<u>This is a modified version of the PLL VCXO described in the article written by KD6OZH in QEX November 1999.</u>

READ THE ENTIRE ARTICLE FROM QEX and THEN READ ALL OF THIS BEFORE YOU BEGIN TO ASSEMBLE. ALSO READ THE INCLUDED "Corrections.txt" which may correct some of this document.

1 Differences between this kit and the article by KD6OZH

Please READ ALL these instructions <u>before</u> beginning any assembly.

Read the ARTICLE by KD5OZH from the QEX (should be in your package). You don't have to understand all the theory, but you do have to understand the construction and tune-up details. These boards are the PLL and VCXO boards. (The doubler and subsequent multiplier circuits are not included. Those parts of the article refer to modifications of "no-tune" boards.)

1.1 Regulator and related items

The article has no voltage regulator for the VCXO. This board has a 10 V regulator. The regulator, a protection diode, and two capacitors are added to the original circuit. This change in voltage required changes in two resistor values to accommodate bias changes. They are R3, which is changed to 150 ohms, and R6, which is changed to 820 ohms.

Almost all resistors are 1/8 watt to allow for a compact board. In practical use, the 10V regulator will drop out at 11.7 V. This is OK for most portable applications. If you expect your +V to drop below this, you should consider changing this to a 9 V regulator. You might have to fiddle with the values of R3 and R6 if you do, and the output power will drop. If you have some other regulator that will do a great job, it's up to you.

1.2 Typos

There are typos in the design and article (you must get the parts in the right places) as follows: There are two R16s. One is on the VCXO board, with the value of 10 Ohms. The second R16 is on the PLL board and is 62K. There is no C3. There are two C23s on the PLL board. One is a 0.01 uF and the other is a 0.047 uF bypass. There are two R21s, but fortunately they both have the same value. The design did not deal with the unused half of the op-amp. I put in an extra 10K resistor (near the op-amp, marked 10K).

1.3 Transformer

A Minicircuits T9-1 transformer was substituted for the hand-wound one in the article. It works OK, producing about 1 dB less output than the original, at significantly less effort and sorrow. If the pins are not straight on yours, try to carefully straighten them out before inserting it into the board. Observe that the dot is near R12. If you are really keen on winding your own transformer, you will need a core and some wire.

1.4 L1

There is a close-up photo of L1. You <u>may</u> need to drop one turn (not near the tap) for frequencies above 94 MHz. Try it the way it is first, and if the tuning capacitor is way at the end of its range, try removing one turn. You will have to ADD one turn for frequencies below 92 MHz. Between 92 and 94 MHz the way it is shown should work. How do you know? If the circuit does not oscillate at all, the wrong number of turns could be the reason. If it does oscillate, but cannot be made to lock at a control voltage from 1 to 10 V, it probably should have a different number of turns. You will discover this during the final tuning procedure. Look at the photos.

I made mine by winding a few turns, marking where I wanted the lacquer removed for the tap, unwinding, using medium steel wool to remove the lacquer insulation, and then winding. I then soldered a pin to the tap point made of a clipped resistor lead. When the coil was done, I tinned the leads. Maybe you have a better way of winding a tapped toroid coil, but this technique worked OK for me. I use #24 wire (supplied in the kit).

Instead of soldering the L1 in, I simply press it in and bend the wires so that there would be good contact, but did NOT solder. If things tuned up fine, then I would solder. If not, I could easily remove L1 and add or subtract one turn and try again. If the table below is filled in, your crystal was checked, so follow it for L1.

YOUR FREQUENCY	NUMBER OF TOTAL TURNS L1

1.5 L2 and C10 and C11

L2 is a hand-wound coil in the article. I found a high quality 390 nH coil (0.39 uH), so that you don't have to wind this one. It works quite well. There is space for a hand-wound one if you insist. (I will likely need a toroid.)

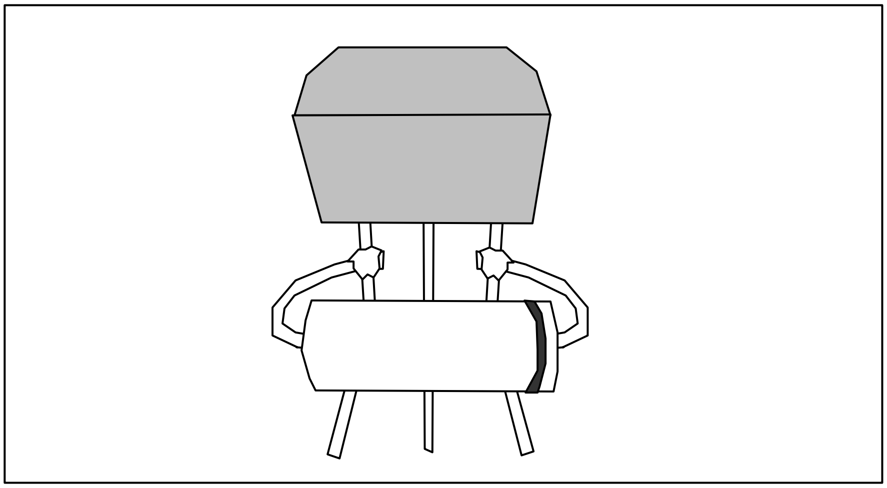
C10 and C11 are switched so that they will fit (they are in parallel, so they can be switched with no affect on the circuit).

1.6 Sample harmonics reduction Capacitor

There has been sufficient second harmonic energy in most of the units to cause the capacitively coupled prescaler (over on the PLL board) to lock onto the second harmonic instead of the fundamental output frequency. After experimentation, I found that in those cases where the problem exists, the application of a .0047 capacitor in parallel across the BNC output connector for the sample signal (in the VCXO box) cures this problem completely. Therefore, this capacitor is added to the parts, and hand marked ".0047 for sample output". Just solder it between the center pin and the ground lug for the "sample out" BNC connector inside the VCXO box. If you find that the main oscillator output has harmonic energy that causes problems, you might experiment with a similar remedy on the output connector. Most applications work fine with some second harmonic output.

1.7 Protection Diodes

A protection diode is added to the 5V regulator on the PLL board (and also to the new 10V regulator on the VCXO board). Both of these diodes are attached directly to the regulator(s) prior to inserting the regulator(s). I forgot to add the diodes when laying out the board, sorry. First, insert the regulator to get the leads bent properly. Note the available space for the diode, remove the regulator and bend the diode leads and solder. Check to see that it still fits and clears OK. See the photos.



Connection of diode to regulator

These protect the diode in case there is an accidental short circuit of the power source. Without the diodes, such a short circuit (even for a few milliseconds) could destroy the regulators.

1.8 Extra C13 capacitance.

I added a 1.0 uF capacitor (C13B) in parallel to C13 (a 0.1 uF) control voltage low pass filter. I found that this helped in situations in the shack where there are power line spikes that get into the power supplies. If you are hill toping only, I would suggest trying the circuit without this extra C13B. If you don't need it, great – this is an interesting cap to have in your parts inventory!

1.9 Booster amplifier, added circuit

I added a booster amplifier circuit to the output of the VCXO. Without this, the power will run from about +1 dBm to about +4 dBm depending on crystal, frequency, and some component variations. If you need +4 or so, you might just change the values of the output pad. Look at the board- there are two output connections next to a ground connection. If you need more power, up to +14 to +17 dBm, such as is needed to directly drive a doubler or a long coaxial cable and splitters, etc, you should add the booster amplifier circuit. None of the components for this are in the original circuit, so instead of assigning them C, R, RFC, and U part numbers, I have just put their values on the board. One error was made however. The space marked "18 uH" next to the output of the MAV11 will take a 1 uH choke. The MAV11 has poor to adequate S12 so does not isolate very well. Any external loading might cause frequency variation. If this is a problem, consider adding the MAV11 amplifier and then an external 3 or 6 dB coaxial pad to the output.

The one distinct disadvantage of using the amplifier if you don't need it is that it draws power and dissipates it as heat (about ¼ watt). One way to proceed (if you don't know if you will need it) is to insert all parts except: do not insert one end of the 180-Ohm ½ watt resistor, and also do not insert one end of the 220-pF capacitor (leave short pig-tails), thereby neither drawing current nor loading the circuit. Then, later, if the extra output level is needed, these "loose ends" can be soldered into place, and the output can be take from the appropriate output point.

The two surface mount capacitors are in parallel so don't worry about mixing them up.

1.10 Boxes

If boxes are provided in your kit (they are in most), they will be pre-drilled for the board mounting screws, and have either pilot holes or full holes drilled for the BNC and RCA connectors and the power feed-throughs. I have placed mounting screws in the bottom for the boards. These are fastened with nylon nuts. You will place the boards onto the screws, (on top of the nylon nuts) and fasten with steel nuts. Do not tighten the screws, or you might strip the nylon nuts. If you have to remove the screws, take care when replacing them to not over-tighten, and to adjust the exact position so that the board slips over the screws without binding.

Most boxes are flanged. Hammond provides these flanges. They can be removed if you wish. I find that they facilitate easy mounting.

A BNC cable and an RCA cable are provided in most kits. This is just one less thing you will need to find. Most BNC cables are surplus; the RCA's are new. Open the boxes when you unpack the kits, the hardware is stuffed in them.

When you assemble the feed-through, care must be taken to not over-tighten because the feed-through metal is very soft. One way to make sure to tighten correctly is to use a split ring washer, and tighten just until it flattens. I tried to include a split ring 4-40 washer for the feed-through.

For grounding, an additional hole is drilled beside the feed-through hole. In this hole you should use another 4-40 screw to mount the inside and outside ground lugs. This way you won't put the ground lugs on the feed-through. The only lugs I could get are kind of large. They work, but if you have smaller ones, use them instead.

1.11 Crystal

The Crystal can be either a TO-5 can type, or an HC-49/U type. If you use a TO-5 type, then you probably should use the supplied TO-5 socket. An HC-49 type crystal should be soldered directly in, but if you think you might change the crystal, it is possible to use the TO-5 socket and "plug-in" HC49 leads (you decide). If you are using an HC49 type crystal, there is a set of small holes provided to run some #30 gauge wire through to hold down the crystal. Whether or not your crystal requires heat, a 60 degree Centigrade PTC is provided. If you don't need the heater, don't put it in (it draws current and makes unnecessary heat).

If you do, you should also fashion a piece of Styrofoam to cover both the heater and the crystal to keep them in good physical contact and insulate them from the box. If you get it just right, the oven will press onto the heater and crystal as the box cover is tightened down. Try to leave space around the Styrofoam for a tuning tool to adjust C1. When doing testing and adjustments without the box cover in place, use a rubber band to hold the oven onto the board so that it can stay "at-temperature".

An alternative way of mounting an HC-49 crystal is vertical. Tack solder one side (the grounded side) of the heater to the crystal case. Then, a Styrofoam cover can be fashioned to cover this vertical structure. I find that this works quite well, even without tack soldering. I leave the details up to you.

A set of crystals has been specified to ICM as the "TWO" series with correct specifications for this circuit. When they are used, no additional reactance is needed as is described in the article. There are four part numbers in the series depending on case type and temperature. TWO4 is the most common and cheapest – HC49U case, heated to 60 deg C.

CRYSTAL SUPPLIED?	HOLDER TYPE	HEATED?

2 Order of construction

The order of construction is not critical, but I found that if items are done in this order, things go smoothly. The idea is to put the shortest components on first, gradually going to taller ones, so that the board can be laid with its component side on the table and soldered with minimum rocking and component movement while soldering. All holes are plated-through. You only have to solder one side.

All components dependent on orientation have some sort of marking on the board. The positive lead of Tantalum capacitors is longer and goes to a square pad which should have a + sign nearby (not all + signs came out clearly). Diode bands are marked, and pin 1 of the ICs has a square pad. Also there is a U-shaped mark on the printed rectangle at the end of the IC with pin 1. The ICs themselves have either a dot or a U-shape near pin 1. If in doubt about any polarity of any component, check the circuit against the board wiring.

<u>An important note on soldering</u>. Unfortunately, I did not go through the added work of thermally isolating the ground pads. (I now know just why the professionals at my work use this isolation technique). <u>This means that every ground connection will take considerably more heat than other connections</u>. The difference is quite noticeable unless you are using a professional $500 soldering station. You might have to crank up your iron, keep it very clean, make an effort to assure excellent contact to the <u>pad</u> instead of the component wire, and give it extra time. I found that cleaning the tip, then tinning it slightly would wet the tip which improves heat transfer. This applies only to connections to the ground plane(s), but there are lots of them. The majority of capacitors have one side to ground on both boards.

2.1 VCXO

Decide on power levels and output circuit (or used advice on preparing for either)

Decide on crystal type (holder, temperature, proper specifications)

Wind Coil (with tap, try inserting, form leads so that fit is good for inserting later), wind with correct number of turns for your frequency range.

Prep voltage regulator and protection diode per instructions

Insert and solder resistors

Insert and solder D1 – be careful, if the leads are bent too close you can chip the glass

Insert and solder TO-5 crystal socket (if you are going to use it)

Insert and solder Surface Mount Components (caps and MAV 11 if used)

Insert and solder L2, RFCs (including 1 uH RFC at MAV11 marked 18 uH)

Insert and solder all caps except Tantalums

Insert and solder Tantalums

Insert and solder remaining semiconductors Regulator with diode, Q1, Q2 and D2 – the printing on the board shows the correct orientation of all components.

Insert L1 (note in description above, L1 turns depends on frequency), you may want to delay soldering L1 because of the possible need to change the number of turns.

Jumper L/C X (if you are using the specified crystal, jumper this with a wire)

Insert crystal (solder if necessary)

If crystal is heated type, for the heater, put some insulation over the (+) lead (the heater is not polarized, but one of the leads is connected to +V), insert heater and solder the leads once you have it on top of the crystal and the leads dressed as they will end up. (You might want to delay this step until you have applied voltage and measured circuit current because the relatively heavy current that the heater draws might mask some other problem.) Place the heater in contact with the crystal (tack solder if you want to). Create a Styrofoam “oven” per instructions. Details left up to you.

Apply power, test

If not using TWO crystal or a crystal designed for this circuit, you may need to insert L or C into the L/C X space. See article. Insert reactance instead of jumper.

You should apply power and test the VCXO for current draw. If it draws significantly more than the table below indicates, check your circuit. Because you have choices regarding use of a heater and the use of the buffer amplifier, there are several possible current levels. They are shown in the table below which is based on applying 13.8V dc. The biggest variable is the heater, which will change depending on its load and temp.

Current Draw for the VCXO, 13.8V DC input. Yours may vary some.

Condition	No Heater	Heater Cold	Heater Warm
No Buffer Amp	22 to 25 mA	350 mA startup	55 to 85 mA
With Buffer Amp	78 to 82 mA	380 mA startup	110 to 140 mA

Adjust for oscillation. It is possible for the circuit to oscillate at a frequency different from the crystal (a different overtone for instance), so its good to have a frequency meter or FM radio nearby to check that it is approximately on frequency. For example, I have had a 90 MHz crystal oscillate at 54 MHz because C1 was not adjusted correctly.

The range of adjustment of C1 over which proper oscillation occurs is quite small, so tune slowly when searching for oscillation.

Set aside, final adjustments require connection to an operational PLL circuit.

2.2 PLL

Check clearance for the 18 pin DIP socket. (If it does not insert, you might have to run a #68 drill followed by a #67 by hand through the holes. In some kits the socket is already inserted, remove it and re-insert it later, but most should be OK)

Insert and solder resistors

Insert and solder capacitors except tantalums

Insert and solder the 18 pin DIP socket

Insert and solder integrated circuits (except 16F84 microprocessor)

Attach protection diode to 5V regulator

Insert and solder 5V regulator with protection diode

Insert any remaining components

Insert a programmed 16F84 micro-controller.

Test by applying 13.8V nominal. Current draw should be about 15 mA.

2.3 Entire System

Interconnect two units temporarily on bench using twisted pairs (connect sample out from VCXO to sample in on PLL, connect control out on PLL to control in on VCXO)

Program the 16F84, and insert into 18-pin socket in PLL. (If you asked for it, I supplied a pre-programmed 16F84. It can be re-programmed if you want to change frequency.)

Input 10 MHz standard signal (usually 0.5 V p-p is sufficient).

After warm-up (if you are using heated crystals you should wait at least 15 minutes for warm-up), check for output from VCXO (power meter, and frequency counter). Retune C1 to make it oscillate on approximate frequency.

Check frequency counter to see if PLL is working (should be on freq and stable, and it should be possible to adjust C1 for a control voltage above +1V and below +11V). If it is not working, try to add the 0.0047 uF sample harmonic reduction capacitor across the VCXO sample output temporarily.

Adjust C1 for approximately +5V control voltage, per article (4 to 6 volts is OK) – but unlike the article, just measure the control voltage at the connection between the two boards. By the way, you should be able to adjust this to at least as high as 9V and at least as low as 2V with the unit locked OK. C1 is very touchy, so it will take a little practice to do this, have patience. If you can't, keep it locked anywhere between 2 and 9 volts, you either have a crystal with incorrect specifications (see next paragraph) or you need to add or subtract one turn from L1. Sometimes, significant RF and noise can interact with the boards when open on the bench like this, so you might not be able to do this adjustment until the boards are in the boxes. If you continue to have problems at this point, contact me. I will gladly debug or put the unit on my bench for troubleshooting.

If you are not using an ICM “TWO” crystal, or a type specified by the article, you might need to add reactance to the VCXO where the L/C/X mark is. I found that crystals specified for Frequency-West bricks needed about 4 turns on a T-37-12 core of added inductance to make them behave. The article has a procedure for determining when you have the correct reactance.

You may also notice that the article mentions a test that requires measuring output to make sure that no more than 0.5 dB of level change occurs. I have found that every correctly operating unit has at least 0.5 dB of level change, and some as much as 0.75 dB. If you perform this test and find that the change is less than 0.5 dB, congratulations.

If you are using an ICM “TWO” crystal, or type specified by the article, but can’t get suitable locking range (from +2V to +9V) then you may need to add or subtract one turn from L1. Generally, the lower frequency crystals need more inductance and therefore work better with one extra turn. Most crystals above about 94 MHz require that one turn be removed.

When the units are not in boxes, they are quite sensitive to electric fields. I found that my soldering iron causes fluctuations in frequency. The boxes, closed, and wiring run through coax helps tremendously. This also dramatically reduces spurs.

Put connectors into boxes, tighten, put boards into boxes, put feed-throughs in and tighten per instructions (do not over-tighten), connect signal and power points appropriately. Connections should be made with short wires, twisted if possible.

Interconnect the boxes, (cables may be provided) and test again.

I found that after running at least 4 hours, with the lids on, the control voltage should be readjusted (by removing the lid on the VCXO and adjusting C1) to bring it back to 4 to 6 volts range. If you intend to run it continuously, it should be checked and adjusted again after about 3 days. Crystals age, and so the control voltage should be monitored every month or two. If it every goes below 3 volts or above 8 volts, it is probably time to re-adjust C1.

If your use is intermittent, such as hill-topping, you should probably do a cold start and adjust for close to 5V after about 3 or 4 hours. Then, perform cold starts to determine how much warm-up time to expect in the field.