Wide Range Crystal Pulling For Homebrew Radio

Introduction

Perhaps most radio amateurs think of simple crystal pulled VFOs as being very limited in frequency tuning range. While this is often true, it is also possible to tune crystal VFOs over a major portion, or all of the HF CW areas from 40M upward (30M, 20M, 17M, etc.). Tuning 30 Khz in the 40M CW area is quite possible. The basic technique is to parallel up to four crystals of the same frequency near the high end of the band. Then inductors in series with the crystals can be used to reduce the frequency by about 25khz (more or less). As the inductance is increased, the frequency stability and amplitude of the VFO output decreases gradually until it reaches a frequency region where it rapidly becomes intolerable.

This article demonstrates a simple Colpitts oscillator circuit that is used to provide typical test data samples under various conditions. The data samples generated are typical because crystal parameters vary considerably according to manufacturers and production lot variations. The newer HC49S miniature “strip” crystals are less tunable than the large HC49U “disc” crystals. Beware of “strip” crystals that are packaged in a large HC49U can. Yet, the “strip” crystal can be tuned easily when three or four are connected in parallel. Another advantage is that four crystals increases the power handling capability by four times. Crystal overheating causes excessive frequency drift long before the crystal fractures from being overstressed. These days the HC49U crystals can be obtained for a bit more than $2 each while the HC49S types are available for less than a dollar. Occasionally, even less on Ebay.

Two basic methods will be discussed. The first involves using common ordinary RF chokes, often in series in order to realize a larger value inductance along with a higher Self Resonant Frequency (SRF) than can be obtained with a single choke. If high SRF chokes are available then only one or two chokes might be necessary. A SRF of about twice the crystal frequency is desirable though a bit less will get by. The second method is to wind a powdered iron core inductor and use a shunt capacitor to increase the effective inductance at the crystal frequency.

Generally, varactor tuning reduces the tuning range possible. We have not tried using hyper abrupt junction varactors so this remains to be an area for exploration. The high tuning capacitance ratios needed can be obtained from air variables, poly tuners, and homebrew “flap tuners”. Crystal pulling requires generating high values of reactance, which makes low capacitance desirable. Most high capacitance variable capacitors tune very little frequency change in the larger capacitance range. Thereby most of the frequency change happens over the upper end of the rotation range. This allows for the use of small capacitance variables and simple homebrew tuners. A small amount of tuning range can be sacrificed for getting better tuning linearity and resolution. Occasionally there are exceptions to this rule.

The circuitry herein will be limited to a simple Colpitts oscillator along with a simple clipping mode buffer amplifier that operates over the 1 to 25 Mhz frequency range. In order to achieve best results a high resolution frequency counter is required. 1 hz resolution is desirable, more than 10 hz is not desirable. Otherwise be conservative in terms of your tuning range goals (only 10 to 15 kHz). A 100 hz resolution frequency counter will not easily detect frequency instability.

John Clements likes to monitor xVFO stability by using a nearby receiver connected to his PC along with a sound card program with a long running waterfall display. Initially he was using WSJT-X, a JT65 and JT9 digital mode program by K1JT, but recently found Spectrum Lab by DL4YHF to provide a better display with much more flexibility. The visual jumps and drifts are easier to see than staring at a frequency counter.

Preliminaries

Realize that the crystal and tuning/pulling components should probably Not be mounted near other components on a circuit board. Let's consider a high quality 33uH pulling inductor/choke with a SRF of about 24 Mhz. This type of choke will likely cost about $2, however, these chokes are generally no longer supplied in small quantities. Yet they might be available at surplus dealers for a quarter to half a dollar each. A 33uH choke with a 24 Mhz SRF implies an equivalent parallel capacitance of about 1.3 pF. To be on the safe side, plan on mounting the crystal(s) and inductor(s) up in the air on spacers and perhaps bare perforated board. Perhaps more than an inch is a good idea.

Recall the words "Homebrew Radio" in the title of this article. Crystal pulling is Not being promoted here as a commercially viable method. There is too much component variability that is not under the control of the designer. Yet many find it fun to build simple transceivers that can be excellent for pulling in radio contacts. For example, most CW operators realize that on the east coast of the U.S.A. it is quite easy to work trans-Atlantic stations with a simple rig. Neither does the antenna have to be all that great. Working with simple rigs is a hobby and challenge in itself.

Crystal VFOs work fine with a low cost Poly Tuner (Polyvaricon). However pushing a half turn tuner more than 12 to 15 Khz can be troublesome due to limited resolution. Such a limited range xVFO can probably be keyed and used in a QSK rig. Notice the word "probably". With more pull you should maybe be content that the xVFO re-starts when the rig is manually switched between transmit and receive. As long as the re-starting is reliable, be happy about it.

Tuning is not the only reason for crystal pulling. With an xVFO we often have to deal with standard crystal frequencies that are off from what we want by 5 or 10 Khz. On a band where up to a 25Khz pull is easy and reliable, then a 10Khz initial pull still leaves 15Khz more for the poly tuner to provide a good chunk of frequency agility.

The basic problem with crystal pulling is that the crystal has mechanical modes of oscillation including the Fundamental Mode that is the easiest to pull. External electrical components can only go so far before the "activity" of the crystal begins decreasing and stability degenerates.

Also realize that a Receiver Incremental Tuning control (RIT) will behave differently at various amounts of pull. Not using an RIT control in a transceiver with a transmit mixer is an option that works fairly well. By making the crystal filter wider a small amount of RIT can be realized by pulling the BFO frequency by plus or minus 150 Hz or so. And of course, you can eliminate the transmit mixer and use a transmit oscillator running directly at the transmitter frequency along with a so-called “spotting switch” to align the transmit frequency to the frequency of the incoming received signal. An active audio band pass filter, tunable by a single or dual ganged potentiometer, can often be helpful.

Methodology

Figure #1 provides the basic Colpitts oscillator circuit schematic. Notice that Q1 is an ordinary PN2222(a) general purpose transistor. Also notice the reference to a PZT2222(a). The PZT package is a surface mount package that is larger than the TO92 package, and therefore easy to deal with. Most of the general purpose transistors, like the 2N4401 (PN2222a equivalent) or 2N3904 are available in the PZT package (though more expensive than TO92 packaged transistors). PZT transistors are BCE pin out instead of EBC.

Note: Figure #1 appears the beginning of the next page.

40M

We shall begin in the 40M band with 4 x 7050 Khz paralleled HC49S “strip” crystals. In the 40M band the output capacitor (Cp) across the 330 ohm emitter resistor is 270 pf with another 30 to 40 pF due to probe loading by a frequency counter and oscilloscope (DSO) for a total of about 305 pF. Let’s start with a high quality 33uH, SRF = 24 Mhz, pulling choke. Over the poly tuner rotational range the oscillator (VFO) changed from 7044 to 7052 Khz with an output voltage of 5.6 to 6.0 Vpp.

Q1 PN2222a, PZT2222a, 2N3904, etc .

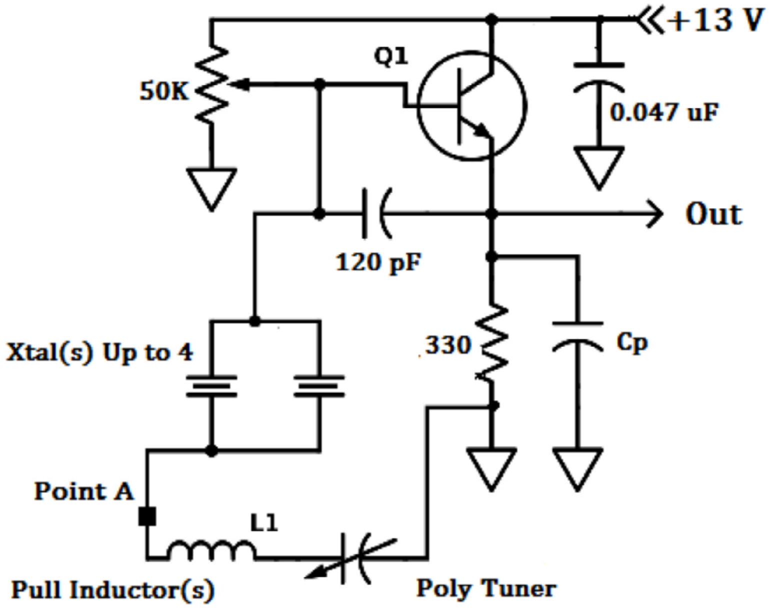

Figure #1 Crystal Pulling Test Circuit

With a single 27 uH with a SRF of about 10 to 13 Mhz, the pull was about 7042 to 7052 Khz. V out was 5.7 Vpp.

With 2 of the said 27uH in series, the pull was from 6989 to 7049 Khz. The lower end was very unstable so we tried another combination (this combination was nearly resonating with stray capacitance in the 7 Mhz area).

With 27uh + 15uH in series, the pull was fairly stable 7031.5 to 7050.5 Khz with V out = 7.0 Vpp.

With 27uH + 18uH in series, the pull was fairly stable 7028 to 7050 Khz at 7.0 Vpp.

So we have a 22 Khz pull while using two series connected low quality chokes. We expect that 30 Khz can be achieved with higher quality chokes or with more lower value low or high quality chokes in series.

4 x 7055 Khz "strip" crystals (with 27uH + 18 uH) moved the range up 5 Khz to about 7033 to 7055 Khz.

Two 7055 KHz "strip" crystals achieved a pull of 7045.6 to 7054.8 Khz with 27uH + 18uH connected in series.

From here onward, the test circuit will include the buffer to be described later (see Figure #2).

Next we have an example of using an inductor of 50 to 55 turns on a T68-2 powdered iron core. A 20pF capacitor was inserted from the top of the inductor or lower end of the paralleled crystals (Point A in Figure #1) to **ground**. The poly tuner was kept between the lower end of the inductor and ground (as shown in Figure #1). There were 3 x 7050 Khz "strip" crystals in parallel. The pulling range was 20 Khz, 7031.8 Khz to 7051.8 Khz.

Note: the series choke method does not work well in oscillator circuits that tend to run at the higher resonant modes of the crystal. This technique helps suppress the higher modes of oscillation.

Increasing the shunt mica or NPO capacitor to 24 pF increased the tuning range to 27 Khz, 7023 to 7050 Khz. Values in the 20 to 24 pF range indicate that the capacitance needs to be roughly 2/3rds of the capacitance required to resonant the inductor at the frequency of the crystal. This increases the effective inductance by about 3 times. Directly winding a core with 3 times the inductance will likely result in a SRF too close to or below the crystal frequency (the inductor becomes capacitive if the SRF is too low).

For better stability at the low end, it would probably be better to use two pairs of HC49S (or 2 x HC49U) crystals about 15 Khz apart in frequency along with a SPDT switch to select one of the two pairs. Otherwise there will be more drift on the low end of the tuning area while the half turn poly tuner will be rather course (at the upper end) and need a mechanical arrangement for higher resolution tuning.

For stability information read the section titled "**Stability Data"** .

30M

Here is the result of using two paralleled 10.116 Mhz “strip” crystals with only one common low cost 15uH epoxy coated choke. The pull was almost 15 Khz from 10.105 Mhz to 10.1195 Mhz. Cp (from Figure #1) was 68 pF. V out was constant at 6.0 Vpp (Note: constant because the clipping buffer hides small oscillator level variations). Since it is not a good idea to run a simple homebrew transmitter or transceiver close to a band edge, this result is adequate while 10.106 to 10.123 Mhz would be more than adequate. 10.125 Mhz crystals along with perhaps an 18 uH choke or two 10uH in series might include the wider range. A similar result might be obtained from a single “disc” crystal (HC49U), or maybe not. Crystal production variations preclude making exact predictions.

20M

We happened to have several **almost** 20M “strip” crystals (13560 Khz) laying around. Two in parallel along with a low cost 10uH choke produced a pull from 13535 to 13562 Khz. This 27 Khz pull demonstrates how easy it is to pull 20M crystals. Easy to pull 20M crystals usually provide good stability over a tuning or pulling range of more than 25 Khz. A higher SRF 10uH choke can be realized by connecting two 4.7 uH or 3 three 3.3 uH chokes in series. Here is the result of two 14048 Khz “strip” crystals along with three 3.3 uH mini-sized chokes connected in series: a quite stable tuning range of 14025.5 Khz to 14050 Khz (a 24.5 Khz frequency range).

For the record, here is the same crystal pair in series with a single 10uH choke: 14024.3 Khz to 14050.0 Khz; a tuning range of 25.7 Khz. The increased range is due to a higher effective inductance caused by the slightly lower SRF (which is equivalent to a slightly higher parasitic shunt capacitance). Therefore, for slightly improved stability at the increased tuning range, a slightly higher inductance series choke combination could have been utilized (maybe 4 x 2.7 uH = 10.8 uH).

Replacing the HC49S pair with a single large 14060 Khz HC49U crystal resulted in a 14046.7 Khz to 14060.9 Khz of tuning; a difference of 14.2 Khz (and very stable). In this example, a single HC49U came up short in regard to tuning range.

Two 14060 large HC49U crystals in parallel tuned by the small capacitance poly tuner section yielded a change from about 14031 Khz to 14064.5 Khz, a quite stable range of 33.5 Khz. After a 15 minute warm up, the drift at the frequency of maximum pull was only 10hz over a time period of 45 minutes.

Output Buffering

Figure #2 is the schematic of the output buffer we decided to use after already producing much of the pull data. Q1 is the PN2222a oscillator transistor with the 330 ohm emitter resistor replaced by a 330 by 22 ohm voltage divider that drives the buffer. The buffer has an input resistance of only about 26 ohms (depends on drive level, Ic, and frequency) while the voltage divider drive has an output resistance of about 20 to 21 ohms. The buffer has high voltage gain to overcome the voltage divider loss as well as provide clipping or limiting of the output waveform. The output stays within minus 3db or so up to about 25 Mhz. The only load attached was about 30 to 40 pF due to two x10 probes feeding a frequency counter and oscilloscope.

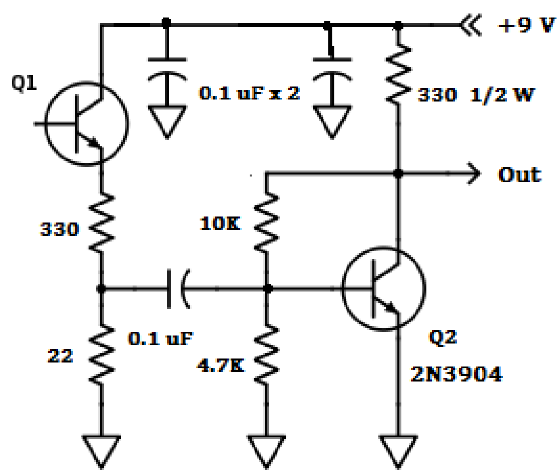

Figure #2 Output Buffer Schematic

The circuit is unusual in that Q2 runs on the edge of saturation. Neither has the circuit been optimized. Originally the oscillator was run on +13 volts, +9 volts or below is recommended. The collector resistor is overrated at ½ watt to run cool and allow for higher supply voltages and various quiescent point settings. Voltage, and perhaps circuit adjustments, can be made to run the oscillator on a lower supply voltage in order to reduce crystal drive/heating. If a simpler 74HCmos type buffer were used, the circuit would be powered by a 6 volt or less supply (perhaps as low as +3 volts). At 40M, and probably higher frequency bands, our circuit and oscillator will also run on a +3 volt supply (actually a bit lower).

Stability Data

Recall the 40M measurements on the oscillator that had 4 x 7050 Khz HC49S crystals, a 50-55 turn T68-2 inductor, and a 22 pF mica capacitor connected from point A to ground, Here is frequency drift data at V supply = +9 volts. The room temperature was constant within a degree F. or so; the time intervals are approximately equal:

2:00 to 3:05 pm: 7019.904, 7019.930, 7019.670, 7019.946, 7019.882

There was one large excursion probably due to a local pump station affecting the power line voltage. The set of data was at maximum pull. Here is more data as the tuning increases the frequency:

3:05 to 3:38 pm: 7029.450, 7029.420, 7029.408

3:42 to 3:57 pm: 7040.140, 7040.137

4:00 to 4:30 pm: 7050.445, 7050.442, 7050.443 <- zero pull

Comparatively speaking, the maximum pull data looks fairly horrible; mostly due to the 7019.670 oddball data point. For several years beginning in January of 1998, AB7SQ ran a 5 watt transmitter that usually ran in the 28 Khz pull ballpark. This was due to doubling the frequency from a standard 5068.8 Khz crystal to 10137.6 Khz, and then pulling down into the 10110 Khz area. Due to strong crystal drive heating, the initial drift was quite noticeable. He received occasional drift complaints but also received comments about the rig having the best ever on the air sound (whatever that means?).

Actually, the rig was very pleasantly stable compared to many of the LC-VFO QRP rigs of those days. Neither should it be a problem at this time unless the receiver at the other end is using a filter less than about 200 hz wide (though the audio pitch change might be slightly annoying). Here is another run with the supply voltage reduced to +4.23 volts:

1:40 - 2:25 pm: 7020.228, 7020.186, 7020.138, 7020.038

2:30 - 3:05 pm: 7030.413, 7030.416

3:05 - 3:25 pm: 7040.575, 7040.566; here are more data samples about half way between 7020 and 7030 khz:

8:36 - 9:46 am: 7025.240, 7025.233, 7025.218, 7025.220

As long as the pull is 25Khz or less, the numbers look good. During a 20 minute QSO less than 30 hz drift is more than good enough. Even though we have never had xVFO problems operating outdoors in mild weather, it might become necessary to not tune too far down from the upper frequency limit (a small pull). Usually more pull is OK in the shade when the outdoor temperature is fairly mild and constant. In the higher frequency bands, pulling crystals 25 Khz is easier so more stability is to be expected. Since the CW area of the 30M band is limited, pulling only 15 Khz in the 30M band will not greatly limit the QSOs available. Thereby, using simple to build XVFO rigs can be quite fun with a reasonably good antenna like a single band vertical with several roof top elevated radials. Yet we have had trans-Atlantic contacts with a wire into a tree and a counterpoise several feet above the ground.

Let's look at 20M stability data taken while using a single section of the poly tuner at an osc./buffer supply voltage of +9. The single 10 uH choke was probably a Fastron series 23 type (used with a pair of 14048 kHz "strip" crystals):

5:36 to 6:03 am: 14024.281, 14024.276, 14024.233

6:05 to 6:40 am: 14035.298, 14035.297, 14035.294 <- very good stability

6:40 to 7:33 am: 14050.018, 14050.009, 14050.009 <- zero pull area

Recall the 14060 Khz large HC49U crystal that was pulled with a single 10uH choke (the same maybe Fastron type, as before). Lets make a higher SRF choke by connecting three 3.3 uH chokes in series (Fastron or Xicon mini-chokes). The supply voltage was +9, and we used only the larger capacitance section of the poly tuner:

10:30 am to 11:00 am: 14046.735,   14046.744 <- good stability

11:01 am to 11:30 am: 14053.211,   14053.199, 14053.196 <- stable

11:30 am to 11:55 am: 14060.940,   14060.939, 14060.940 <- zero pull

More Data (from Tayda)

In this section the data will be restricted to only a few examples of pulling crystals by using very low cost chokes that should be helpful to hobbyists. At the present time, Tayda.com sells a full line of chokes for less than 10 cents each. They are made by Top View Coils (Chinese company?). We happened to have two values laying around that are useful for pulling crystals: 10uH, and 18 uH. The initial data was generated with both the oscillator and buffer running on +9 Volts, both poly tuner sections connected in parallel, and four 7050 Khz HC49S “strip” crystals connected in parallel. Two 18 uH Tayda chokes were connected in series for a total of 36 uH.

2:45 - 3:47 pm: 7033.951, 7033.899. 7033.879, 7033.887

3:48 - 4:20 pm: 7039.300, 7039.310, 7039.330

4:22 - 4:57 pm: 7048.618, 7048.626, 7048.624 < zero pull

Next, let’s jump to generating data with the oscillator emitter shunt capacitor, Cp, reduced to 100 pF, and two 14048 Khz 20M “strip” crystals connected in parallel. Useful data was not obtained with two series connected Tayda 10uH chokes Nor with only one 10 uH choke (pulled to the wrong frequency or else very unstable). Thereby the 10uH chokes were paralleled (mostly not magnetically coupled) to produce about 5 uH:

1:45 - 2:18 pm: 14032.863, 14032.883, 14032.895, 14032.838

2:20 - 2:45 pm: 14036.195, 14036.168

2:48 - 3:17 pm: 14042.519, 14042.536, 14042.461

3:18 - 3:33 pm: 14046.977, 14047.021

The buffer output was 8 Vpp at all frequencies. Next is an example of the frequency difference caused by only the smaller capacitance section, and both sections of the poly tuner connected in parallel:

Smaller capacitance section: 14024.09 to 14050.25 Khz; a diff. of 26.8 Khz.
Both sections paralleled: 14015.52 to 14042.32 Khz; also a 26.8 difference.

This information gives us the idea that the Tayda chokes are useful for economically adding frequency agility to simple crystal controlled QRP transceivers, etc.. Top View makes an EC22 type (no SRF specified), but Tayda seems to be mostly selling the better spec’d EC24, EC36 types. The 10uH EC-24 choke has a SRF of 22 Mhz. The 18uH EC-24 choke has a SRF of 15 Mhz. Both have a Q of at least 40. The EC36 chokes often have SRFs higher than the EC24s, even much higher. These specifications are essentially the same as various other brands of epoxy coated RF chokes. In fact, about the same as the Bourns/JW Miller 78F series of chokes at 1/6th the cost (EC24). The Tayda EC36 chokes **seem** to be about as good as any other brand of epoxy coated chokes. If not, then the price allows for using more of them in series. It is best if they are mostly uncoupled like when mounted 90 degrees to each other (low mutual inductance configuration).

The following half dozen Tayda assortment presently costs about $5 for 60 chokes (10 chokes of each value): 2.2.uH, 3.3uH, 4.7uH, 6.8 uH, 10uH, 15uH. These values used single or in pairs should take care of your crystal pulling needs for perhaps a lifetime of building xVFO radios.

Superhet Transceiver Crystal Combinations

Here are various combinations that come to mind. These are more or less standard microprocessor crystals mixed in with several standard QRP crystals: the crystals are either Qrp, or the usual manufacturer is indicated, or denoted as Std; which means many manufacturers produce the crystal. The numbers can be fudged quite a bit by pulling the indicated crystal along with choosing between series or parallel calibration (series calibrated crystals oscillate at a slightly higher frequency that what is labeled - in most oscillator circuits). IF crystals can be fudged by choosing series or parallel calibration and slightly fudged by the capacitor values used in the crystal filter. The IF crystals can be tuned a bit with a small value capacitor in series with each crystal in the filter.

Here is an example of the notation used in the table below: “12096 + 5990 IF = 18086 = <- 18096 Qrp pulled” means that the transmit crystal is a pulled downward 18096 Khz Qrp crystal OR the transmit frequency of 18086 Khz is synthesized in some manner (like using a transmit mixer/band pass filter combination):

22118 - 4032 IF = 18086 <- 18096 Qrp pulled, others are Std

22112 - 4032 IF = 18080 <- 22118 pulled, all are Std uP crystals

11059 - 4032 IF = 7027   <-   11059 is Std, 7027 is Qrp for Tx

11059 - 4000 IF = 7059   <-   Std and 7059 is pulled 7060 Qrp for Tx

11040 - 4000 IF = 7040   <-   Std 11059 is pulled, 7040 is Qrp for Tx

22118 - 8064 IF = 14054 <-   8064 xtal by IQD in HC49-2,,

22100 - 8064 IF = 14036 <-   Std 22118 is pulled. 8064 by IQD (in UK)

8064 + 6000 IF = 14064 <-   Standards and QRP crystal

8064 + 2048 IF = 10112 <-   Standards and QRP crystal

16257 - 6144 IF = 10113 <-   Qrp xtal, etc., Std 6144 and 16257

14318 - 4194 IF = 10124   <- Std 14318 and 4194

14300 - 4194 IF = 10106 <- 14318 pulled, Std 4194

10738 - 3686 IF = 7052   <- 10738 and 3686 are Std

10718 - 3686 IF = 7032 <- Std 10738 pulled, Std 3686
17734 - 3686 IF = 14048 <- Std 17734.4375 and 3686
11228 - 4194 IF = 7034 <- Std 11228 and 4194
11208 - 4194 IF = 7014 <- Std 11228 is pulled
12096 + 5990 IF = 18086 <- Std 12096, 5990.4 is by ECS
12288 - 5185 IF = 7103 <- Std 12288, 5185 is by ECS
14057 - 3932 IF = 10125 <- Qrp crystal, 14060 pulled, 3932 by ECS
14055 - 3932 IF = 10123 <- Qrp crystal kc9on.com, 3932 by ECS
14050 - 3932 IF = 10118 <- Qrp crystal, kc9on.com, 3932 by ECS
14037 - 3932 IF = 10105 <- Qrp crystals, 14050, 14055 pulled, kc9on
10122 - 3000 IF = 7122 <- Qrp 10125 pulled kc9on.com, 3000 by ECS
11059 + 3000 IF = 14059 <- 11059 Std, 3000 by ECS
11040 + 3000 IF = 14040 <- 11059 pulled, 3000 by ECS
11046 + 3000 IF = 14046 <- 11046 by ECS, 3000 by ECS
6554 + 3560 IF = 10114 <- Std 6554, 3560 is an 80M QRP crystal
16667 - 6554 IF = 10113 <- 16667 by Abracon, 6553.6 Std or ECS
16684 - 6554 IF = 10130 <- 16684 by Citizen, pull 16684 xtal > 5Khz
16681 - 6554 IF = 10127 <- About the same as above
16128 - 6000 IF = 10128 <- 16128 by Abracon, 6000 is Std
16108 - 6000 IF = 10108 <- Abracon 16128 pulled dn 20Khz, 6000 is Std
14745 - 7680 IF = 7065 <- Pull 14745.6 Std, 7680 by ECS
9830 + 4194 IF = 14024 <- 9830 and 4194 are Std
10000 + 4032 IF = 14032 <- 10000 and 4032 are Std or ECS
18000 - 3932 IF = 14068 <- Pull 18000 down, 3932 by ECS
18080 - 4032 IF = 14048 <- Std 18080 hard to find, 4096 is Std
18096 - 4032 IF = 14064 <- Pull 18096 Qrp down, 4032 Std or ECS
21060 - 7030 IF = 14030 <- All Qrp crystals, kc9on.com and ESS
21060 - 7025 IF = 14035 <- ExpandedSpectrumSystems.com <- ESS
9000 + 5069 IF = 14069 <- STD 5069 uP, 9000 Khz from kc9on.com
14060 - 5069 IF = 8991 <- 14060 & 9000 pulled, vendor kc9on.com

IF crystals are usually purchased at the quantity of 10 or more price break (to allow organizing them into matched sets). A crystal filter and BFO requires at least 3 crystals that should be at least somewhat sorted and matched (or at least checked to find duds and oddballs). Some of the oddballs can be used for the BFO.

Presently, purchasing crystals can be hit and miss because you might only be able to get them in large quantity or in surface mount packages.

Therefore, many only become available on a hit or miss basis from vendors that sell electronic surplus in low quantity.

Practical Considerations

Though a Poly Tuner was used to collect the data samples in this article, a half turn variable poly tuner has limited tuning resolution and is perhaps less stable than a half turn air variable. Usually a 12 kHz range will work; otherwise there is a need for improvement. A simple thing to do is construct large knobs by screw attaching ¾ inch thick wood to the back side of a plastic jar lid with a ¼ inch hole in the wood for a shaft, and a sideways threaded hole for a 4-40 or 6-32 screw or set screw. Do to a way the shaft can be connected to the tuner (to be discussed later), a set screw may not be required. It is easy to attach a narrow strip of paper around the diameter or perimeter of the "knob" for calibration. There are other possibilities such as switching between two or three crystals, using a switch to tap a string of pulling chokes, and/or switching between single and paralleled poly tuner sections. Also consider using air variables you might have in your collection (or else pay generously for air variables, especially the reduction gear types). Flap Tuners can work quite well but they are difficult to accurately calibrate due to usually being multi-turn devices (unless cam driven for 2:1 improved 360 degree rotation). Though expensive, perhaps old fashioned gear driven user calibrated dials are still available? These days frequency counter modules are available from China for $10 to $15 (with a risk of Rx QRM being added due to the digital counter electronics).

List of Vendors

QRP Crystals:

3rd Planet Solar -> kc9on.com, ESS -> expandedspectrumsystems.com, danssmallpartsandkits.net (occasionally), E-bay (various vendors)

General Components:

mouser.com, digikey.com, newark.com, jameco.com, alltronics.com, talonix.com, surplussales.com, jpmsupply.com, bgmicro.com, taydaelectronics.com, kc9on.com, danssmallpartsandkits.net, E-bay, electronicsurplus.com, kitsandparts.com

Surplus Molded RF Chokes & Capacitors:

surplussales.com (low cost hi-SRF chokes), alltronics.com, talonix.com danssmallpartsandkits.net, justradios.com, bgmicro.com, E-bay, electronicsurplus.com (Justradio deals in specialized Capacitors (Mica, etc.)

Powdered Iron Cores (not the same as Ferrite cores):

danssmallpartsandkits.net, jpmsupply.com, E-bay, kitsandparts.com

Poly Tuners and Trimmers:

E-bay (various vendors), mikeselectronicparts.com, danssmallpartsandkits.net

Most notable is that surplussales.com has high SRF chokes for about 35 cents, and mikeselectonicparts.com has 141/60 pF dual ganged poly tuners for a bit more than $2 each; and the special mounting screws. A collection of these items is perhaps a good idea for radio home brewers. And, alltronics.com has a huge stock of uP crystals/frequencies for IF and LO applications. Most of the frequencies mentioned in this article are available there (tho. $1 each). And there are many more that make it possible to figure out your own unique combinations for super-heterodyne radios. Many of the frequencies are very unusual or difficult to find; here are a few examples in Khz: 5185, 16128, 8060, 8049, 2000, 3000, 3013.48, 3088, 4068 etc..

Poly Tuner Issues

Here we will demonstrate variations of a little known method of attaching shafts to Poly Tuners. First consider using so-called Compression Inserts that are used to stiffen the end of an air hose so it can be attached to an air driven pneumatic tool (JMG ¼ inch Compression Insert #41288, 21 cents @

ACEhardware.com). Quarter inch diameter compression inserts are short length brass tubes that are flared on one end. We also need a Fuse Bead and a 2.6 mm by 0.46 mm by 6.0 mm (metric) screw that screws into the thread within the stub shaft of the tuner (the fuse bead is a hobby item available from the crafts department of stores; use a 5 mm diameter by about 5 mm long bead) . Put a drop of solder very close to the flared end of the compression insert. Next, use the screw to gently mount the fuse bead onto the shaft without much tightening. Slip the solder modified compression insert over the mounted fuse bead. As you tighten with a small Phillips screwdriver the fuse bead will compress and grab onto the drop of solder. Use care so you do not over tighten and damage the tuner. A small diameter handle screwdriver helps prevent damage due to too much torque.

Of course, if available, about any less than one inch length of solderable thin wall rigid quarter inch diameter tubing could have been used. If not solderable, like aluminum or plastic, drill a 1/16 inch diameter hole all the way through both sides of the tube 2.5 mm from the end to be attached. The hole allows the compressed fuse bead to expand into the hole and grab onto the tube or hollow shaft. Obviously a long shaft can be attached if desired.

An easy to find source of rigid plastic tubing is a Papermate brand round so-called “stick ballpoint pen“. The Papermate pen has an outside diameter of about 5/16 of an inch with a tip at the top that rapidly decreases to slightly less than a quarter of an inch (fits nicely into a standard radio knob). The internal ink cartridge is attached to a removable section at the writing end of the ballpoint pen. This section along with the ink cartridge can be easily removed by twisting it out with a pair of grabbing type pliers. Next, the end of the about one quarter inch diameter section needs to be cut off. This leaves the remaining tube hollow so a long skinny screwdriver can be inserted. The length that can be used is usually limited by the length of the skinny shaft of the Phillips screwdriver that needs to reach down to the screw mentioned previously. Most often you will want a short shaft that includes about 6 mm of the 5/16th inch diameter section along with only what is needed of the near quarter inch diameter section (the inside diameter of the 5/16 inch outside diameter section is about 5mm, the same as the outside diameter of the fuse bead). The depths of the hole in standard knobs are not standardized. Be sure to remember the 1/16 inch diameter cross hole 2.5 mm from the end of the plastic shaft and repeat the procedure mentioned previously.

Actually, most brands of round stick type ballpoint pens are about 5/16th of an inch outside diameter. In a previous section we mentioned constructing homemade wooden knobs with a round plastic jar lid as a cover. In this case we can drill the knob hole to be 5/16th of an inch in diameter and glue in the shaft and avoid the hassle of a set screw (the knob can be removed by removing the cover and inserting the long skinny Phillips screwdriver into the hollow shaft.)

And, of course, the poly tuner body needs to be shielded away from the body of the radio operator; by, at least, an adequate sized conductive front panel.

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