The Signal

OFFICIAL MAGAZINE OF THE COLLINS COLLECTORS ASSOCIATION * Q4 2016 Issue #84

Jim Stitzinger, WA3CEX

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Collins Collectors Association

From the President's Desk…

As the new CCA President, I wanted to take this issue and give you all a brief account of my journey into amateur radio. I am Jim Stitzinger, WA3CEX, born in 1950, and raised on a small farm in Bucks County, PA, where there was plenty of room for equipment, towers, antennas, and yes even field day with a vertical wire hanging from a helium balloon. A fascination with radio began early, as there were always many old cathedral radios and televisions to take apart. My world became focused on amateur radio when a National NC-109 arrived Christmas morning under the tree. The glow of the orange and purple tubes filled my mind with wonder for many years.

By high school study halls were consumed with NRI study books and ARRL license manuals, and this lead to the novice test. My first Elmer, Chuck Curtis, K3QJT, invited me to pull a wagon to his house where he helped me build a home-brew 20 watt, 80 meter CW rig. Later came a Ranger I, and NC-270 to support a General Class License.

Next came a used SX-115 and an HT-32/33. My world expanded to a First Phone License and radio broadcasting at WBMR and WFMZ-FM in Allentown, PA, Also restoring WW2 Jeeps, and my first venture into Collins Radio with a KWM-2 and an NCL-2000. This lasted through the teenage years, early Seminary training, and marriage to Debby. There were many Sunday afternoons doing phone patches from Minneapolis back to PA with the KWM-2 while in Graduate School, with the wonderful help of a second Elmer, Horace Wolf, W3BPJ. After these years a lot of radios had to be sold to pay for the needs of a growing family with 4 young children and the purchase of many library books.

After moving back to PA, I began a vocation of teaching Historical Theology and Apologetics, while putting together a massive Theological Seminary Library. The hobby of Collins Radio grew as well, and I was finding amazing quality Collins S-line equipment during the 70's. I also dabbled in Multi-Track audio recording. This lead to a trip to Nashville to buy Elvis Presley's personal 16 Channel Ampex tape recorder which I sadly sold some years later.

The building of College and Seminary Libraries expanded with the eventual relocation to Southern, CA in 1987 to build several large libraries for the Master's College and Seminary. During these years radio acquisitions and operation of Collins and Rockwell Radios continued, as well as other high-end equipment including National, Harris, Racal, Sunair, Watkins Johnson, and Rohde & Schwarz among others. Around 1990, I realized I could not support all of these different units and decided to sell everything in order to leave a more narrow and in-depth focus on Collins and Rockwell equipment.

At this point, I set out to locate all the existing Collins amateur dealerships and visit those that still remained. There was much literature, signs, clocks, parts, and memorabilia to be found, including the Collins Communication Van. Among the vast amount of literature was the HF-80 catalog, which opened a whole new opportunity of collecting and operating. This lead to establishing a vendor relationship with Rockwell Collins and the sale of a lot of HF-80 equipment back to the factory. This relationship provided an opportunity to fund my collecting hobby and to meet many quality Collins and Rockwell engineers in Cedar Rapids and Richardson. Some have remained wonderful friends to this day.

In the succeeding years, I put together collections, including Post-War Collins, A-Line, S-Line Equipment, HF-380, HF-380A, and HF-80 Rockwell Collins, along with a website HF-80.com. In addition, I collected the Collins operating desks, several Rockwell Collins AN/TSC60(V) Com Central Shelters, and a 1956 M-38A-1 Jeep with a Collins TRC-75 1 KW radio from the Viet Nam era. Also included is the huge Rockwell Collins twin tower 237B-3 2-30 RLP (Rotating Log Periodic) antenna, some Post-War large Collins transmitters, some Collins Broadcast Equipment, and almost all of the Collins Receivers (each with its own innovations) as well as some of the Collins Green Military Radios. There was also time to collect old Collins-made tubes from the period 1936-38, during the RCA lawsuit, some Collins prototypes including the 30S-2/3, a Collins research Library of over 6000 items, and Collins and Rockwell Memorabilia including the original factory punch card time clock and office typewriter. The most recent collection has been Collins Pre-War equipment beginning in 1933. The earliest piece is the Collins 150B. I have been privileged to work closely with J.B. Jenkins, W5EU, Gary Halverson, K6GLH, and Parker Heinemann, W1YG. These men are giants in Pre-War Collins history.

My vocation as a professional Librarian and Historian has been bridged with a Collins advocation "on steroids" in one combined effort. At age 66 I am and very much looking forward to leading the CCA following the great leadership of Bill Wheeler, Floyd Soo, Sandy Meltzer, Butch Shartau, Bill Carns, Scott Kerr, and others. I have been richly blessed in the Collins and Rockwell hobby and look forward to sharing what I have learned with all of the CCA and learning from all of you. I recently joined the board of the Arthur A. Collins Legacy Association and trust all of this, along with our strong ties to the AWA, can help preserve the amazing unfolding story of Arthur Collins and the Collins Radio Company for a future generation.

Jim Stitzinger, WA3CEX
President, CCA

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OFFICIAL JOURNAL OF THE COLLINS COLLECTORS ASSOCIATION ©

Issue Number Eighty Four - 4th Quarter 2016

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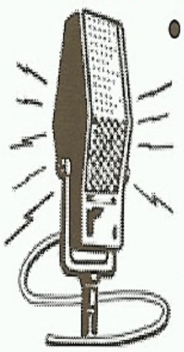

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You can renew your membership or join the CCA on our website using the "JOIN US" link.

From the Editor

In this issue of the Signal, we have the second and last half of a two part article written by Bill Carns, N7OTQ – our past President and past Signal Editor. Bill took on the job of rebuilding a 30S-1 for a friend and it turned out to be a huge job! I think this is our first in-depth look at the 30S-1, which actually shows how robust this 1 KW amp is after 50 some odd years of service! Bill shares his experiences of solving some of the problems that one might encounter in restoring one.

The second article is one written by our Technical Editor, Don Jackson W5QN. Don took on the job of unraveling the mystery of S-line crystals and why they might react differently in different S-Line radios. He did lots of testing and concluded that design changes over the years gave various receiver/transmitter versions capacitive loads in the oscillator. His attention to detail unravels this mystery – one that is discussed many times on the reflector. He also gives tips on ordering S Line crystals. Great work, as always, Don.

Also, please see the summary of the Board of Directors changes below, along with the Bio of our new President, Jim Stitzinger WA3CEX on page 2.

As Bill used to say – Enjoy!

Editor in Chief,
Scott – KE1RR

The New CCA Board of Directors:

Jim Stitzinger WA3CEX – President
Ron Mosher K0PGE – Treasurer
Dennis Kidder W6DQ – Secretary
Jim Hollabaugh K6TMU – 20 Meter Net Manager

Please go to CollinsRadio.org and you can see full details on each board member.

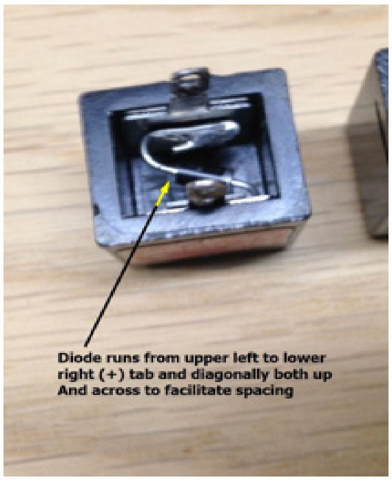
30S-1 Bias Supply Overhaul - Part 2

By Bill Carns, N7OTQ

Assembling the new rebuilt "Faux Selenium" 1N4007 diodes

Take all of the empty cases and carefully rough up the inside wall being careful to not apply a lot of pressure to the sidewall. Set all of the "empties" aside. Find a slab of plywood or board that will be the set-up fixture and drill enough holes in the board so that you can line up the cases with the studs down in the holes so the epoxy can cure. Make the holes just slightly smaller than the outer thread diameter so that you can roughly screw the cases into the board. Also note that when soldered (and flat) the two contact lugs are not facing the same direction. They will be after being bent into position.

Now, finish soldering up as many sets of salvaged contacts and 1N4007s as you will need. Use the diagram and pictures as a guide and make the little "Z" diagonal structure shown that will then fit into the cavities. DO NOT FORGET TO HEAT SINK the little diodes for their protection while soldering.



Finished Diode structure and placement in the cavity for fit

If you are shaky and old like me, use a short piece of shrink tubing over the top of each solder lug to make sure you do not get epoxy on it. You can cut it off later when the epoxy is cured. Do NOT run the tubing all the way down. Leave room for the epoxy. The tubing should go down to just at the bottom of the solder lug proper. Shrink the tubing so you can push on it later without moving it down. I did not do that and I wish I had.

Testing: Using a good grade epoxy (not fast curing), mix a small test batch of epoxy and test fill one extra empty salvaged diode housing. I used Locktite Long Cure which sets in about 30 minutes and comes to holding strength in 3 hours and full cure in 24 hours. (It also has a yellowish cast to it which mixes well with a small amount of brown pigment for that tan color. See below.)

Note: Each cavity is almost exactly 2 mL in volume less the contact and diode assembly. I would mix up about 4 mL of epoxy for each unit you are doing so it is controllable. The Locktite dispenser holds 25 mL of product so about 1/8 of a stroke of the applicator will give you enough for one cavity taking into account the losses during mixing and loading.

You do not need to bother with putting in the contacts on this test. You are just going to test for shrinkage during curing so you know how full to make the cavity when you fill the final product. Come back tomorrow and check the test cavity and decide how much you need to overfill for shrinkage. At the same time that you test for shrinkage, mix a small amount of brown pigment or oil based paint into the epoxy if you are anal about the color – like I am. A little goes a long way. If you use the Locktite Long Cure I recommend, there is no need to test. The shrinkage is zero.

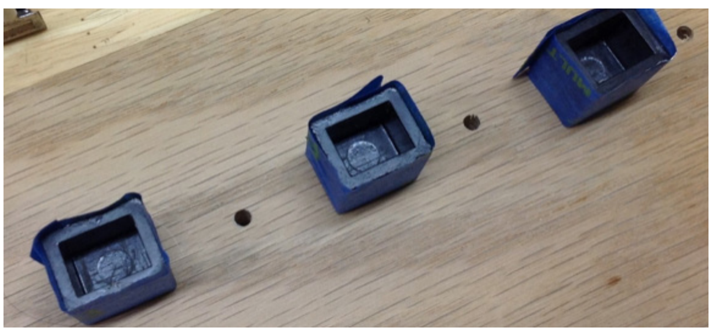
While the test is curing, talk with your local large animal vet and convince him you are not a druggie and get a few new large animal 60 mL syringes to use to place the final epoxy potting. You need the wider needle opening version. 60 mL syringes can be bought on the internet or eBay for about $2.50 each. They are real handy. My vet sold me some for the same price.

Time for the final assembly of the 1N4007 diode stuffed Model 50 product.

Now, cut a couple strips of tinfoil that are just as wide as the long edge of the case. A width of ¾ inches works well. It gives you just a little overlap so that you do not have to be super careful about the alignment. Grab a roll of masking tape or painters tape and cut as many rectangles of foil as you have labels to cover. Make the rectangles just cover one side of the cover. Finally, cut as many strips of tape 4 inches long as you have cavities and put one of those pieces of foil on each piece of tape on the sticky side in about the middle of the tape (the long way). You are going to use that foil to protect that nice label you are trying to save from being destroyed when you pull off the tape after curing. See above picture.

Hint: Cut the tape 4 inches to start with and then tuck each end around and down so it will stick to the work surface sticky side up. Then place the foil about in the middle. Then, after the foil is in place, pick the tape up by the foil area where it will not stick to your fingers and trim the tape back to three inches long. This will save you a lot of grief trying to hold that sticky tape while you place the foil.

Now, place each piece of tape against the housing making sure you align the foil with the label side - But, make the top of the tape protrude about 1/8 inch above the cavity lip. Finish wrapping the tape around all sides of the case keeping it all parallel and pulled tight to both sides of the label so you do not upset the alignment. Then make sure you wind up with a small protrusion all around the top. Now you have a little "dam" that will hold back the top fill of the epoxy after you determine how much extra to allow for shrinkage. If you apply the correct amount of epoxy you will not need much of that lip, but it is there for protection and to help you ID the label face of the package.



Plan on mixing up enough epoxy to fill the units you have prepared. Then 2X it for losses and loading of the syringe. More is better and you do not want to run out. Put just the smallest amount of pigment into the mix and get it thoroughly mixed and the light brown color you want. You can always add more. Do not overdo the pigment. It does not take much and you do not want to destroy the chemistry of the epoxy.

Have everything ready because once you mix that epoxy and get the color right, you will have to move right along so that the epoxy does not start to stiffen up in the syringe in-between the "Half Fill" load and the final top off.

When you load the syringe, make sure to tape the tip over temporarily before you load, or you will have epoxy running out of the tip before you are finished loading. When you are finished loading the syringe, hold the syringe laterally, and quickly take off the tape on the tip. JUST BARELY start the plunger (this will start to push out some epoxy so have a paper towel ready) and then – after wiping off the forced out amount, turn the syringe tip up and allow the air to come to the top. This will take a minute, but the tip will clear and the big bubble will go to the top and then you can push the plunger all the way in until epoxy starts to come out again. It is now ready to use. Stand it on its plunger handle if you need to "Park it" for a moment.

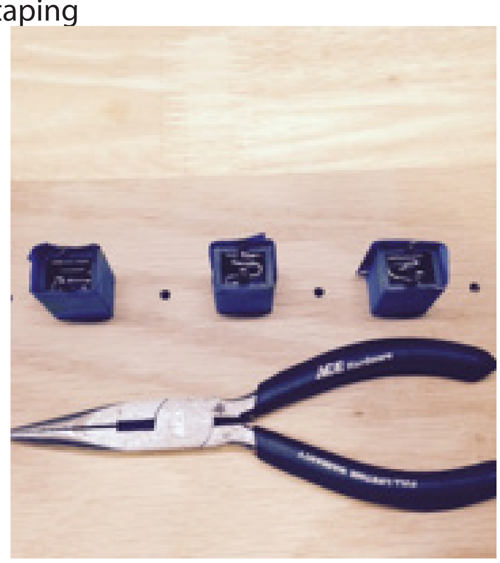
With all of the prepped cases screwed into the board, quickly take a Q-Tip shaft and some epoxy and wet the inside of the long faces where the contacts will fit. Do not get epoxy right up to the top. Stay down about 1/16 inch.

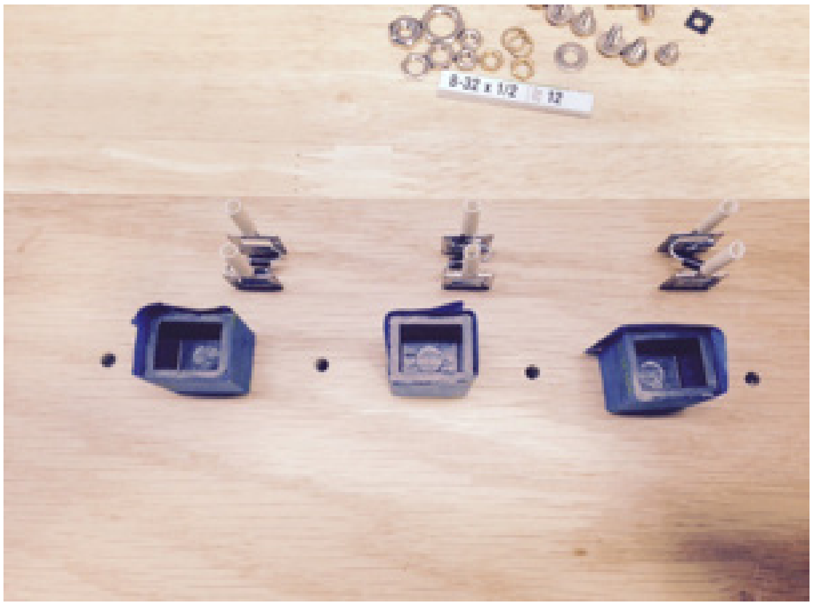
Now, using the syringe that you have loaded, fill each of the cavities just half way up. DO NOT OVERFILL AT THIS POINT – Just half will do. When you have enough in the "half full" step, you can "break the flow" by stopping pushing and then raising the syringe straight up until the epoxy beaks the little remaining thread and it falls straight back into the loaded cavity. Do not pull the syringe away until that thread breaks or you will drag a string of epoxy out of the cavity.

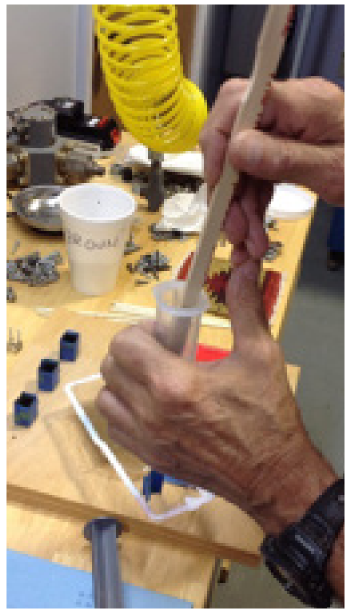
When the cavities are loaded half full, place one 1N4007 diode assembly into each cavity making sure that you center the contacts against each long face internally and that the tabs are parallel and vertical. Check the polarity before you push the assembly down into the epoxy - MAKE SURE that you have the cathode band of the new 1N4007 placed towards the label (Red + side on most diodes) side of the case. You can identify the label side by the small amount of foil sticking up above the inside of the tape on the case. Pre-stress the solder tabs by making the spacing just slightly bigger than the cavity (but parallel) prior to placement. Once you pour that final epoxy in there, you are not going to be able to move the solder lugs around too much without destroying the parallel geometry and/or getting epoxy up on the lugs – a soldering no-no! Get them the way you want them before the epoxy pour and then leave them alone except for the smallest of adjustments.

Fill the final amount carefully and slowly so it has time to settle, or you will wind up over-filling and using that tape dam.

Trial fit before and after taping



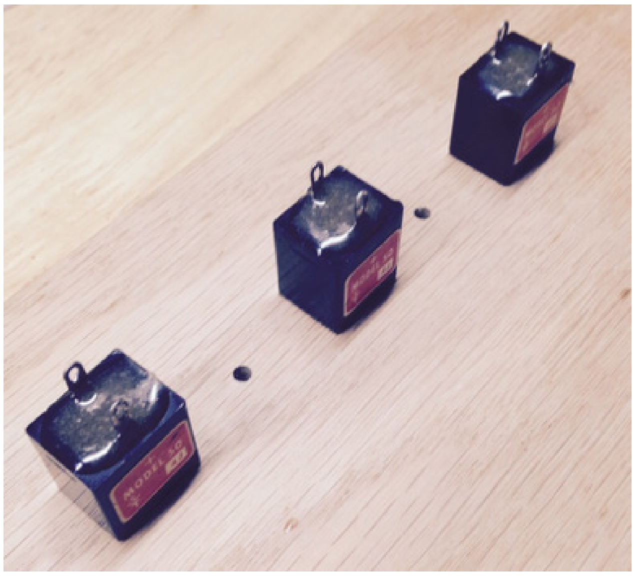




Ready for business – Left, the taped units waiting for pre-fill

Now, slowly inject the final needed amount of epoxy into the center from one side of each cavity. Apply it slowly so that the epoxy has time to flow into and under the diode connections and not make bubbles. Be careful not to bump the contacts or get epoxy on the contacts.

Now, be patient. Tomorrow is another day. While you watch "paint dry", you can start taking apart whatever it is that you are replacing those diodes in. For me it is that bias supply. Wait at least two days until you solder on the new diodes that you have made.



Ready for final component install and wiring of the bias supply

Using the replacement rebuilt faux Model 50s, the bias supply can now be reconstructed – returning it to its original look. Given that we started this journey low on negative bias, we get a bonus because, with the much lower forward voltage of the silicon 1N4007s, the resulting available negative bias will go up by about 7 volts just from that impact. What will happen due to the replacement of the diodes and the filter caps remains to be seen. I will say that the selenium Model 50s that I took out (paralleled with 1N4007s) were leaky, so this should also add up to a better bias pot range.

Those original filter caps were removed and carefully checked on a Sprague Tel-Ohmike TO-5 and they were in excellent condition - No discernable leakage on the 6 mA scale at 200 Vdc applied. The Power Factor was also measured and hovering around zero. Not too bad for their age (1983 date code). I could just not bring myself to putting in a new Chinese mini-electrolytic from the 21st century.

Below I have documented both the topside diode wiring and also (and more importantly) the bottom view wiring so that a unit can be returned to stock condition if it has been molested. The Collins Radio Manuals for the 30S-1 are sadly lacking - particularly in details about the under-shelf wiring and component placement.

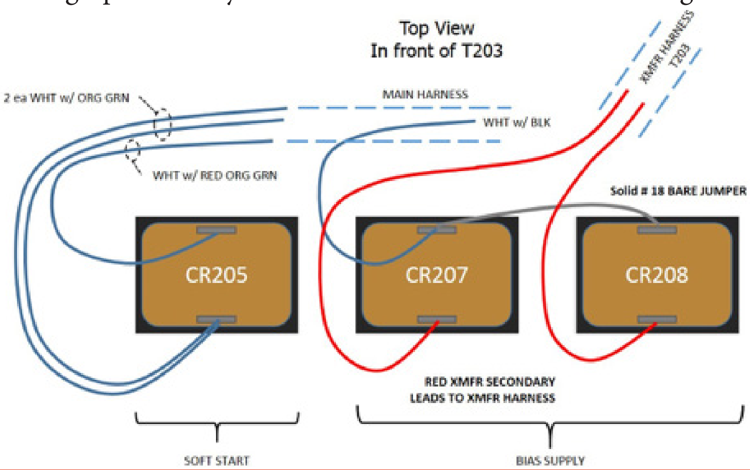
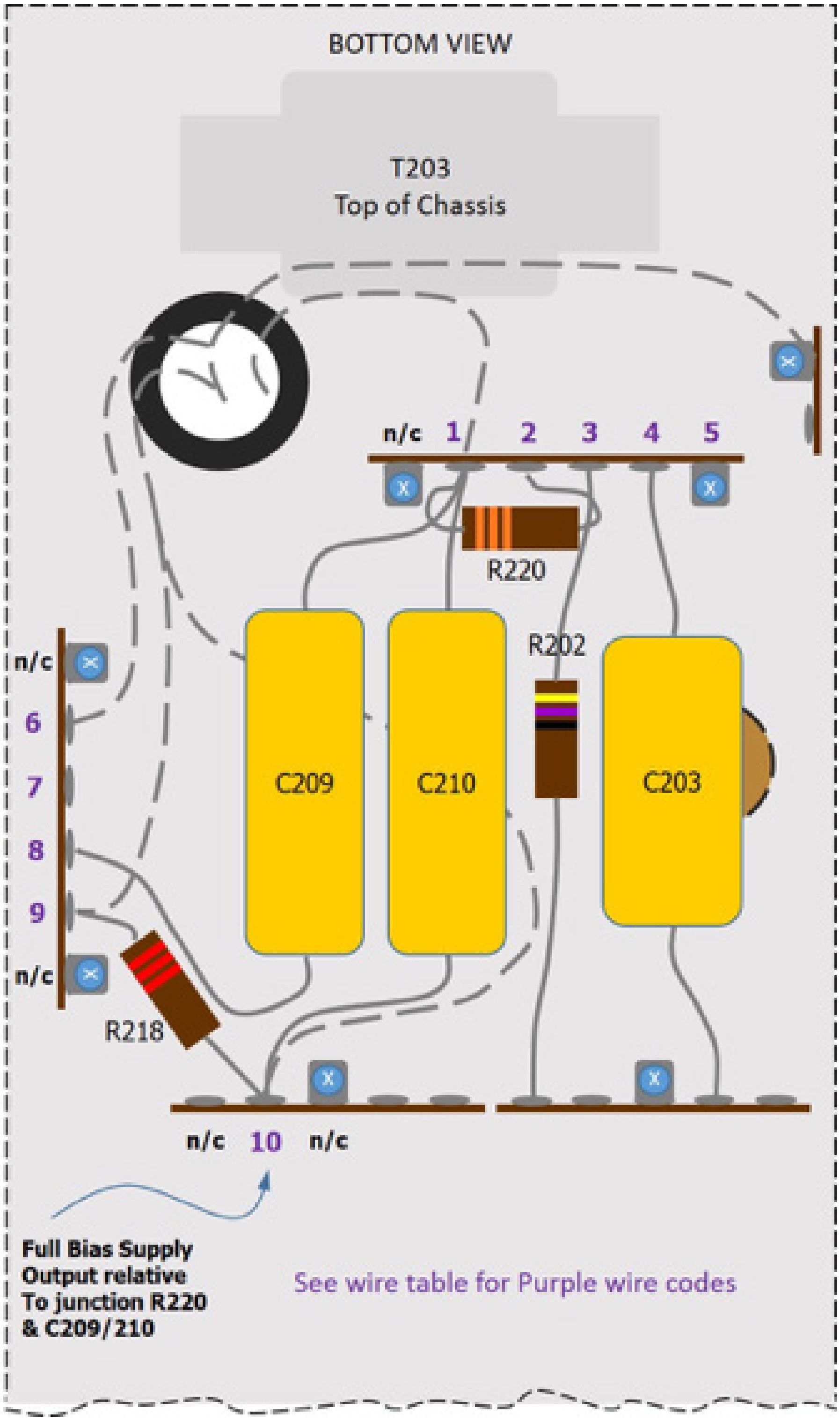


Figure of Diode Wiring for Replacement Diodes

Capacitor wiring aid diagram w/ color codes (See below table)



Wiring Code Table showing Terminal Lug Number (Purple)

Lug No.	Quan. Of Wires		Wire	Color 1st Code	2nd Code	3rd Code
1	3+ below	Bias Return	RED	YEL		
	+ 2 Caps + R		WHT	RED	BLU	
			WHT	RED	BLU	
2	1 + R		Wht	RED	GRN	
3	1 + R		WHT	RED	ORG	GRN
4	1 + Cap		WHT	ORG	GRN	
5	3	GND	SH'LD Gnd			
			WHT	ORG		
			WHT	ORG	BRN	
6	3		BLK (Small)			
			WHT	BLK		
			WHT	BLK	GRN	
7	3		BLK (Small)			
			WHT			
			WHT			
8	2 + Cap		WHT	BLK	GRN	
			WHT	BLK	GRN	
9	1+R		WHT	ORG		
10	2+R+Cap	Bias Negative	WHT	BLK		
			WHT	BLK	BLU	

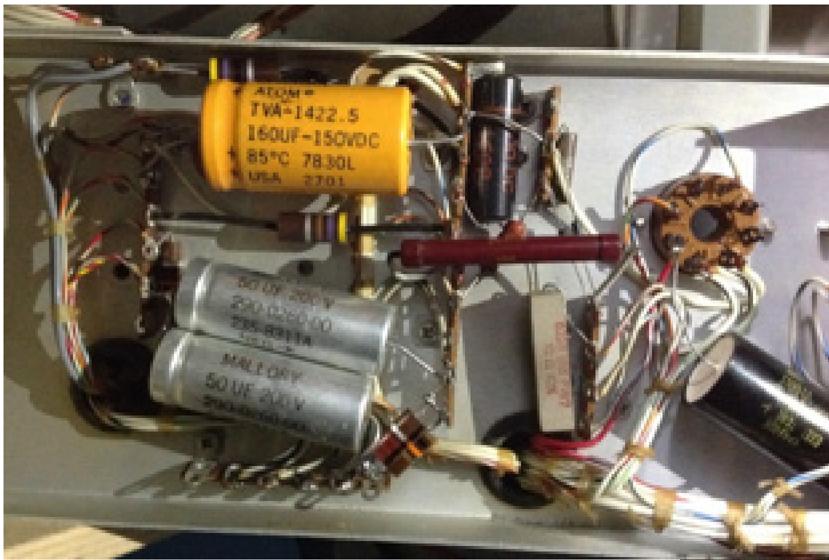
After the rewiring and replacement of the diodes and the capacitors, it is now time to reverse all those instructions and put the harness back where it belongs, then replace the HV lead (You do not want to forget that!) and then the shelf.

Use an old aircraft install trick and get yourself two nice awls. When you are aligning (and holding) the shelf in there and starting screws, use the awls to find and hold the back holes in alignment.

Do not start those sheet metal self-tapping screws with a power screwdriver. Get the holes aligned and start the screws by hand or you will wind up "re-tapping" new threads and after a couple of times having done that, those holes will strip out. When it comes time to put that cable clamp screw back in there, have your partner push a number 6 screw about 1 inch long through the hole and, from the inside, you put the clamp (in the correct position on the cable) and then the washer and then the nut down over the longer small screw.

That makes it much easier to find and get all the hardware where it belongs. Then, while you hold your finger around the clamp, washer, and nut, have your partner carefully pull the longer small screw out and slowly push the Pan Head Phillips #8 screw that belongs there back in the hole while you feel "center" and start to thread on the nut. Have your partner push the screw in with a screwdriver seated so it will not turn. Once started, then have your partner start to turn the driver in and tighten the screw. Leave that taped in "Catch Rag" in there just in case. It may take a couple of shots of trying to get that nut back on and you don't want to be chasing hardware around back in that blind area.

Be careful about getting the harness in the rear through the cutout and make sure you do not pinch any wires between the wall and the shelf. Here is what it looks like all put back together and reinstalled in the cabinet.



30S-1 Shelf Top & Bottom view as repaired

30S-1 Shelf Top & Bottom view as repaired

Above: Shelf back in place (with that "original" look)

Time for a test run.

For the purpose of checking out the supplies, just terminate the input RF port with a 50 ohm small dummy load to make sure no instability occurs, and then terminate the output in the normal 1 - 3 KW 50 ohm load.

This will allow powering up the amp and checking all of the supplies and the amp keying. Then, set up the idle current and make the bias voltage measurements to make sure the supply is back to normal operation. No RF is applied for now. Test leads can conveniently be run out the back through the 516F-2 shelf cable access hole and a VOM set on top of the amp while measurements are made.

Test Results

VC209 (Total Negative Voltage Available)	- 91.0 Vdc
VC208 (Bias Applied to Tube)	- 47.5 Vdc @ 150 mA idle(Tube 1)
VR219 (Bias Range R219 CCW to CW)	- 78V to - 33.0 Vdc

Commentary – or Shame on Me

These results were as expected and I went ahead and set the idle current up at 150 mA. Thus encouraged, I left the amplifier keyed for a while and monitored the idle current. It was drifting up with time and that is not as it should be. Inspection of the applied bias indicated that the bias itself was stable.

I suspected immediately that this tube – unknown to the owner and unknown to me – was a bit gassy. Time to do a little heat soaking with just the filament on and see if that helped.

I ran the amp – just the filaments for about 8 hours - and this morning I decided to apply the HV again and key it up and see if the idle current had stabilized.

This is where the shame on me comes in.

This was after all a completely unknown tube to both of us. We also knew that the previous owner had had difficulty with the amp and had tried to fix it himself. That having failed, the 30S-1 (and that tube) sat for 15 years before he finally sold the amp to Dwayne.

When I got involved, among other issues – now resolved – I knew that the bias supply was dinged. Shame on me.

Fortunately, my external biasing test harness was still in place and I also had the multimeter set on Grid Bias.

I lit off the HV and, before I could even key the amp, the plate flashed over to the grid and the grid meter and my test meter went sideways in a hurry. BAD! I hit the big off switch and pulled that tube….all the time fearing that I had just blown up that newly rebuilt bias supply. Good luck prevailed and all is well in that department.

But, there was collateral damage and it was aggravated by the fact that three fuses had been increased in order to capitalize on the installed 4CX1500B – Another bad plan.

So, as I said – shame on me. The first thing you do with a NOS long in storage – or unknown high power HV tube is Hi Pot test the darn thing plate to grid. If it is gassy, leaky, or has elements sagged from lateral long term storage, the Hi Pot tester will tell you right now. I got careless because it had run for a brief period a few months ago in my presence and I skipped that important step.

Now I am waiting for another NOS tube and doing diagnostics on the supplies. Tomorrow we will start the testing process for the amp itself all over again. This time I will not be skipping the Hi Pot testing. Stand By.

Supplementary Information

Model 50 notes:

Any Selenium rectifier current density is usually about 50 mA/cm2 of active area 1)
The Model 50 plates are almost exactly 1 cm2
Breakdown Voltage of a typical Selenium plate structure is 25 Volts per plate
The Model 50 has 8 plates and is rated at 200 Volts reverse breakdown

- Many of the Selenium rectifiers that have the blue plates typically have extended plate area for heat dissipation and this area should not be counted in the active area. Only plate, or layer, contact area counts when estimating the current density of a Selenium.

S-Line HFO Crystal Loading Capacitance

By Don Jackson, W5QN

Introduction

A few years ago, Gaylord Hart, WD7ODD, brought up a question on the CCA reflector concerning the oscillation frequency of the High Frequency Oscillator (HFO) in his 75S-3B and 32S-3 radios. The problem was that the same crystal, when plugged into the two radios, produced different oscillation frequencies. The difference exceeded the expected frequency deviation. My curiosity piqued, I decided to look into it a bit further.

What Impacts HFO Frequency?

Crystal parameters are the primary frequency control mechanism in the HFO. When you order a crystal for your radio, you may specify the frequency, initial frequency tolerance, temperature range and tolerance, aging characteristic, and mechanical characteristics. More often we simply call our favorite crystal manufacturer, tell him the frequency and the radio in which it is to be used, and the manufacturer will build the crystal to their internal specification for that radio. A key part of that specification is the load capacitance (CL) of the radio.

The load capacitance (CL) is fundamentally a characteristic of the oscillator circuit. CL is the capacitance that creates a parallel resonance at the desired oscillation frequency (FL) when connected in shunt with the crystal. A crystal manufacturer can then use CL to design the proper crystal unit for that oscillator circuit. Although the actual oscillator circuit usually operates with the crystal in its “inductive” region, a crystal manufacturer may test the crystal by placing the crystal in series with CL, which creates a series resonant circuit at the desired frequency of oscillation, FL. Note that CL does not apply to oscillator circuits in which the crystal operates at its “series resonant” frequency, Fs. For a “series resonant” crystal oscillator circuit, CL is not relevant.

The S-Line HFO circuit is an “electron coupled Pierce” design. Many of us are familiar with the common Pierce circuit, in which the feedback signal is fed back from the plate of a triode. In the S-Line circuit, the screen grid functions as the “plate”, while the actual tube plate functions as an isolating stage for the oscillator. This configuration provides excellent isolation of the oscillator from external circuitry. A description of this circuit may be found in “The Handbook of Piezoelectric Crystals for Radio Designers” by James Buchanan.

I spoke with Darell Brehm, WA3OPY, of International Crystal Manufacturing (ICM) about the specification they use when we order a crystal for the Collins S-Line. There are many parameters involved, but the primary ones we will be concerned with are the initial frequency tolerance and CL. The federal specification ICM uses (MIL-C-3098/3C) states the initial tolerance is ±50 PPM (Parts Per Million), and CL is 32 pF. Ignoring crystal aging, 50 PPM error for a 10m band crystal at 15.5775 MHz is about 779 Hz. However, taking into account that this fundamental frequency is doubled in the HFO on 10m, the error is doubled to 1.558 kHz. Since all S-Line radios theoretically should have the same CL, this 1.558 kHz error should approximate the most we should see with a new crystal, no matter what radio the crystal is installed in. Unfortunately, considerably larger frequency errors are observed depending on the radio. So, what is going on here?

What is Going On?

In a nutshell, the problem is that changes were made in the HFO circuitry over the life cycle of the 75S and 32S radios that changed CL of the HFO. The chart of Figure 1 shows the results of CL measurements on a number of S-Line radios that confirms this to be the case. Especially note the difference in CL of the 75S-3/B vs. 32S-3 radios. The combination of the a ±50 PPM crystal frequency tolerance in combination with the mismatch of a crystal designed with a CL of 32 pF, but installed in an HFO that has a much lower CL, accounts for the large HFO frequency differences seen between the two families of radios.

Although I haven't been able to definitively determine why Collins made the HFO circuit changes, Bob Jefferis pointed out that ASAB 1005 for the 75S-1/2 lowered C79 from 100 pF to 47 pF, apparently in order to increase the HFO drive to the mixer. Since C79 is analogous to C105 in the 32S-3, it is reasonable to assume that C105 was lowered from 130 pF to 82 pF for the same reason. If anyone has more detail on this, please let me know.

Test Results

To determine if Gaylord's observation was typical, I characterized three crystals from the 10m band and calculated CL for my radios with each of the three crystals. These three crystals were then tested in radios belonging to Bob Jefferis (KF6BC), Dick Weber (K5IU), Scott Kerr (KE5RR), Darell Brehm (WA3OPY), and Mike Sedgwick (K7PI).

For reasons that will become apparent, I decided to divide the results into two categories:
1) Comparison of standard 75S-3/B with 32S-1/3 radios.
2) Comparison of 75S-3A/C and 32S-3A radios, which have the additional crystal deck.

The results of category 1) are shown below in Figure 1.

Looking at the data, you can see three data points for each radio, representing CL for each of the three crystals. It is clear that CL is independent of the particular crystal used to calculate CL. The slight variation in CL is within the tolerance of the frequency and motional measurements. The most important thing to note is that the data makes it clear that CL is indeed different for the 32S3 than for the 75S-3/3B radios. Certainly this is not what the Collins engineers intended, but changes in the HFO design early in the 32S-3 production cycle lowered CL from the "standard" Collins S-Line value of 32 pF to a value of about 25 pF.

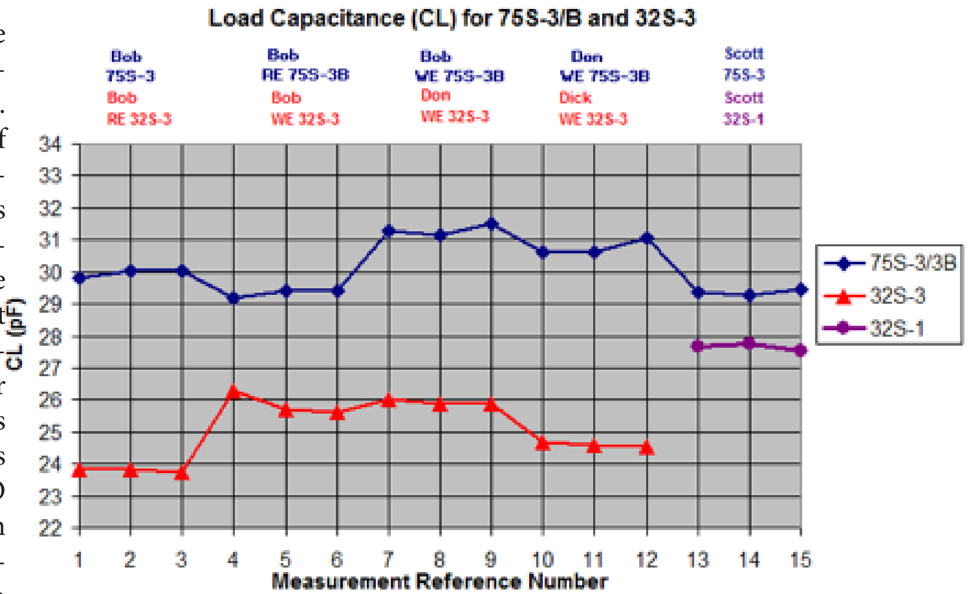


Figure 1 – CL for Standard S-Line Radios

The primary cause of this reduction in CL was the change in C105 from 130 pF to 82pF, but other changes had some impact as well. The average value of CL for the 75S-3/B receivers in our data set is 30.5 pF, while the average for the 32S-3 is 25 pF, a 5.5 pF difference.

I expected the 32S-1 to have about the same CL value as the 75S-3, as the 32S-1 was built prior to HFO circuit changes implemented in the 32S-3 series. Although CL for the single 32S-1 available is a couple of pF lower than the 75S-3, it is still higher than all the 32S-3 radios measured. It would be nice to have data on more samples of the 32S-1.

Figure 2 is a plot of the frequency error (Parts Per Million) of the crystal fundamental as a function of CL mismatch from the 32 pF specification value. Keep in mind that for RX/TX frequencies above 12 MHz the error shown in the graph must be doubled because the crystal fundamental frequency is doubled to create the desired HFO frequency.

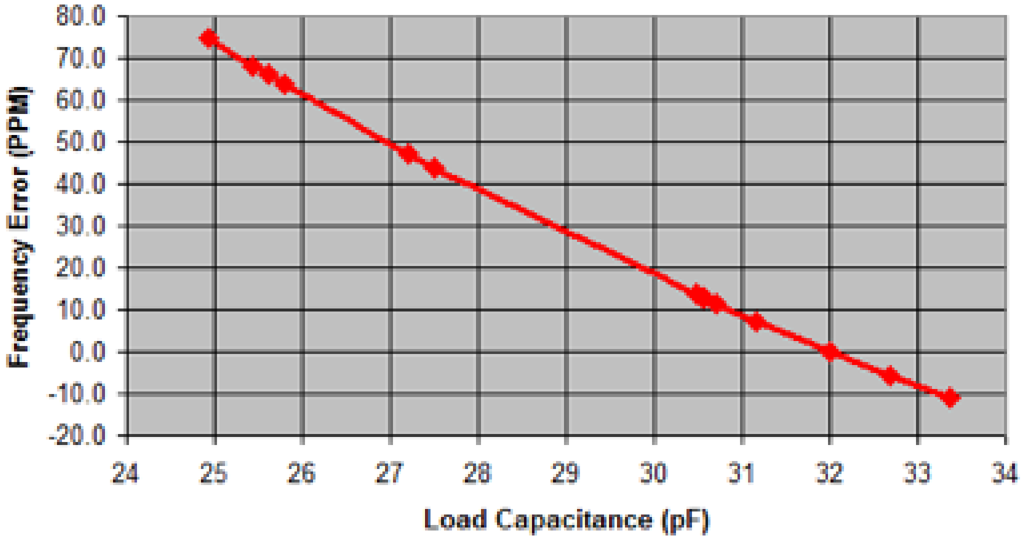


Figure 2 – Frequency Error vs. CL Mismatch

Since 1 PPM for a 15.7 MHz crystal equals 15.7 Hz, the chart shows that the oscillation frequency (FL) of a 15.7 MHz crystal differs by about 60 PPM between radios having a CL of 30.5 pF and 25 pF. Assuming the crystal we are using is actually designed for a 32 pF CL, the difference in the FL of the 75S-3/B and 32S-3 fundamental frequencies would be 942 Hz (5.5 pF X 15.7 Hz). Since this frequency is multiplied by 2 in the radio, the total frequency difference due to CL would be about 1.88 kHz.

Figure 3 shows data taken for category 2) radios with the auxiliary crystal deck installed. This data has peculiarities that are specific to this group of radios, requiring additional head-scratching.

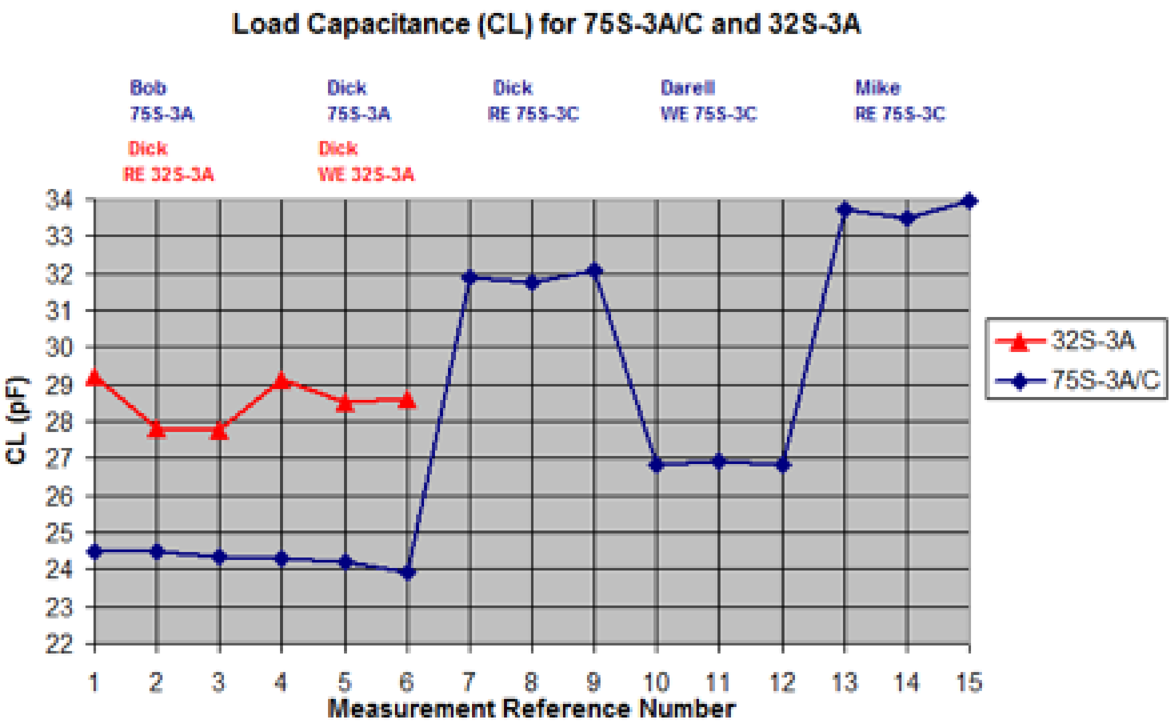


Figure 3 – CL for Radios with a 2nd Crystal Deck

As can be seen from the 32S-3A data in Figure 3, both radios tested had pretty consistent CL values coming in at about 28.5 pF. A point to note here is that when a 32S-3 is modified to a 32S-3A, there is no "CL compensation" circuit modification as is the case with the 75S modification. The average CL for these two 32S-3A radios is about 28.5 pF, which is about 3.5 pF higher than CL for a standard 32S-3. This seems reasonable since the second crystal would be expected to add some capacitance due to wiring and cable length.

The 75S-3A/C results are considerably less consistent. However, most of this is explainable based on the removal (or not) of C78 as specified in the instructions of Service Bulletin 3, which describes the process for adding the second crystal deck. It is presumed that Collins removed C78 to compensate for the added capacitance of the second crystal deck. As can be seen in Figure 2, CL for two standard 75S-3 factory built radios were measured to be about 29.5 pF. Unfortunately, Figure 3 indicates that removing C78 in a 75S-3A over-compensates for addition of the crystal deck, dropping CL to a value of about 24.5 pF.

The next odd result is Dick's factory built 75S-3C, which has a high CL compared to the 75S-3A units. This seemed so bizarre that I asked Dick to check C78 to make sure it had been removed. When he looked at the circuit, he found that it had not been removed, resulting in the higher CL. Darell's 75S-3C has a CL in the range that might be expected for that radio with C78 removed.

Mike's factory built 75S-3C is a very interesting case. Its CL is quite high, but close to the desired original 32 pF design value. Initially, this suggested C78 once again had not been removed, even though it was a factory unit. Upon investigation, Mike found that C78 was indeed still installed, but its value was 10 pF, not the usual 15 pF. Although it is speculation on my part, this suggests that Collins eventually addressed the CL issue and chose 10 pF as a better compensation value for the added crystal deck.

How Can CL of an Oscillator Circuit Be Determined?

In theory, we could look at a schematic of the oscillator circuit and determine CL. You would disconnect the crystal from the circuit, and measure the capacitance across the terminals. Although this seems simple enough, in practice it is not effective. The reason is that there are many stray capacitances in the circuit, as well as significant capacitances that don't show up in the schematic, such as "Miller Effect" capacitance that is significant in triode circuits. Fortunately, it turns out that if we know the "motional parameters" of a typical crystal that is to be used in the oscillator circuit, we can calculate CL. It is interesting to note that the crystal used for this measurement need not be on the desired eventual frequency. Most any similar crystal will produce essentially the same CL results.

Measuring Motional Parameters

There are several approaches to determining crystal motional parameters, but I find that the "3 dB Bandwidth" method is accurate enough for our purposes, and does not require a vector network analyzer, or any modification to the oscillator circuit, as do some other approaches. A good description of various methods is given by Jack Smith (K8ZOA), and can be found on the web at: http://www.cliftonlaboratories.com/Documents/Crystal%20Motional%20Parameters.pdf

To use the 3dB method, it is required to characterize a crystal similar to the one that is to be used in the circuit. By "characterize", I mean that the "motional parameters" of the crystal must be measured. Figure 4 shows the theoretical model of a crystal and its motional parameters.

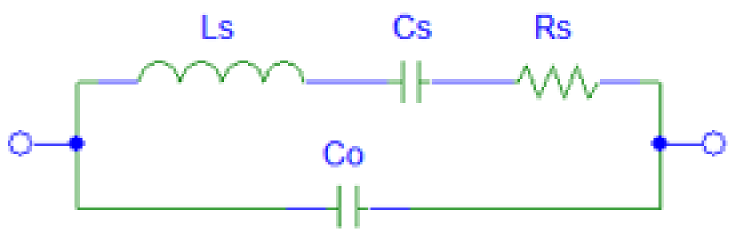


Figure 4 – Crystal Model Motional Parameters

The crystal motional parameters can be determined using a signal generator and voltmeter, with the crystal installed in series between the two instruments. However, frequency and amplitude accuracy must be very good. To be repeatable, 10 Hz frequency accuracy and .1 dB amplitude meter accuracy (or better) is suggested. Although this basic equipment can do the job, a good scalar network analyzer is better. I use a Rigol DSA815TG, which has built-in marker functions for frequency and automated 3 dB bandwidth measurement. Connect your equipment as shown in Figure 5 to measure the following quantities:

Fs – Series resonant frequency of the crystal.
Fp – Parallel resonant frequency of the crystal.
BW3dB – The 3 dB bandwidth at the series resonant frequency, Fs.
Attenuation – Insertion loss of the crystal at the series resonant frequency, Fs.

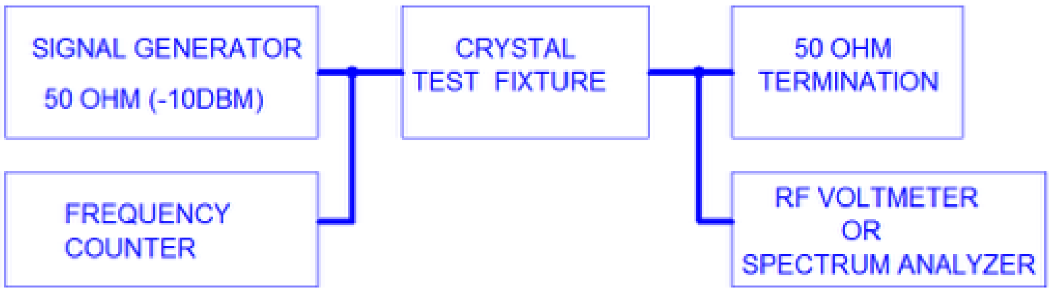


Figure 5 – Motional Parameter Measurement Block Diagram

If you are using a spectrum analyzer with a 50Ω input impedance, you will not need the 50Ω termination. Use the termination only if the RF Voltmeter is a high impedance device.

Figure 6 is a photo of the crystal test fixture I built for testing the crystal in a series configuration. Although a fixture such as this is very handy, you can do the job with just a crystal socket and 50Ω coax cables soldered to the socket terminals.

Figure 6 – Crystal Test Fixture Photo

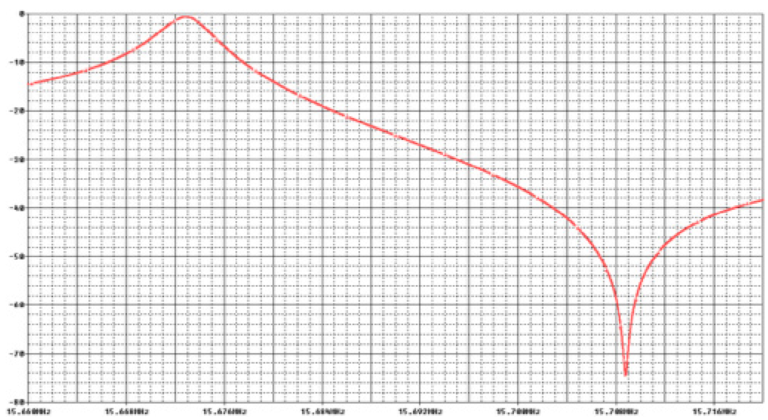


Figure 7 – Crystal Swept Response

If you are fortunate enough to have a scalar network analyzer available, you should be able to generate a swept crystal frequency insertion loss response similar to that shown in Figure 7. Fs is at the peak on the left side of the curve, and the 3 dB bandwidth is measured at this peak. The attenuation parameter is the loss in dB at the Fs peak. The parallel resonance frequency, Fp, occurs at the notch on the right side of the response curve. In the region between Fs and Fp the crystal has an inductive reactance, and FL will occur where this inductive reactance is equal to the capacitive reactance of CL.

I won't go into the calculations here, but let me know if you wish to calculate crystal motional parameters, and I'll email you a spreadsheet that does the calculations for you.

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It is worthwhile mentioning that the accuracy of the motional parameter measurement is significantly impacted by the precision of the resistances terminating the crystal test fixture. Although 50 Ohms is the nominal source/load value for most RF test equipment, it is by no means accurate enough for determining crystal motional parameters. However, if a resistor having a precisely known value is temporarily substituted for the crystal, this source of inaccuracy can be greatly reduced. My spreadsheet provides for this calibration procedure.

Another approach to obtaining the motional parameters of a "test crystal" is to simply purchase a crystal along with its motional parameters. ICM quoted me $26 for a 10m crystal, including motional parameters. If you go this route, be sure you specify that you require motional parameters to the maximum accuracy and resolution available by the manufacturer.

After you have the crystal motional parameters, plug the test crystal into your radio and accurately measure the frequency of oscillation, FL. Knowing Co, Cs, Fs, and FL, CL can then be calculated using the spreadsheet.

Conclusions

The data and measurements collected for this article show that changes to the 32S-3 HFO circuit, in particular, lowered its CL by several picofarads, explaining why the same crystal installed in a late production 32S-3 results in a higher FL than when installed in a 75S-X radio. From an operational standpoint, this isn't much of an issue, since adjustment of the frequency dial fiducial can compensate for the difference, assuming the 32S-3 and 75S-X radios are using their own HFO.

Measurements indicate the typical HFO frequency difference between a 32S-3 and 75S-3/B due to CL mismatch is about 1.88 kHz. Add to this a crystal tolerance of about 1.56 kHz (50 PPM) results in a worst-case total difference of 3.44 kHz. The adjustment capability of the frequency dial fiducial is a bit over ±5 kHz, which is easily sufficient to account for a 3.44 kHz error. Of course, if crystals are purchased to a better tolerance, with the correct "custom" CL for your radio, a much more accurate FL will result.

It is possible to increase the CL of a 32S-3 by installing a capacitor from V12-pin 1 (control grid) to ground. I tried this on my own 32S-3, and was able to pull CL up to 32 pF. There was a slight decrease in drive level, but not significant to normal operation.

75S-3A/C radios with the optional 2nd crystal deck are interesting because SB3 instructs that C78 be removed. Data indicates that this overcompensates for the additional capacitance of the 2nd deck, resulting in a low CL. There is evidence that this issue was addressed in late versions of the 75S-3C. If someone out there has more information on this, please let me know.

If you have time on your hands and wish to purchase crystals for your radios that produce HFO frequencies closer to the ideal, the CL of your radio can be measured with reasonable precision. Once CL is known, a crystal manufacturer can produce a crystal customized for you application. The cost of these "custom" crystals is little more than a standard crystal. A method for calculating CL from crystal motional parameters is described. Motional parameters for a suitable crystal may be determined by measurement, or obtained from a crystal manufacturer upon purchase of a crystal.

Thanks to Bob, Dick, Darell, Mike and Scott for their help with this article.

Cheers,
Don, W5QN


DECEMBER 1956
Best Wishes for the Best Christmas Ever
A COLLINS SSB rig can be yours now with Collins time payment plan.