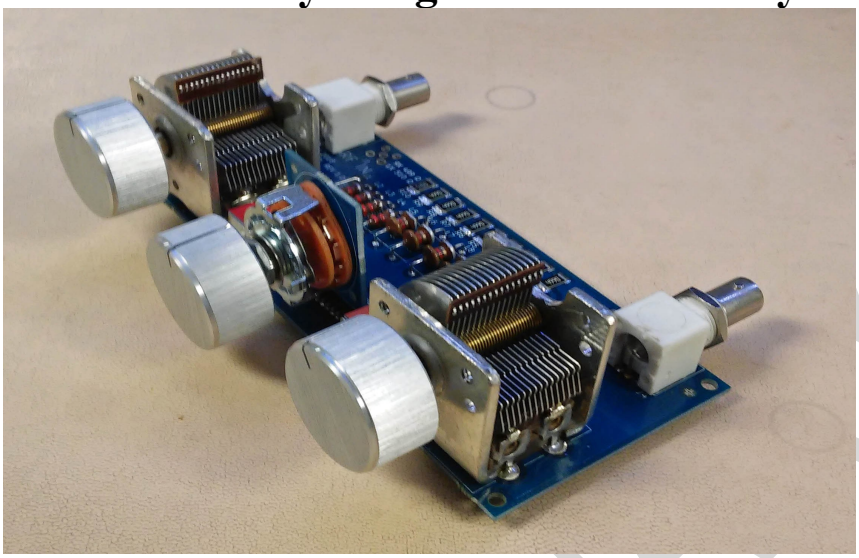
K5ABL HF-6m QRP Tuner Kit
Self-contained assembly designed to embed in your project



This tuner was originally conceived as a companion for DIY transceiver kits like the QCX, uBITX and other amateur radio transceiver kits. It was designed to be self-contained and easy to integrate into an enclosure. All controls are located on a single plane for easy attachment to a front panel. It also has 4 corner mounting holes for secure mounting to a base plate or enclosure bottom. This design is now being offered as a kit through my company web site at http://www.celeritous.com The latest assembly instructions may also be obtained there or at http://www.K5ABL.com.

The tuner was designed to match a 50 ohm output transceiver to antenna impedances of roughly 12.5 Ohms to 400 Ohms over the 3-55MHz range and achieve an SWR match of better than 1.5:1 in the Amateur bands over that frequency range. The power handling capabilities are primarily limited by the 12 position rotary switch which is nominally rated for 1A continuous current. This implies a maximum power into 50 Ohms of I^2R or 50W maximum. A better, more conservative limit would be 20-30W which matches the dummy load capability.

The design is based on a C-L-C Pi Matching network which provides the broadest possible matching range for impedances greater than or less than the source impedance. It uses two 15-360pF air variable capacitors and a series of fixed inductors which are successively switched in series to provde inductances from 200nHy to 20uHy. Best of all THERE ARE NO TOROIDS TO WIND!!!!!. Fixed through hole inductors with combined self-resonances well beyond the band of interest were chosen to provide an easy to assemble, consistent and repeatable product.

In addition to the tuner function, the tuner features a switch to bypass the tuner as well as an integral 50 Ohm dummy load which may be switched into circuit. When the dummy load is switched into circuit (note – in the current design enabling the dummy load does not disconnect the tuner from the antenna – this will be fixed in a future revision)

The photo above shows the original Rev 1.0 assembly which used surface mount resistors for the dummy load. The current Rev 1.1 design has been modified to use all through hole components to

make assembly easier and more accessible to builder. The surface mount load resistors have been replaced with a single 30W 50 Ohm load resistor and a custom heat sink to allow higher/longer power dissipation into the load.

Specifications

Frequency Range:	3MHz – 55MHz (1.8MHz with less matching range)
Impedance matching range:	12.5 Ohm to 400 Ohm nominally
Maximum Power:	30W Continuous in tuner mode 10W Continuous Dummy load
Board Size:	5.8” x 2.5” (147.32mm x 63.5mm)
Overall Height (Assembled)	1.675” (42.5mm)
Network Type:	C-L-C Pi Network 15-360pF C 200nHy – 20uHy L
In/Out Connectors:	BNC or SMA

Kit Contents

The kit is divided into 14 packages as follows.

You can use this as a check list for inspecting the kit contents.

- □ 1 4x 200nHy Inductors for reference designators L2-L5*
- □ 2 5x 1.2uHy Inductors for reference designators L6-L10
- □ 3 2x 4.7uHy Inductors for reference designators L11, L12
- □ 4 2x BNC or SMA right angle RF connectors for reference designators J1,J2 or J3, J4
- □ 5 2x 13-360pF air variable capacitors for reference designators C1, C2
- □ 6 1x Rotary Switch PCB
- □ 7 1x 1 Pole 12 Position rotary switch for reference designator SW1
- □ 8 1x 1x13 2mm right angle header for mounting switch board
- □ 9 1x DPDT right angle toggle switch for reference designator SW2
- □ 10 1x SPST right angle toggle switch for reference designator SW3
- □ 11 1x 50 Ohm 30W resistor and 1x Thermally conductive pad for reference designator R1
- □ 12 1x Hardware kit consisting of:
  - □ 1x 2mm hex key
  - □ 1x Inductor bending tool
  - □ 12x M3 button head cap screws
  - □ 12x M3 split ring lock washers
  - □ 2x M3 flat nylon washers
- □ 13 1x Tuner main PCB
- □ 14 1x Heat Sink

As you may have noticed, any special tools not normally found on your workbench have been provided. A 2mm Hex key is the only tool you will need for the M3 3mm hardware for mounting the air variable capacitors and the heat sink. There is also a 3D printed bending guide for the inductors

which will help you correctly bend the leads on the inductors to make sure there is adequate strain relief, proper lead spacing and centering of the components.

The air variable capacitors and heat sink are pre-drilled and tapped for the M3 hardware. A thermally conductive pad is provided to go between the dummy load resistor and the heat sink to avoid having to deal with messy thermal grease. Split ring lockwashers are provided to prevent screws from backing out over time and to prevent over-torquing of the screws. One only needs to tighten the screw until the split ring is flat plus ¼ turn to prevent stripping out threads in the capacitors and heat sink.

If you examine the main printed circuit board you will see that most components include not only legends indicating the reference designator but also the component value and/or function where space permits. This reduces assembly errors and rework.

Critical Assembly Note:

Most of the tuner assembly is straightforward and component identification is simple. The one area one can easily get into trouble is in the rotary switch assembly. It is very easy to assemble the switch and/or the header to the wrong side of the PCB. I designed it and it has happened to me! Pay close attention to the photos when assembling this and do a fit check and double check it before completely soldering it. I will normally only solder one pin on the connector and one pin on the header and fit check it before committing to soldering the rest of the pins. This allows easier unsoldering and disassembly if required.

Kit Assembly

Tools Needed:

You will at a minimun need to provide the following tools and materials to assemble this kit.

- □ Soldering iron of at least 40W and preferably temperature controlled
  If you are going to build many kits this is a worthwhile investment. The power is needed for rapid recovery to proper temperature and for soldering some of the heavier connections like the air variable leads or the BNC mounting pins. These are available for less than $40 from a variety of sources.
- □ Electronic wire solder of .032-0.40 (0.8-1mm) diameter with flux core.
  Solder may be lead or lead free. Lead is generally easier to work with 60/40 or 63/37
  Solder should contain a flux core. It may be rosin or water soluble
  Under no circumstances use plumbing of acid flux solder
- □ Electronic “flush” or “diagonal” or “side” cutters to trim the through hole leads
  Make sure you get ones small enough for PCB work and not a set of linemans cutters. A search for electronic side cutters on Amazon will show you the general style you need even if you don’t buy from them.
- □ Needle nose pliers to help bend or straighten leads
  Small needlenose with smooth or flat jaws will do best with lead bending and tweaking without marring the lead.
- □ Volt-Ohm Meter or VOM to help do final testing

If you don't already have a red Harbor Freight meter you got free you are probably the only one. You don't need a $150 Fluke meter for this. Something small, cheap, simple and expendable will do. You are primarily looking for something to measure resistance and continuity and you don't need 4 ½ digits of precision for this project.

□ Adequate Lighting

Nothing fancy. A small desk lamp will do. This project really doesn't need a magnifier, just good lighting so you can readily identify parts color codes or markings and inspect solder joints.

□ Small 5X – 10X Magnifier

This is optional but a good 5X to 10X magnifier will help in inspecting solder joints and look for possible shorts.

General Order of Assembly

Being that this is almost entirely through hole construction I generally approach the assembly by doing the shortest components first and work up to the taller ones. This allows you to flip over the board (assuming you don't have some fancy assembly vice or fixture) with the components down and gravity will hold the parts in place (for the most part) while you solder them. If you do taller parts first you must rely on bending the leads on the back side to try and keep the components flush against the board or even tape them in place.

Another good habit is to solder one lead of each part you've inserted and flip the board over and make sure the components are flush and parallel to the board before soldering the other leads. This makes adjustment easier if a component is tilted one way or another with respect to the board.

If you are a novice at soldering or haven't warmed up a soldering iron in a decade or two I would definitely leave the rotary switch assembly until last so you get some soldering experience under your belt. While I don't consider it to be advanced, the smaller 2mm pitch on the header does take some finesse.

The kit packaging has taken this approach into account and the parts bags will be used more or less in order of their numbering.

Assembly Step 1 – Inductors

Just a quick note here. You may have noticed that there is no L1 provided in the kit. This was originally a 220nHy inductor but when the prototype was assembled the tuner would not work at 28MHz or 50MHz. Some measurements were made and the stray inductance presented by the PCB traces and switch when the tuner was bypassed was about 200 nHy by itself. L1 was removed and replaced by a straight piece of wire and it then worked as designed at the upper frequencies. So when you are placing, soldering and cutting the leads of the other inductors, reserve a cut lead for placement at the L1 position. I know – I could have eliminated it in the second revision and perhaps I will in a future revision but it was just easier to leave it that way and not disrupt the entire layout.

1A - 220 nHy Inductors

Using the bending guide provided use the smaller, shorter recess, place a 200 nHy inductor in the recess and firmly bend the lead down into the slots on the side of the guide. The bend radius should be fairly sharp and not overly rounded. Test the bent inductor in one of the 220 nHy spaces to make sure the lead spacing is correct and the leads do not splay out or get wedged inward when the component is flush against the board.

Bend all four inductors and insert into positions L2 through L5 and solder. Make sure not to populate L1 and to reserve a cut lead for it.

1B 1.2 uHy Inductors

Using the bending guide provided use the larger, wider recess, place a 1.2 uHy inductor in the recess and firmly bend the lead down into the slots on the side of the guide. The bend radius should be fairly sharp and not overly rounded. Test the bent inductor in one of the 1.2 uHy spaces to make sure the lead spacing is correct and the leads do not splay out or get wedged inward when the component is flush against the board.

Bend all five 1.2 uHy inductors and insert into positions L6-L10 and solder.

1C 4.7 uHy Inductors

Using the bending guide provided use the larger, wider recess, place a 4.7 uHy inductor in the recess and firmly bend the lead down into the slots on the side of the guide. The bend radius should be fairly sharp and not overly rounded. Test the bent inductor in one of the 4.7 uHy spaces to make sure the lead spacing is correct and the leads do not splay out or get wedged inward when the component is flush against the board.

Bend both of the 4.7 uHy inductors and insert into positions L11 and L12 and solder.

Assembly Step 2 – RF Connectors

Depending on the kit you purchase it will have either two right angle BNC connectors or two SMA right angle connectors. The assembly is similar for either and are the next tallest components.

2A – BNC Connectors

It is a good idea to remove the nut and washer on the BNC connectors before assembling them to the board. This keeps the washer from interfering with fully seating the connectors. The BNC connectors have two mounting pins which basically keep them attached to the PCB and two pins at the back which provide the center conductor and shield connections to the PCB. This can sometimes be tricky to get all four pins aligned at the same time. The mounting pins are a snug fit and the connector will have to be seated firmly to get them flush and parallel with the board.

Be sure not to bend or kink the RF connection leads and that when the connector is fully seated against the board that they are not shorted together. The lead relief may not be perfect on the shield/ground lead in particular but I advise against doing much manipulation of this lead or it may break where it exits the rear of the connector. The connector should hold itself in place without much problem while soldering.

Make sure you apply adequate heat for a long enough period of time to heat the mounting pins and get a good solder joint. Remember you are heating the connector body as well and it may take some time with a low power iron.

2B SMA Connectors

The SMA connectors are not as challenging to insert into the board but may be more challenging to keep in place while soldering and to provide adequate heat to solder the four body pins.

I recommend inserting one connector at a time, flippng the board over and soldering the center pin of each connector first. Inspect the connector after soldering the center pin only to make sure it is flush to the board and preferably exiting square to the board. You should be able to reflow the center pin to adjust this while in contact with the connector body without getting burned.

After the connectors are square and flush on the board, solder the four body pins. Make sure you apply adequate heat for a long enough period of time to heat the mounting pins and get a good solder joint. Remember you are heating the connector body as well and it may take some time with a low power iron. This time the body will be very hot!

Assembly Step 3 – Toggle Switches

3A Bypass Toggle Switch

3B Dummy Load Toggle Switch

Assembly Step 4 – Air Variable Capacitors

Assembly Step 5 – Rotary Switch Board

In order for the rotary switch to be in the same mounting plane as the air variable capacitors and for the switch connection to be correct it is vital to observe how the header and switch are mounted and which side of the board they are mounted to.

The convention is as follows: The side of the board with the header and switch silkscreen outline and reference designators is the “front side” or “component side” of the board. Both the header and switch mount on this side. The side with the Celeritous Copyright notice and the header pin numbering is the “back side” and will ultimately wind up facing the rear of the tuner. When complete the swtch board assembly should appear as shown in photos __ and __/

5A Attach Right Angle Header
It is easiest to attach the header to the switch board first and then adjust the board assemblies later to achieve a square and flush seating of the switch board to the tuner board.

In order for the switch board to sit flush on the tuner board it is imperative that the straight pin side of the header be inserted into the switch board from the fron side. The bent lead side of the header must face down in the final assembly and will be inserted into the tuner board later.

Insert the header and flip it over and solder one lead near the center of the header. Inspect the header to make sure it is seated flush to the board and the right angle pins are parallel to the board. Adjust as needed. Once the connector is flush and square finish soldering the rest of the header pins.

5B Attach Rotary Switch
Inspect the switch pins and straighten any that are bent. Fit the switch to the front of the switch board and seat firmly until it is level with the board. There will be a small gap between the board and bottom switch wafer due to a shoulder on the pins.

Solder one pin and inspect for correct orientation and that is is level and as far into the board as possible. Complete soldering the switch pins.

Assembly Step 6 – Attach Rotary Switch Board to Tuner Board

Assembly Step 7 – Dummy Load resistor and heat sink

Assembling the dummy load and heat sink is a bit involved. In order to minimize stray lead inductances to the dummy load resistor and provide firm attachment to the heat sink and the PCB the resistor is mounted in a recess in the PCB. The heat sink attaches to the PCB then the resistor attaches to the heat sink in order to make good thermal contact. Finally the resistor leads are solder to the surface pads on the back side of the tuner board.

7A Affix thermal pad
Make sure the flat side of the heat sink is clean and dry. It is a good idea to clean it with rubbing alcohol and let it dry thoroughly. Do not handle or touch the flat side after cleaning until the thermal pad is affixed.

Gently peel the gray thermal pad off of the carrier and place it on the flat part of the heat sink adhesive side down. The hole in the thermal pad must be centered over the center hole in the heat sink and the bulk of the pad oriented towards the furthest mounting hole as shown in photo __

7B Mount heat sink to board
With the Tuner board facing down and the flat part of the heat sink facing up, align the heat sink so the thermal pad appears in the square opening at the rear of the tuner board and the heat sink tapped mounting holes align with the mounting holes in the PCB as shown in photo __.

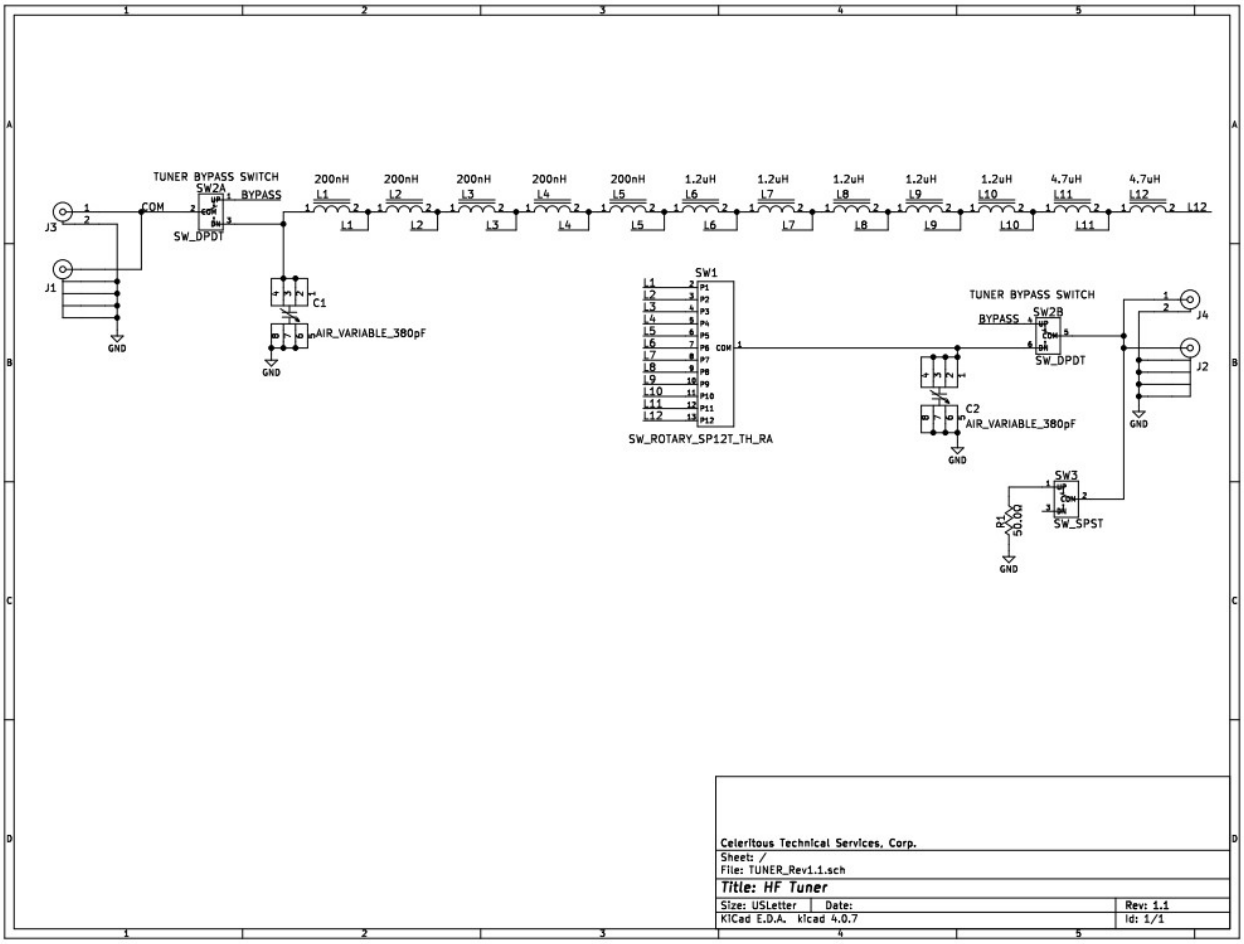
Using an M3 screw with a lockwasher next to the screw head and a nylon washer next to the board, attach the heat sink to the PCB as shown in photo __. Tighten only until the split ring is compressed to be flat. Do not overtighten or you risk stripping the threads in the heat sink.

7C Mount Dummy load resistor to heat sink and solder to board

With the board still face down and with the thermal pad in the cutout window, drop the dummy load resistor into the opening with the lettering side up and with the hole in the resistor aligned with the tapped mounting hole in the heat sink.

Using an M3 screw with a split ring lockwasher only, insert the screw through the dummy load resistor and into the tapped mounting hole in the heat sink and tighten just until the split ring flattens. Do not overtighten or you risk stripping the threads in the heat sink.

Assembly Test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BYPASS
COM
SW_DPDT
J3
J1
GND
C1
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200nH
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