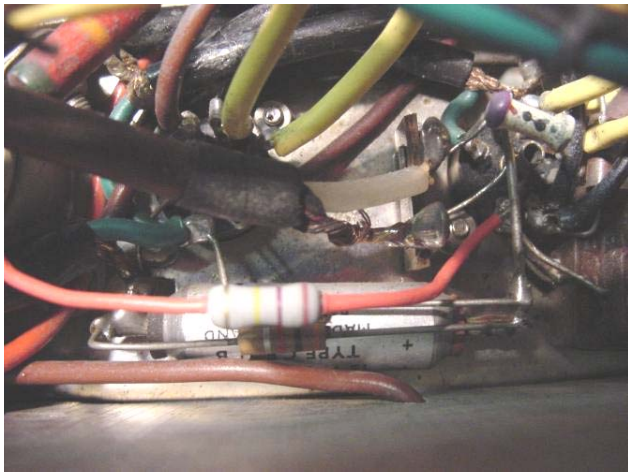
Resistors most prone to failure and common symptoms? – in my experience:

- Carbon composition types from all the valve era (and after!). These little guys can change value in your junk box without ever having passed an electron or changed from room temperature! The reason for this is hard to explain, but is likely due to age-related changes in the composite material binding the carbon, perhaps absorption of moisture (or desiccation in dry conditions) could accelerate this. Whatever it is these should be suspect – I once repaired a large GE consol radio (1939 vintage) where every single carbon composition resistor had gone high in value (some by several megohms). Of my humble Eddystone collection, the youngest valve model, an 830/4, dating from 1968, had a higher percentage of out-of-tolerance resistors than my older sets dating from the 1950's (S.740, S.750 and S.770R) – I suppose this relates to the manufacturer specifications for the components and the amount and type of service the sets have seen, how near their rated dissipation level the components were operated under, as well as prevailing environmental conditions (heat/cold cycling and humidity). Film construction types appear to be much more reliable, though again, be wary of the carbon variety.

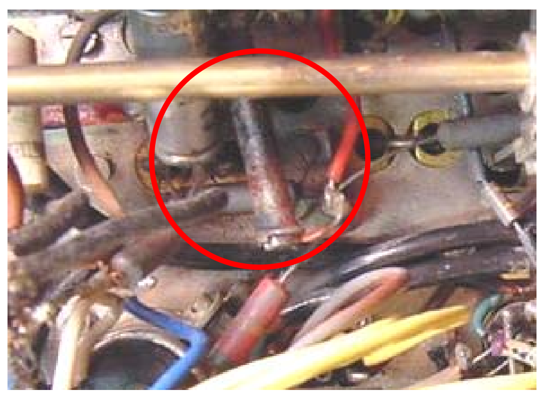
Two 'high' wattage carbon composition resistors removed from an old radio under repair: little or no cosmetic indication that one is open circuit and the other measured several tens of megohms

- Changes in resistor values, even by quite large amounts (say twice the value) do not always result in readily discernable faults conditions – valve radios will usually continue working even when many components are out of tolerance – however, the resultant voltage variations from design can not only result in degraded performance, but may also eventually result in shortened life of other components, eg. caps, valves, chokes or transformers, so it is important to replace those resistors that are known to be significantly our of tolerance.

- Carbon composition resistors can make very effective noise, crackle and intermittent click generators – if the noise is not controlled by the AF gain control, suspect the anode load resistor in the first AF stage, then the grid resistor of the output stage – even if they test ok for resistance value. If the noise is controlled by the AF gain pot, then suspect an anode load or screen dropper resistor in earlier stages. Shown in the photo to the left is a replacement 1watt 270kohm 1st audio (6AT6) anode load resistor installed in my S.750 – before this was fitted there was uncontrollable crackling from the audio stages – fixed for 20 cents.



- Screen dropper and anode load resistors often 'roast' due to excessive dissipation following failure of the associated decoupling capacitor (by shorting) – look for blackened or blistered components. My advice is to always replace a resistor that has experienced such stress, even if it tests out ok.
- The cathode resistor of the output stage tends to go high in value with age, altering the grid bias, resulting in distortion and/or low output.
- Higher-dissipation wirewound types, especially the glazed porcelain body variety (eg. as manufactured by 'Painton' or 'Welwyn'), can run extremely hot (eg. the 140ohm HT surge-limiting resistors in the power supply of my 830/4, rated at 6 watts, were running at almost 300 C: whilst this is (just) within the typical maximum ratings for this type of construction (350 C according to Jones – see references), their leads were conducting this heat to the supporting terminal posts and had, over many years, 'baked' the plastic insulation of the posts to a point were they were disintegrating. I replaced these resistors with 10 watt ceramic body types that run at around 150 C. Wirewound units tend to go open circuit in failure: be



Appearance of a (slightly) 'roasted' resistor in my S.750. Although this one was within tolerance – I should change it out…

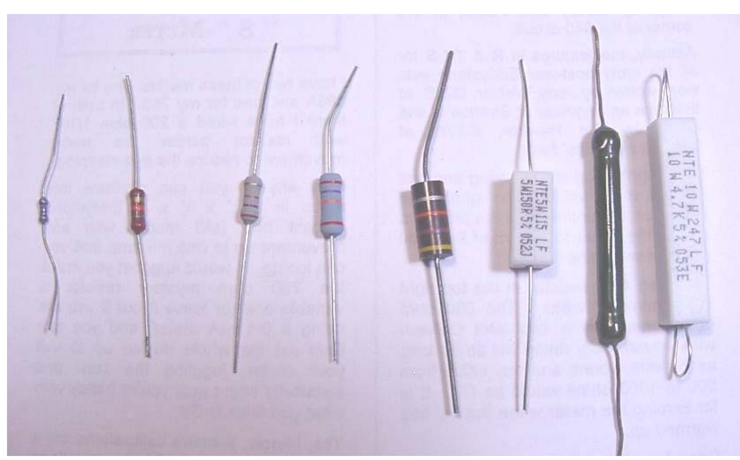
suspicious of components with severely discoloured, blackened, cracked or missing insulation.

- Carbon track variable resistors (pots) used for volume controls tend to develop fault conditions that generate noise and crackling rather than complete failure, though I have encountered open circuit pots. The degradation of the control performance due to wear is usually exasperated by the ingress of dirt or oily residues from the shaft/bushing of the component. Often a squirt of ‘Servisol’ or ‘De-Oxit’ cleaner and ‘working’ the control several times to clean the track can remedy an effective and long-lasting cure. Older controls can sometimes be dismantled and cleaned/repaired in extreme cases - often not the case with more modern types which sometimes don’t even have a hole or gap into which to squirt the cleaner, however, a small hole can be drilled carefully in the side of the pot casing for this purpose if needed. The use of carbon track pots in any applications where a DC current passes through the track/slider (even a few mA) should be avoided as this can result in intermittent connection or high resistance developing on the track at the normal point of contact. My S.750 had its 10kohm IF gain wirewound pot replaced at some point with a carbon track unit – I replaced it immediately with a wirewound unit.
- Wire-wound pots tend to become erratic with use/age, due to wear on the resistance wire and/or contact surface.

The ‘gubbins’ out of an older wirewound pot showing slider and resistance element

Selecting Replacement Resistors

Replacement resistors are usually selected from modern-day versions of the three main construction types as noted earlier – they are all still manufactured. Bear in mind the caveats noted above, especially observing the wattage rating – modern components of equivalent wattage tend to be smaller in size, so I usually purposely select a component of twice the wattage rating of the component being replaced to both enhance reliability and ‘look the part’ (see Thomas Jones book, Peter



Selection of new replacement fixed resistors: from left – a 1/4w, 1/2w, 1w and 2w ‘modern’ film type resistors, a 2w carbon composition unit, a 5w ceramic wirewound, 10w porcelain and 10w ceramic.

Lankshear's Lighthouse article and the Radiotron Designers Handbook for discussion on resistor ratings).

Low-wattage Fixed Resistors: For most AF, IF and RF applications, any general-purpose replacement modern resistor types available today can be used, though as noted

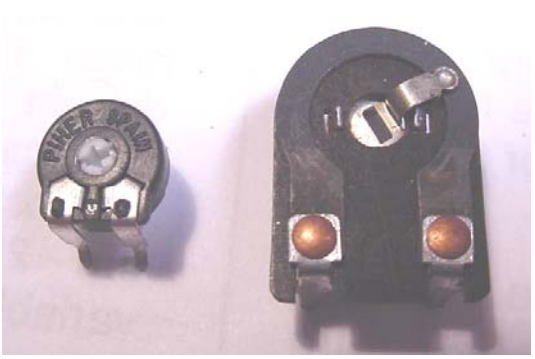
above, I tend to use higher wattage ratings than originally specified. Do not use wirewound types as a substitute for other resistor types – especially in RF and IF circuits – unless of a special construction, these generally have a significant inherent inductance that can easily upset the operation of tuned circuits (acting as chokes or coils). Also, be wary of using low wattage film-type resistors in critical RF stages (tuned circuits) of VHF and UHF sets due to their small, but potentially problematic, inductance value (the resistance element film is sometimes etched into a spiral as part of the manufacturing process, effectively forming a small coil) – this is the only application that carbon composition types are preferred (modern carbon composition components tend to be much more stable than those used pre-1970's). All these types can be purchased in ¼ watt through 2 watt ratings, usually at 2% or 5% tolerance: I do not use anything below ½ watt rating for valve sets and tend to use 1 and 2 watt resistors the most. I tend to buy them locally for a few cents each (in packs of 2 to 10).

Wirewound Resistors: Porcelain-body types tend to command a price premium and I

tend to use the cheaper ceramic body types. These are available in 2, 5, 10 and higher wattage ratings and are ok as replacements for other types. 20% tolerance is usually ok. Cost tends to be around $1.50 each locally, singly or in packs of 2. Hard-to-find multi-tap wirewound types can be replaced using several fixed wirewound units of suitable wattage ratings strung together in series/parallel arrangements to give the correct resistance values.

Variable Resistors (pots): Physical size often dictates what can be used, as well as if the pot has a switch attached. AF gain pots are log-law 'tapers' and must be replaced with the same taper: use of a linear taper will make adjustment of the set volume very difficult. As previously noted, RF and IF gain pots (linear taper), usually working in the cathode circuits, have a DC

component flowing through the track/slider, hence the need for wirewound-type components here. Also, the wattage rating should be taken into account – carbon slider pots can dissipate very little power, whereas wirwound units can dissipate up to several watts. In order to preserve a semblance of authenticity, I remove 'tested good' pots from old scrap valve radios, clean them and store them for re-use: whilst typical valve radio AF gain pot values of 250kohm through 2mohm can still be purchased at low cost (around $2.50 locally), modern units tend not to look the part, especially if chinese characters are stamped into the plastic or metal body – though ‘out of site out of mind’ may be an ok philosophy if look-alike repalcements are not available. Tone controls tend to be linear taper carbon track units and these are readily available.



Preset pots also come under this category: in my experience the ‘cermet’ track types are pretty reliable, as are the sealed carbon-track types. The cheaper variety, with exposed tracks (one on the right of the photo), are prone to corrosion and dust problems with age. They can, however, be cleaned up easily using a Q-Tip and some Servisol or De-Oxit cleaner. None of these types are present in valve Eddystones I have encountered though.

Closure

Well, that is about it on resistor ‘Lore’ – these humble (though prolific) components, often thought to be sleepy little passive devices, can cause all sorts of headaches and must be treated with respect. As with my article on capacitors, 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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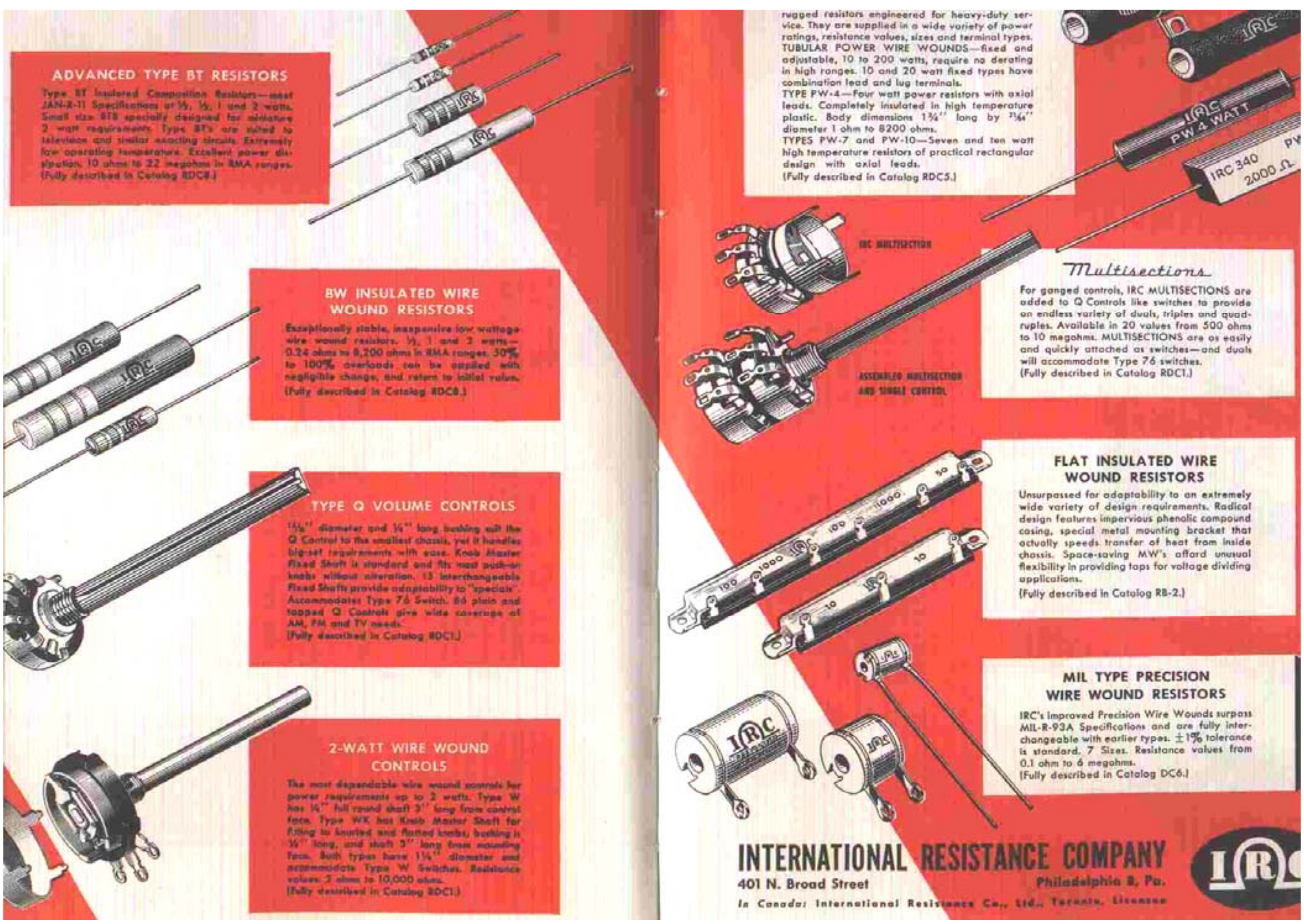
Some Useful References

- Electronic Components Handbook, TH Jones, 1978, Chapters 4, 5 and 6
- Radio Communications Handbook, RSGB (eg. 4^{th} Ed, page 1.6)
- Radio Amateurs Handbook, ARRL (eg. 57^{th} Ed. page 21, 518)
- Radiotron Designers Handbook (Langford-Smith), 3^{rd} and 4^{th} Editions
- Restoration of Valved High Frequency Communications Receivers, Chris Parry, G8JFJ (http://www.vk2bv.org/radio/), section 11.2
- Various EUG Lighthouse articles, including:
    - Power Supply Problems in Eddystone AC/DC Receivers by Tor Martinsen
    - Eddystone Receiver Repairs for Beginners – Part 5 by Peter Lankshear (Issue 75, p31)
    - Duffers Guide to Valve Set Fault Finding – Part 4 by Graeme Wormald (Issue 89, p38)
- Some web-based articles/resources on resistors include:
    - http://www.dannyg.com/javascript/res/resload.htm
    - http://www.uoguelph.ca/~antoon/gadgets/resistors/resistor.htm

- o http://search.globalspec.com/productfinder/findproducts?query=Resistors&se=bus&BDCDCMP=6288
- o http://www.fda.gov/ora/Inspect_ref/itg/itg31.html
- o http://www.vintage-radio.com/repair-restore-information/valve_resistors.html

Over 50 years old and still going strong when removed from a scrapped piece of radio kit – this large-wattage glazed porcelain body wirewound had obviously been many times over-rated for the application – not the slightest hint of discolouration or crazing of the body. I guess size and cost were not a consideration here…



1954 Resistor advert