

# K2 Temperature-Compensated PLL Reference Upgrade

Rev. E, March 24, 2005

## Description

This upgrade kit significantly improves the stability of the K2's VFO, reducing drift per unit of temperature by as much as 90%. It is especially useful with a K2/100, since operation at higher power will cause faster heating inside the cabinet. The circuit, designed by John Grebenkemper, KI6WX, uses a thermistor to temperature-compensate the varactor diodes in the PLL reference oscillator.

All parts used in the upgrade are installed on a small PC board that substitutes for resistor network RP3 on the RF board. (See photo of installed thermistor board on page 4.) You can assemble this small board now (see page 2), or when it is needed during assembly of the K2. All related manual changes are shown below.

### If your K2 is not yet assembled, make the following changes to the Owner's manual:

- On page 47, right column, last step: Make a note to install the **thermistor PCB assembly** at the location of RP3, rather than the original resistor network.
- On page 50, left column, first step: Make a note to use only the 12.096 MHz crystal supplied with this upgrade kit, which is marked **ECS 12.09-CD** (there may also be a lot number, which can be ignored). Your K2 may have been supplied with 1 or 2 crystals of a different type. *Only one crystal is now needed (X1). X2 will not be used.*
- On page 54, right column, second step: Make a note to substitute a 12- $\mu$ H inductor (supplied with this upgrade kit) for the original 10- $\mu$ H unit supplied with your K2 for use at L31.

**If your K2 serial number is lower than 3000**, you should first install the BFO mod kit (Elecraft part number BFOMDKT). The BFO modifications are already present in K2s with serial number 3000 and higher. **NOTE:** The BFO mod kit originally included a 12.096 MHz crystal for use in the PLL reference oscillator. This crystal is now supplied with the PLL upgrade kit. However, if you installed the crystal from the BFO mod kit, you will probably *not* have to remove it. This is covered in the PLL upgrade kit instructions.

## Upgrade Kit (E850138) Parts List

Ref	Description	Qty	Part #
RF-L31	12 $\mu$ H Shielded Inductor	1	E690019
RA	33K 1/4W Resistor (org-org-org)	1	E500057
RB	12K 1/8W Resistor (brn-red-org)	1	E500089
RC	2.2K 1/8W Resistor (red-red-red)	1	E500088
RD	1.8K 1/8W Resistor (brn-gray-red)	1	E500087
RE, RF	10K 1/8W Resistor (brn-blk-org)	2	E500092
THM	Thermistor, 10K, 3% (small orange body with black and brown stripes near leads)	1	E500091
RF-X1	Crystal, ECS 12.09-CD	1	E850007
MISC	Thermistor PC Board	1	E100152
MISC	#24 Green Wire, Insulated	1 ft (30 cm)	E760008

## Thermistor PC Board Assembly

- Locate the thermistor printed circuit board. One side will be labeled with THM and the letters A through F. All components will be installed on the labeled side, and soldered on the other side.
- Install 1/8th-watt resistors RB, RC, RD, RE, and RF in their respective positions as shown on the board. (Be sure to check the color codes carefully.) Do not pull on the resistor leads, as they may be fragile. Solder all of the leads, then trim off as much of the excess length as possible.
- Install resistor RA (33 k, 1/4 watt). Solder and trim its leads.
- The thermistor has an orange body with black and brown stripes. The thermistor is fragile, so avoid bending its leads any more than necessary. Insert the thermistor at THM (the part is symmetrical and can be installed in either orientation). With the thermistor body touching the circuit board, solder and trim its leads.
- The remaining 8 holes on one edge of the board are used as leads to replace RP3. Strip a 6" (15 cm) length of green hookup wire. Cut the bare wire into 8 pieces of about 0.75" (2 cm) in length. Solder each wire into one of the holes so that most of the lead protrudes from the component side.
- On the component side, bend each lead to a 90-degree angle so that it points away from the board.
- The circuit board is now complete and ready to be installed on the K2 RF board.

## Thermistor board installation at time of K2 assembly

- Complete K2 assembly through page 47 of the manual.
- Locate the position of resistor network **RP3** on the RF board. Slide each of the 8 leads of the thermistor board through the corresponding holes at RP3. The components on the circuit board should be facing U6, and the thermistor should be oriented toward the position of crystal X1. **(See photo, page 4.)**
- Once all of the leads are inserted, slide the board down so that it is flush against the RF Board. It may be necessary to bend the thermistor board toward U6 so that the solder joints on the bottom of the RF board can clear C87. The thermistor board and its parts should not be touching U6 or its pads.
- Make sure that the edge of the thermistor board is contacting the RF Board along its full length, or there may not be enough clearance for an audio filter option (which mounts on the Control board). Solder the eight connections on the bottom side of the RF Board.
- This completes installation of the PLL reference oscillator upgrade. Check your work to make sure there are no shorts between the thermistor board and other components.
- Continue with K2 assembly and test as described in the K2 owner's manual. **You will not use the Test** instructions in this document. However, you should keep this instruction sheet for reference. You may wish to read the **Theory of Operation** section (page 4).

## Thermistor board installation in an assembled K2

- Remove the top, bottom, and left side covers from the K2.
- Remove the Control Board from the K2.
- Locate inductor L31, which is near the left front side of the RF Board, mounted on the bottom side. Cut the inductor's leads. Straighten the leads with long-nose pliers, then use a soldering iron to remove the leads from each hole. *Do not pull on a lead until after the solder has melted;* otherwise you may damage the plated-through hole in the PC board. **Note:** The holes for L31 and other components to be removed will be cleaned out later.
- Locate crystals X1 and X2, which are mounted on top side of the RF Board near L31. Only X1 will be present if your K2 is s/n 3000 or higher, or if you installed the crystal supplied with the BFO mod kit.
- If your board already has only one crystal (at X1), check its part number. If the part number contains **ECS 12.09-CD**, you can skip the instructions below that deal with removing and replacing the crystals. (There may also be a lot number on the crystal, which may be ignored.)

- If you determined that you need to remove X1 (and X2, if present): (1) Heat and lift the ground lead soldered to the side or top of X1. (2) Alternately heat each of the crystal leads on the bottom side of the board while gently rocking it back and forth on the top until it falls out. (3) Remove X2 in the same manner (if X2 is present).
- Locate resistor network RP3, which has 8 pins and is near X1 and L31. RP3 must be removed. First, bend it back and forth until the leads break. Then, from the bottom side of the board, heat each of the leads with a soldering iron and gently remove them using long-nose pliers.
- Using solder wick or equivalent, clean out each of the holes that was used to mount L31, RP3, X1 and X2. This includes the two ground holes for X1 and X2.
- Install the new crystal at X1. The crystal should be mounted flush to the circuit board and the leads trimmed so that they are nearly flush with the circuit board.
- Solder the ground wire to the side of X1. (Remove the ground wire for X2 if present.)
- Install the new L31 on the bottom of the board. The new L31 looks identical to the old one except the value is 12  $\mu$ H. The inductor should be installed so that its body is flush against the circuit board.
- The thermistor board will be installed at RP3's location. Slide each of the 8 leads of the thermistor board through the corresponding holes at RP3. The components on the circuit board should be facing U6, and the thermistor should be oriented toward X1. **(See photo, page 4.)**
- Once all of the leads are inserted, slide the board so that it is flush against the RF Board. It may be necessary to bend the thermistor board toward U6 slightly so that the solder joints on the bottom of the RF board can clear C87. The thermistor board and its parts should not be touching U6 or its pads.
- Make sure that the edge of the thermistor board is contacting the RF Board along its full length, or there may not be enough clearance for an audio filter option (which mounts on the Control board). Solder the eight connections on the bottom side of the RF Board.
- If your K2 serial number is lower than 3000, make sure you have installed the BFO modification (BFOMDKT). One of the items supplied in this kit is a 2.7-k resistor. This resistor, designated R19, must be soldered across pins 7 and 8 of resistor network RP2 (in the PLL area).
- If you have an older K2 (early revision A or Field Test), you may have a 100 k resistor network installed at RP2, which is in the VCO area. If so, you'll need to solder two 10 k to 12 k resistors across RP2: one across pins 1-2 and the other across pins 3-4, on the bottom of the board. (There's no need to remove RP2, which can be difficult. The paralleled resistors will suffice.) Any type of 10 k to 12 k resistor can be used; 1/8th watt or 1/4 watt, any tolerance.
- This completes the installation of the PLL reference oscillator upgrade. Check your work to make sure there are no shorts between added components and other parts of the K2 circuitry.
- Reinstall the side and bottom covers on the K2. Reinstall the Control Board.

## Alignment and Test

- Connect the K2's internal frequency counter probe to test point TP3 (PLL reference oscillator).
- Turn on the K2; it should power up normally.
- In the Menu, locate and activate **CAL Fctr** as described in the K2 owner's manual. You should see a reading on the frequency counter. When you tap BAND- the counter should read about 12085 kHz. When you press BAND+ the counter should read about 12098 kHz. The difference between these two readings must be greater than 9 kHz. If this isn't the case, there is something wrong with the modification.
- Connect the frequency counter probe to test point TP1 (VCO).
- Install the top cover, and allow the K2 to warm up for at least 30 minutes at room temperature.
- Switch to 40 meters and run **PLL CAL** as described in the manual.. **Note:** If you have firmware revision 2.00 or later, **CAL PLL** is run only on 40 meters, not on each band. If you have older firmware (revision 1.XX), we strongly recommend that you obtain an upgrade, as VFO tuning linearity has been dramatically improved.
- If you installed the BFO modification but have not re-aligned your BFOs, do so now.
- This completes alignment.

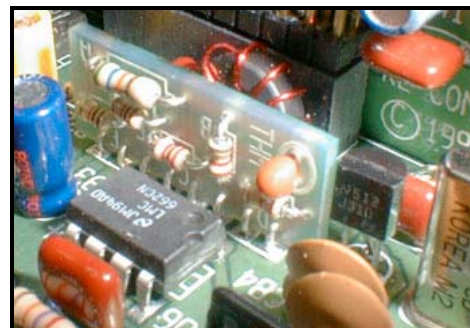
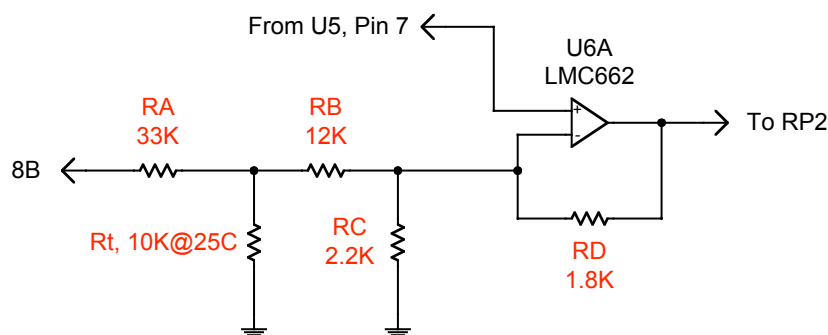
## Theory of Operation

The thermistor circuit works by applying a variable offset voltage to varactor diodes D16 and D17 to compensate for drift in the PLL reference oscillator. As temperature increases, the uncompensated oscillator will drift down in frequency. The thermistor causes a slight increase in the bias voltage to these diodes as the temperature increases.

The resistor values have been chosen to minimize the drift of the PLL Reference Oscillator over its entire tuning range (typically 10 to 13 kHz). There will still be some residual drift due to component variations and the BFO. The residual drift will usually be less than 100 Hz over a temperature range of 50F to 110F. This is an order of magnitude better than the uncompensated circuit.

### Schematic

The schematic and a photo of the modifications are shown below. All resistors in combination establish the nominal gain of DC amplifier U6A. The relative values of RA-RD and the thermistor,  $R_t$ , set the rate of gain change with temperature. RE and RF (not shown) replace resistors that were contained in RP3 and have no functional effect on the compensation circuit. In the oscillator itself (also not shown), L31 has been changed to 12  $\mu$ H, and X1 is a new crystal with improved temperature stability.



### Stability Measurement and Compensation Adjustment (Expert Builders Only)

The procedure below can be used to test and optionally fine-tune the K2's frequency stability as a function of temperature. **This information is provided for builders who have accurate frequency measurement capability and wish to experiment with the thermistor compensation circuit. Otherwise resistor RA should be left at its original value of 33 k, which will provide very good results.**

To measure the drift of the K2:

1. Allow the K2 to warm up for 30 minutes or longer at room temperature (top, bottom, and side covers should be installed).
2. Switch to the band to be tested (we use 20 meters for comparisons). Set the POWER control for about 1 watt, and connect the K2 to a dummy load.
3. Enter TUNE mode and measure the K2's transmit frequency using a frequency counter, synthesized receiver, or other stable instrument. (An alternative is to carefully check the frequency of a reference signal on the K2, such as WWV.)
4. Transmit at 10 to 20 watts into a dummy load for 15 to 30 minutes using TUNE mode. (Use an internally-installed KPA100 at 20 watts if available). This should increase the internal temperature of the K2 by 15 to 30 degrees F, depending on whether a KPA100 was used or the K2 was "barefoot."
5. Re-measure the K2's transmit frequency at the 1-watt level soon after you stop transmitting (because of the thermal mass, you have several minutes in which to make this measurement). Again, a receive frequency test can be used as an alternative.
6. The difference in the two frequencies indicates the amount of drift.

On 20 meters, with both the BFO and PLL reference modifications in place, typical drift using this test is 5 to 20 Hz per 15 degrees (F) of temperature change. Before modification, a K2 might drift 100 Hz or more over the same temperature range.

After both the BFO and PLL modifications have been made, the value of resistor RA on the thermistor may optionally be varied to reduce the drift further. Increasing the value of RA decreases the compensation and will shift the drift toward negative values. The value of RA should not be made smaller than 15K or larger than 56 k. **Note:** CAL PLL must be re-run and drift re-measured after making any change to RA.