Heathkit of the Month #93:
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KIT RESTORATION
Heathkit CS-1
Condenser[1] Substitution Box.

Introduction:

Back in Heathkit of the Month #038 the Heathkit CS-1 Condenser Substitution Box was covered[2]. Later, that CS-1 substitution box was used to temporarily replace a suspect capacitor in an old communications radio. The capacitor was a 0.015 µf 400V paper capacitor but using the substitution box resulted in making the problem worse. The faulty capacitor was completely removed from the radio and checked on the Heathkit IT-11 Capacitor Checker (HOM #002)[3]. While the capacitance was within 20% of its marked value, the capacitor had excessive leakage at 400V and even all the way down to 150 volts. The capacitor location was bridged with a new capacitor on hand for another project and the problem disappeared. The CS-1 must have some problems, so it was put away for a rainy day project.Recently the CS-1 capacitor substitution box was again needed; it was time to check and restore it.

CS-1 Preliminary Evaluation:

The 18 capacitance values were each measured with a digital capacitance meter, then the IT-11 was used to evaluate leakage; the IT-11 is able to evaluate capacitors up to 600 volts for excessive leakage. The equivalent series resistance (ESR) was also approximated using the size of the eye tube opening on the IT-11. **Table I** shows the results. All but four of the capacitors needed replacement.

Here is a link to the index of Heathkit of the Month (HotM) articles:

http://www.w6ze.org/Heathkit/Heathkit_Index.html

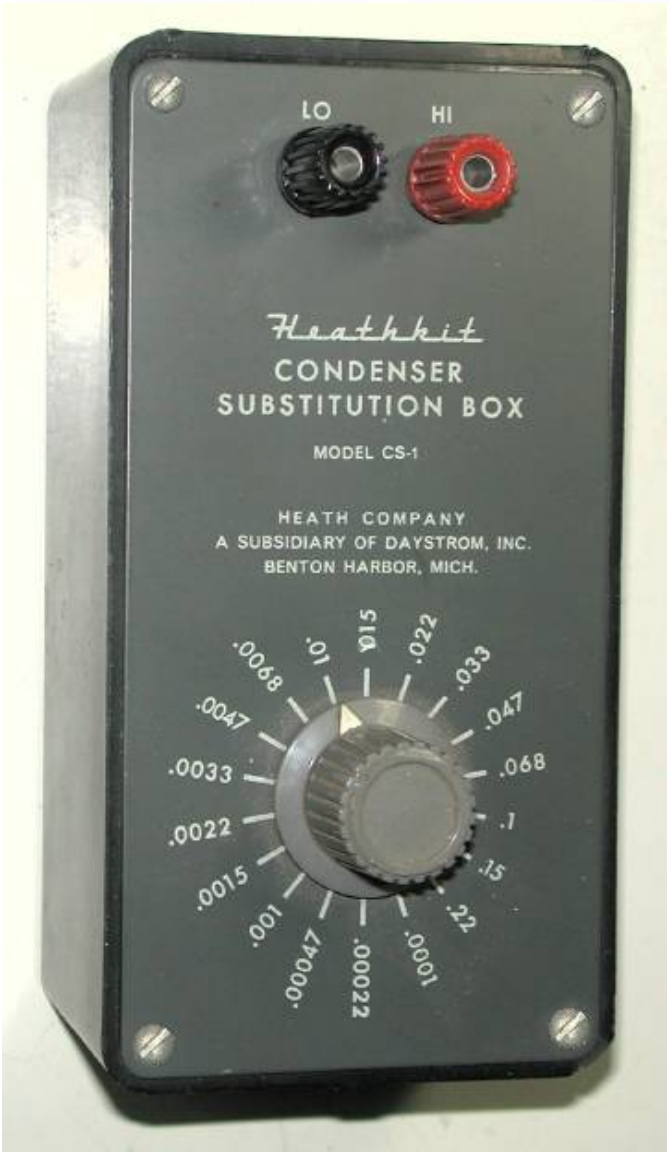

Figure 1: The Heathkit CS-1 prior to restoration

Obtaining Replacement Capacitors:

The CS-1 uses 18 capacitors starting with three mica capacitors of 100, 220 and 470 pf. Beyond those, they range from 0.001 µf (1000 pf) to 0.22 µf in a 10, 15, 22, 33, 47, 68 sequence. Other than the three mica capacitors, the rest are axial tubular paper capacitors. Some years back paper, as a capacitor dielec-

ORIGINAL HEATHKIT CS-1 CAPACITOR EVALUATION										
		Marked			Measured					
#	Units	Value	Tol.	Volts	Value	Tol.	Leakage Voltage	Excess ESR	Brand	Cap. Okay
1	pF	100	5%	500	106	6.0%	> 500	no	Sangamo, Silver Mica	NO
2	pF	220	5%	500	219	0.5%	> 500	no	Sangamo, Silver Mica	YES
3	pF	470	5%	500	467	0.6%	> 500	no	Sangamo, Silver Mica	YES
4	nF	1.00	10%	600	1.50	50.0%	< 500	yes	Sangamo, Type 33 molded paper capacitor	NO
5	nF	1.50	10%	600	2.30	53.3%	< 400	no	Sangamo, Type 33 molded paper capacitor	NO
6	nF	2.20	10%	600	2.60	18.2%	< 450	yes	Sangamo, Type 33 molded paper capacitor	NO
7	nF	3.30	10%	600	4.20	27.3%	< 400	yes	Sangamo, Type 33 molded paper capacitor	NO
8	nF	4.70	10%	600	5.80	23.4%	< 450	yes	Pyramid IMP molded paper capacitor	NO
9	nF	6.80	10%	600	9.70	42.6%	< 450	yes	Sangamo, Type 33 molded paper capacitor	NO
10	µF	0.010	10%	600	0.012	20.0%	< 500	yes	Pyramid IMP molded paper capacitor	NO
11	µF	0.015	10%	600	0.021	40.0%	< 50	yes	Sangamo, Type 33 molded paper capacitor	NO
12	µF	0.022	10%	600	0.031	40.9%	< 500	yes	Pyramid IMP molded paper capacitor	NO
13	µF	0.033	10%	600	0.040	21.2%	< 200	no	Sangamo, Type 33 molded paper capacitor	NO
14	µF	0.047	10%	600	0.055	17.0%	< 200	no	Micamold Tropicap molded paper capacitor	NO
15	µF	0.068	10%	600	0.088	29.4%	< 50	no	Sangamo, Type 33 molded paper capacitor	NO
16	µF	0.100	10%	600	0.112	12.0%	< 350	no	Sangamo, Type 33 molded paper capacitor	NO
17	µF	0.150	10%	400	0.148	1.3%	> 400	no	Pyramid IMP molded paper capacitor	YES
18	µF	0.220	10%	400	0.220	0.0%	> 400	no	Pyramid IMP molded paper capacitor	YES

TABLE I - Evaluation of Original CS-1 Capacitors

tric, was replaced with polypropylene film for lower capacitance values and polyester film for the larger capacitor values. These dielectrics are coated with metal resulting in smaller physical sizes with higher voltage ratings. **Figure 2** shows the nine largest capacitors removed from the CS-1 above their replacement capacitors. Note the significant difference in physical size.

Axial capacitors are becoming harder to obtain, and their prices are rising as demand diminishes. Mallory/CDE series 150 capacitors, used as replacements, are getting scarce unless bought in large quantities. Good quality axial capacitors may still be obtained through *Just Radios*[4] at reasonable prices. These newer capacitors are not just smaller, they are expected to have a much longer and more stable lifetime due to their polymer film dielectric material. The fifteen capacitors that replace the paper axial capacitors cost a total of $7.61. The three smaller mica capacitor replacements (500V) were in-house, but near completion of the restoration the decision was made to upgrade them to

1KV mica capacitors, which will be purchased in a future order. Thus the original micas were tack-soldered in-place awaiting the arrival of the new capacitors.

Disassembly of the CS-1:

The CS-1 was completely disassembled and all solder terminals were cleaned. The switch was lubricated and the contacts cleaned. The old capacitors were discarded as was the "condenser mounting unit" which is a question-mark shaped piece of #10 solid tinned buss wire. More on this part later.

Reassembly of the CS-1

The original layout of the CS-1 was tight due to the large size of the original capacitors (See **Figure 3**). The twelve smallest capacitors (0.0001 µf to 0.022 µf) mount vertically from the switch to the curved part of the "condenser mounting unit". The manual instructs that the leads be cut to the specified length and that the spacing between the top of the largest of these capacitors (0.022 µf) and the mounting unit be at most 1/8". The remaining six capacitors are too large to

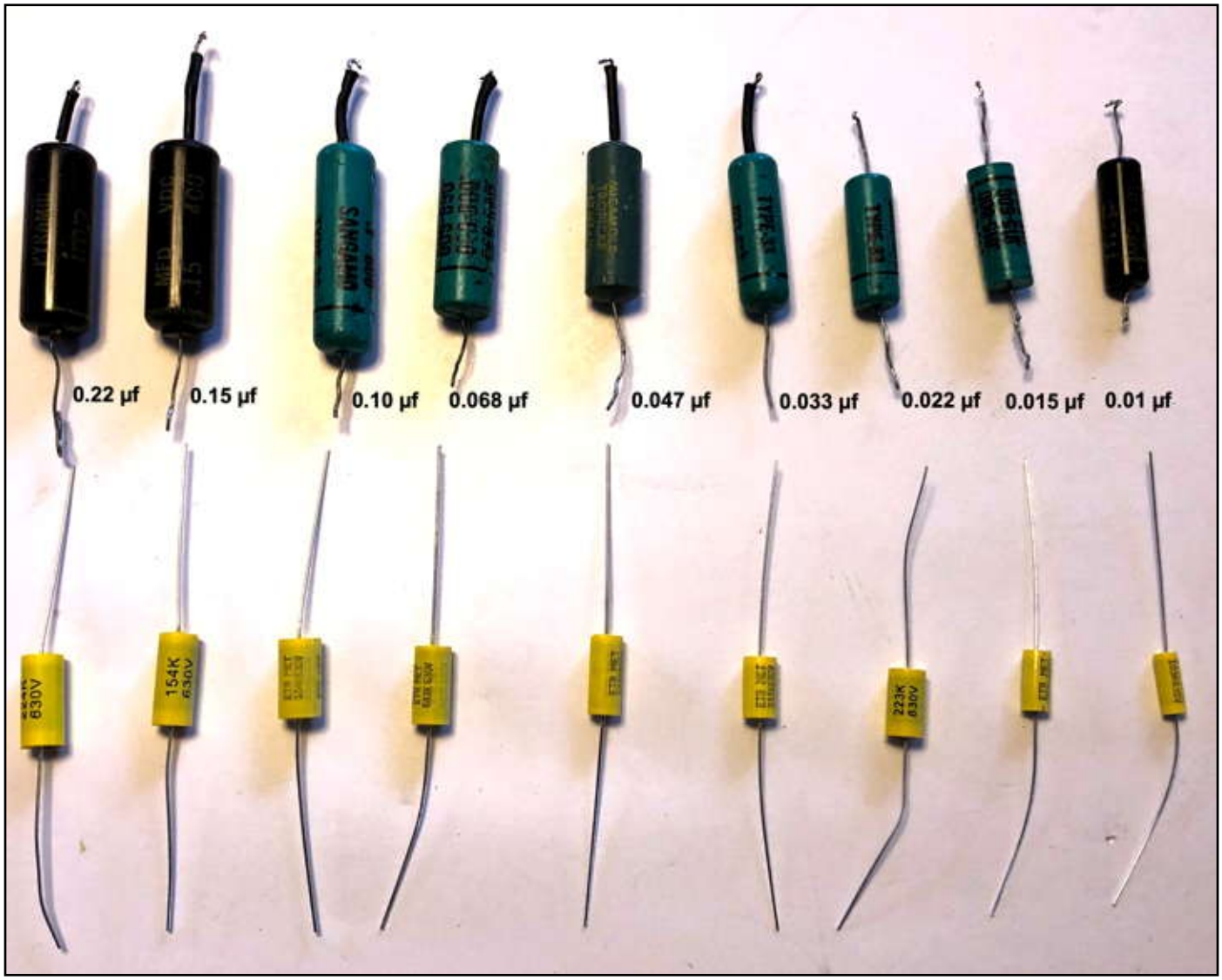

Figure 2: size comparison of the nine largest capacitors and their replacements. The voltage rating of the old capacitors are 600 VDC except for the two largest, which are 400 VDC. All the newer capacitors are rated for 630 VDC.

Figure 3: Internal view of the original CS-1.

mount vertically and mount horizontally with their common lead connecting either to the straight part of the mounting unit or the black terminal solder-lug.

Reassembly begins with reinstalling the switch, plastic insulator and the two binding posts per the manual instructions. **Figure 4** is the partially assembled CS-1 awaiting the addition of the capacitors.

Due to the smaller size of the replacement capacitors a new "condenser mounting unit" was fabricated. The plan was to fabricate it from #10 soft drawn solid copper wire and then work-harden it so it will keep its shape well. Home Depot sells solid #10 SD copper

Figure 4: partial reassembled CS-1 awaiting capacitor installation

wire[5] by the foot. Unfortunately the pickup date kept slipping, and finally, in desperation some #12 solid copper wire that was on-hand was used. The new mounting unit has a complete 2" diameter circle and with an 'L' shaped tail that terminates at the black common capacitor binding post lug.

Prior to installing the mounting unit all the capacitors should be soldered to their correct switch terminal. With the physically smaller capacitors it is possible to mount all the capacitors vertically around the switch, with room to spare, and easily clear the back of the cabinet. This is done with the lead between the capacitor and the switch terminal formed in a 'U' shape so one end of the capacitor can mount close to the front panel. Now the new "capacitor mounting unit" shape can be adjusted and trimmed for best fit. The unit should be about 1/4" above the end of the largest capacitor, but there is lot's of room to play with. This will give plenty of clearance between the mounting unit and

the back of the bakelite cabinet. Before installing the mounting unit, get a plastic or rubber hammer (or use a metal hammer and and a soft piece of fabric between the copper and the hammer) and tap the copper with the hammer against a solid piece of metal along its length and around the wire's diameter. A small anvil helps for the circular part. The idea is to work-harden the copper wire without flattening it. You'll notice the wire becoming stiffer as you proceed. Work the circular part heavier than the tail as it will tend to anneal (get softer again) when the wire gets hot due to soldering[6].

Now solder the mounting unit tail end to the common binding post lug and carefully solder the top capacitor leads to the ring end. Finally, don't forget the wire that goes from the red binding post lug to the wiper terminal of the switch. Alpha #22 stranded 1000V wire was used (Alpha type 1551). Heed the following warning for your other projects that use voltages over 300 volts.

CAUTION

When restoring older tube-type electronics, especially transmitters and other devices that have voltages above 300 VDC, be sure to use appropriate voltage rated wire.

A lot of today's wire is intended for lower voltage applications and is only rated for 300 VDC, sometimes even less. Wire rated for 600 V and 1KV is available but hard to find in hobbyist stores. Spaghetti tubing can also be used to increase the insulation properties of wire.

Figure 4: Completed wiring for the restored CS-1. Note that the three mica capacitors in the 10 o'clock to 11:30 o'clock position are just tack-solder in position awaiting replacement with 1KV silver mica capacitors.

Finally it is probably a good idea to make a new set of test leads for your CS-1. One red and one black. Banana plugs and alligator clips are still easy to find, as is quality test wire (thought the price has gone up).

Summary:

There are still many CS-1 Condenser Substitution Boxes and their descendants in use in ham shacks and electronic labs, it is likely their components have deteriorated with time. This has always been a handy piece of test equipment. Heathkit first released the

CS-1 in 1956 and followed it with the IN-22 (1962), IN-47 (1967) and finally the IN-3147 (1977) which remained in production into the 80's. When the IN-47 replaced the IN-22 they replaced the word "condenser" with "capacitor." All are very similar to the CS-1, and many of each model were sold. They can still be used with transistorized equipment, and at the lower voltages leakage may be less of a problem than ESR and the length of the test leads.

What's Next?

The IT-11, mentioned near the beginning of this article, is getting old, other than an oscilloscope and VTVM, it is probably one of the most used test equipment items in the shack. It is due for a full restoration; Perhaps that will be a future article.

Meanwhile there is a Heathkit IP-27 LV Regulated Power Supply on the shelf that would make a good topic. I have the manual but have not plugged it in since I got it. This too would make a good topic. Anyone have any other ideas for kits to write on?

73, from AF6C

This article originally appeared in the July 2019 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

Notes:

1. The electronic industry replaced **condenser** with the more descriptive word **capacitor** in the fifties or sixties. The exact date is elusive.
2. www.w6ze.org/Heathkit/Heathkit_038_CS1.pdf
3. www.w6ze.org/Heathkit/Heathkit_002_IT11.pdf
4. www.justradios.com A supplier of capacitors and resistors. They are located in Canada, but ship from the US. I've placed numerous orders from them, and have always been happy. They have a $20 US minimum order so plan ahead or pool orders if you are purchasing just a few items.
5. Home Depot item #10626090 Southwire 10-Gauge Solid SD Bare Copper Grounding Wire 34¢ per foot.
6. Google "Tempering copper wire" for some You-Tube videos on tempering and annealing copper wire.