AM/FM Radio Kit Model AM/FM-108CK
Dordt's Alignment Instructions

Elenco makes an AM/FM radio Kit for teaching purposes. The instruction manual that comes with the kit is targeted at vocational-technical students who have a high-school diploma. The manual that comes with the kit (The Elenco manual) recommends using the usual equipment used in a repair shop for alignment. These instructions provide equivalent or superior results and make use of general purpose electronics lab equipment. These tuning instructions also modify the tuning range of the kit so that it can receive the extended AM band (530 – 1700 kHz). This radio was designed using the older 540 – 1600 standard, but a simple change in the frequencies used for alignment will enable it to operate over the entire 530 – 1700 kHz range where AM stations are now found. These changes will make the label on the radio's dial a little inaccurate on the high end, but it is not a very accurate label in the first place. The dial calibration error that tuning up to 1700 kHz introduces is inconsequential.

A note on the extended AM band: There is an interesting history of the frequency allocations for AM broadcasting (FM too for that matter). In brief and omitting a lot of detail, AM broadcasting started on one frequency, 833 kHz, for all stations. Stations in the same city time-shared that frequency. In 1923 the band of 540 – 1350 kHz was dedicated to AM broadcasting by government regulation. A year later that was increased to 540 – 1500 kHz. In 1941 the top end of the dial was raised to 1600 kHz. Finally, in late 1997 the FCC expanded the band again, up to 1700 kHz. Also, traveler information stations are assigned to 530 kHz, extending the band downward. (Reference: White, "Building the Broadcast Band," http://www.oldradio.com/archives/general/buildbcb.html.)

Recommended Equipment—AM Alignment

1.) Soldering iron, solder-sucker or re-work iron, solder, sponge, etc.

2.) Adjustable power supply, two sections, 0 – 15 V and 0 – 200 mA or more. (Elenco XP660 or equiv.) One section will be set to a low current. After shorts are ruled out, the other section will be used to supply normal current. Connect the negative terminals of both sections together with a patch cord.

3.) DMM, set to 20 V DC range, with common lead connected to negative terminals of power supply.

4.) Simpson 260 VOM, with common lead connected to negative terminals of power supply. Set to the 2.5 V range, –DC function.

5.) GwINSTEK model GFG-3015 function generator (also known as a "signal generator")

6.) BNC to banana screw terminals adapter

7.) 5.6 Ω, 1/4 W resistor.

8.) Capacitor substitution box. Set to 0.2 μF (or 200 nF).

9.) Oscilloscope—only one channel needed. 20 MHz or more bandwidth, with a 10X probe.

10.) Counter/Timer set up to measure frequency (Global 5001 or equivalent). Also, a specially modified (for AC coupling at the probe tip) 10X oscilloscope probe connected to the A input of the Counter/Timer.

11.) Various patch cords, mostly banana-banana but also one banana-e-z-hook and one e-z-hook-to-e-z-hook.

12.) Magic wand (Ferrite on one end, brass on the other end. See Elenco manual page 27.).

Important note 1: The function (signal) generator will unavoidably radiate signals which the radio is sensitive enough to pick up. If there is more than one signal generator on at a time, these radiated signals can cause confusing results. It is ideal if you can turn all the signal generators in the room off, except the one in use. It is usually possible for two or more people to work simultaneously—with two or more signal generators on at a time, but then if things are acting strangely, try turning the other signal generator(s) off.

Important note 2: Always make sure the oscilloscope probes are set to 10X if there is a switch on the probe. Failure to do this will result in bogus alignments (due to excessive loading effects) and probably a radio that does not work. The ground clip of the oscilloscope should be used for all measurements. Connect it to TP15 on the radio's circuit board. Test point T15 is provided specifically for this purpose.

Recommended Equipment—FM Alignment

1.) Soldering iron, solder-sucker or re-work iron, solder, sponge, etc.

2.) GwINSTEK model GFG-3015 function generator (also known as a "signal generator")

3.) Oscilloscope—only one channel is needed, 60 MHz bandwidth or more, with a 10X probe.

4.) Adjustable power supply, two sections, 0 – 15 V and 0 – 200 mA or more. (Eleco XP660 or equiv.) One section will be set to a low current. After shorts are ruled out, the other section will be used to supply normal current. Connect the negative terminals of both sections together with a patch cord.

5.) DMM—connect the common terminal to the negative terminals of the power supply. Set the DMM on the 20 V DC range.

6.) Two BNC cables, jack-to-jack adapter, BNC to banana screw terminals adapter, 6" of hook-up wire.

Section 1B—After Small Parts and Large Parts are Soldered

1.) Visual inspection Look for cold solder connections and solder bridges. If there are any questionable solder joints, fix them immediately instead of hoping for good connections.

2.) Power Test Adjust section A of the power supply to 9.5 V, 10 mA. The meter on the power supply is accurate enough for this adjustment. (But 10 mA probably is only one minor division of the meter's scale, so be sure it is zeroed correctly! To set the current limit, short the supply out with a patch cord, then set the meter to measure current, and adjust the current limit knob.) The current limit is needed to protect the transistors in case of a wiring error. Be sure the power switch on the radio is set to "off" and the meter on the power supply is set to measure voltage. Connect the power supply to the battery holder on the kit. Observe the voltmeter on the power supply—it should remain at 9.5 V. Turn the radio on. The voltmeter on the power supply might take a momentary dip, but is should quickly stabilize again at 9.5 V. If the kit passes this test, proceed to the bias test. If it fails, there is a power-to-ground short. Diagnose the problem before proceeding.

3.) *Bias Test*. Set the DMM to the 20 V DC range. First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Then check TP15. It should be 0 V.

Then check the voltage at TP1. It should be 4.75 V ±0.5 V.

If this is not the case, check transistor types and for correct connections.
Q14 has numbers 656***0*** or 8***0***50 on it.
Q10 and Q11 are both type 2N390***4***
Q13 has numbers 656***2*** or 8***5***50 on it.
Q12 is type 2N390***6***
Also check for correct resistors.

4.) *Gain Test*. Adjust section B of the power supply to 9.5 V, 200 mA. The meter on the power supply is accurate enough for this adjustment. Reconnect the radio to the B section instead of the A section so that it can now operate at normal current levels. Connect a 400 Hz, sinusoid with the amplitude set to 0.5 V peak-to-peak to the **negative** side of C41. Adjust the volume control. You should hear the 400 Hz tone. Important: keep an eye on the output voltage of the B section of the power supply. It should stay at 9.5 volts. If it does not, then power is going into heat somewhere. Go back to using the A section of the power supply (with 10 mA current limit) until the problem is diagnosed. (Check especially for a melted headphone jack or shorted speaker connection.) If you hear the tone and the power supply voltage remains normal, the radio passes the gain test.

5.) *Distortion Test.* Connect an oscilloscope to the Negative side of C43. (Or to the speaker terminal that is also connected to the earphone jack.) Use a 10X probe with the ground clip connected to TP15. Set the oscilloscope for 1 V per division deflection and 500 μs per division sweep. Adjust the volume control until clipping just sets in. When the radio is powered from the B section of the power supply (200 mA limit) the oscilloscope should show at least ±2.5 V deflection (5 V p-p) without clipping. The power supply voltmeter should still show 9.5 V.

Sections 2, 3 and 4—after all these parts are soldered

1.) *Visual inspection* Look for Cold solder joins, solder bridges.

2.) *Power Test.* With the power supply adjusted as shown above in Section 1B step 2, connect the radio to section A of the power supply and check for normal voltage. If the voltage does not remain at 9.5 V diagnose the problem before proceeding. For the remainder of the tests, reconnect the radio to the B section so that it can draw up to 200 mA.

3.) *Bias Tests.* Make these tests with the radio turned on, AM/FM switch set to AM, volume at minimum, no station tuned in. (If enough of the radio is built to tune a station in.) Set the DMM to the 20 V DC range. First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Then check TP15—it should be 0 V. Then check these voltages:

   3a. Emitter of Q9, 1.1 V plus or minus a few tenths.

   3b. Emitter of Q8, 0.8 V plus or minus a few tenths.

4.) *Disable Q7*. If it is installed, Q7 must be disabled. This can be done by connecting the collector ("C") of Q7 to TP6 with an e-z-hook-to-e-z-hook patch cord.

5.) *Signal Generator Setup*. Weak signals are needed for the next tests. Connect a 5.6 Ω 1/4 W resistor across the output of the signal generator. Connect the resistor directly across the binding posts of the BNC to banana adapter customarily used on the main output. This attenuates the output of the signal generator by a factor of about five less than the displayed amplitude. (With no load, the open circuit voltage of the signal generator is two times more than the displayed output because the signal generator is calibrated for driving a 50 Ω load). Set the signal generator to 455 kHz, 1.0 V peak-to-peak output (the actual output will be 0.2 V peak-to-peak or 0.1 V peak.). Also set the DC offset to zero.

6.) *Signal Generator Connection*. Connect the capacitor substitution box set to 0.2 μF in series with the positive output of the signal generator and then to TP4. (**Caution: failure to put the capacitor in series could cause about $100 damage to the signal generator.**) Connect the ground or negative terminal of the signal generator to the radio's ground via the negative power supply terminal (or to TP15). Use an ordinary patch cord with banana plugs and an alligator clip attachment.

7.) *VOM Setup and Connection*. Set the Simpson 260 VOM to the 2.5 V range, –DC function (That is, the "minus DC" setting). Connect its common to the negative power supply terminal. Connect the + (red) lead to the bottom of R42 on the radio's circuit board.

   (If the reading is negative or down-scale, switch to the +DC function and then adjust T8 (black adjustment screw) for a reading of 0 or less and then switch back to the –DC function.)

8.) *2nd AM IF Tuning Adjustment*. Use a non-magnetic tool (such as a plastic alignment tool) to adjust T8 (black adjustment screw) for a maximum reading on the VOM. After adjustment the VOM should indicate –1.3 V, ±0.5 V (about half scale).

9.) *1st AM IF Tuning Adjustment.* If Q7 is installed, leave it disabled. (See Step 4 above.)

   Connect the 455 kHz signal generator through the capacitor box (0.2 μF) to TP6, (along with the short to the collector of Q7 if necessary).

   Leave the VOM connected to the bottom of R42.

   Reduce the output of the signal generator until the VOM reads about zero but not below zero. Then adjust T7 (white) for maximum on the VOM. Again, reduce the output of the signal generator until the VOM reads about zero and not below zero. Again, adjust T7 (white) for a maximum reading on the VOM. Repeat this process until you get a maximum at near zero and less than 0.5 V bias on the VOM. (Actually, that will be between –0.5 V and 0 V since the meter is set to read negative voltage.)

Section 5—After Small Parts and Large Parts are Soldered

1.) *Visual inspection* Look for Cold solder joins, solder bridges.

2.) *Power Test* With the power supply adjusted as shown above in Section 1B, part 2, connect the radio to section A of the power supply and check for normal voltage. If the voltage does not remain at 9.5 V diagnose the problem before proceeding. For the remainder of the tests, reconnect the radio to the B section so that it can draw up to 200 mA.

3.) *Bias Tests* Make these tests with the radio turned on, volume at minimum, no station tuned in. (If enough of the radio is built to tune a station in.) First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Then check TP15. It should be 0 V.

4.) *Disable Q7*. This can be done by connecting the collector ("C") of Q7 to TP6 with an e-z-hook-to-e-z-hook patch cord. The emitter of Q7 should be at 1.0 V, plus or minus a few tenths. (1.1 V if Q7 is not disabled.)

5.) *Mixer Output Tuning Adjustment* Leave Q7 disabled as described in Step 4 above.
Connect a 5.6 Ω, 1/4 W resistor in parallel with the main output of the signal generator. Set the signal generator 455 kHz, 0.05 V peak-to-peak output (Actual output will be 0.005 V peak due to the 5.6 Ω resistor), zero offset, sinusoid, and connect it through the capacitor substitution box (0.2 μF) to TP7.

Set the Simpson 260 VOM to the 2.5 V range, –DC function. Connect its common to the negative power supply terminal. Connect the + (red) lead to the bottom of R42 on the radio's circuit board.

Adjust T6 (yellow) for a maximum reading on the VOM.

After adjustment, connect the oscilloscope to TP3. It should show a sine wave of at least 3 V peak-to-peak. (5 V p-p is typical.) After this check, disconnect the oscilloscope probe from the radio. (The loading effect could reduce the accuracy of the following calibrations.)

6.) *Temporary Tuning Dial* Gently turn the tuning capacitor fully clockwise until it stops. Then borrow a tuning dial that has a label on it. Do not apply your own label at this time. Press the borrowed tuning dial on the shaft of the tuning capacitor. Put the AM section of the dial's label on top. Be sure the AM antenna's wires are clear of the dial. Bend any resistors and capacitors that are close to the dial down flat to the circuit board and away from the dial so that your fingers can easily manipulate the dial.

7.) *Oscillator Tracking Confidence Test* Enable Q7. (Entirely remove the jumper between Q7's collector to TP6. Do not leave one end connected since the stray capacity will de-tune the circuit.) The radio might tune in stations at this point—ignore that. (Turn the volume down.)

Make sure the signal generator(s) are powered off and not connected to the radio.

Connect the oscilloscope to the collector of Q7. Set the oscilloscope for 200 mV/division deflection, 250 ns/division sweep, AC coupling. The oscilloscope should show a sinusoid of about 1 V p-p (5 divisions) more or less. The frequency of this sinusoid should change when you adjust the tuning dial on the radio. If these observations are OK, proceed, otherwise perform step 8 below and then recheck. If it still is not working, debug.

8.) *Preset Trimmers*
A number of the following adjustments interact with each other. By putting all the adjustments in the center of their range you will reduce the amount of adjustment that might be needed. First, set all four trimmer adjustments on the back of the tuning capacitor unit for maximum capacity. That means you should adjust for the minimum amount of visible metal and the maximum amount of plastic visible. Second, turn each adjustment one-quarter turn CLOCKWISE (direction is important). Now all the trimmers are set in middle positions. From now on, never turn a trimmer more than one-quarter turn away from the middle position. (If you turn some trimmers counterclockwise to their middle positions and others clockwise, the edges of some

plates get too close to each other and all four will greatly interact with each other further complicating the alignment process. Be sure you turned each trimmer CLOCKWISE from the maximum capacity position.)

Using a felt-tip pen, mark the green side of the PC board with the name of each trimmer, see Figure N, page 32 in the Elenco manual. The labels to write are "AM ANT," "AM OSC," "FM ANT," "FM OSC."

9.) *Oscillator Tracking Alignment*
Disconnect the oscilloscope probe from the radio before doing the next steps. (It will cause a tuning error if it is left connected.)

We will use the counter/timer feature of the signal generator to measure and set the frequency of the radio's local oscillator under several different conditions.

Borrow an oscilloscope probe from your oscilloscope and connect it to the COUNTER input of the Instek signal generator. You must use a X10 oscilloscope probe to couple the signal to the counter input otherwise the loading effect will make the following adjustments horribly inaccurate.

To enable the counter, on the signal generator press and release SHIFT and then GATE. The GATE indicator should illuminate in the display. (Repeat this later when you want to toggle the counter feature off again.) Set the counter/timer for 0.01 s gate time by pressing just GATE repeatedly until the 0.01S indicator is illuminated. Connect the oscilloscope probe tip to the top lead of C31. Connect the ground clip of the probe to TP15. Turn the tuning dial on the radio fully counterclockwise to its stop (below the 540 kHz mark on the dial). The GATE indicator should start blinking and a frequency should be displayed. The frequency should change when you turn the tuning dial on the radio.

If you cannot get the counter to work, try removing the probe from the signal generator and connecting it to the oscilloscope input again so that you can see what signal is present at the top lead of C31. Set the oscilloscope to 50 mv/division, 250 ns, DC coupling. You should see a signal of about 50 mV (one division) peak-to-peak. Once you achieve that, move the probe connection back to the COUNTER input of the signal generator.

For best accuracy with the adjustments below, keep the oscilloscope probe away from the tuning knob. More specifically, don't let it lay right over the tuning knob.

8a.) Gently turn the tuning dial fully counterclockwise until it stops (below 540 kHz on the AM side of the dial). Adjust L5 (red) so that the counter/timer shows **981 ±3 kHz**. (The actual display might be 0.9800 MHz.) An ideal setting would be 985 kHz, but that would leave no margin for drift due to parts aging and temperature changes. The ideal setting is found by adding the IF frequency to the lowest frequency of a radio station that can be tuned in, 455 + 530 = 985 kHz. By deliberately tuning a few kHz low, you assure that the tuning dial will reach the lowest possible station.

8b.) Now gently turn the tuning dial on the radio fully clockwise until it stops. (above the 1600 kHz mark on the dial). Adjust the AM oscillator trimmer capacitor on the radio until the counter/timer shows **2159 ± 3 kHz**. The oscillator trimmer capacitor is on the back of the tuning capacitor—see Figure 25, page 29 in the Elenco manual. (The probe detunes the circuit by about 1 kHz at this end of the dial only. The ideal is the upper frequency to be tuned, plus the IF frequency, minus the detuning effect due to the probe. 1700 + 455 – 1= 2154.)

Adjustments 8a and 8b interact with each other. You will need to repeat them in sequence until you converge on settings of L5 and the AM OSC trimmer capacitor which give the correct frequencies on both ends of the AM dial.

10.)*Antenna Tracking Adjustment*

Disconnect the probe for the counter/timer from the radio, if it is still connected. Turn on the signal generator and set it to 600 kHz, 1.0 V p-p output, zero offset, sine wave with the 5.6 Ω resistor in parallel with the output. The negative output terminal of the signal generator should not be connected to anything. The positive output should go through the capacitor substitution box (0.2 μF) to a patch cord that is connected to nothing. This patch cord should be looped around the AM antenna one turn, but not connected to anything. The wire is a transmitting antenna—placed very close to the receiving antenna for now! It is transmitting silence since there is no modulation on this signal. Connect the oscilloscope to TP3. Set the oscilloscope for 1.0 V/division, 500 ns/division. Adjust the radio's tuning dial to tune in the signal generator at about 600 on the dial. Watch for a maximum on the oscilloscope. Turn up the volume and listen. The speaker should be silent. If you hear a radio station, re-tune until you get the signal generator's silent signal via the speaker and a maximum on the oscilloscope. Tweak the tuning knob on the radio for a maximum amplitude display on the oscilloscope. Test to be sure you have tuned in the signal generator and not a radio station or some interference from a computer by pulling the (positive) patch cord loose from the front jack of the signal generator. Then the oscilloscope should display a much weaker signal. Now you are ready for the real adjustment.

9a.) With the 600 kHz signal generator well tuned via the tuning knob, slide the antenna coil on the ferrite rod to maximize the amplitude of the signal displayed on the oscilloscope. Then make the adjustment more sensitive by reducing the output of the signal generator, until the signal on the oscilloscope gets a little noisy. (A noisy signal jumps around on the oscilloscope screen) Again slide the antenna coil and adjust it for a maximum display on the oscilloscope. Adjust the shim to get an appropriate amount of friction so that the coil stays where you put it but can still be moved. When the adjustment of the coil position is close, use the *magic wand*, (see Elenco Manual page 27) for making fine adjustments. See Figure 1 in this handout. (Figure 22 in the Elenco manual shows incorrect technique for using the magic wand.) Move the magic wand along the axis of the coil right up to the end of the ferrite rod—as if you wanted to lengthen the ferrite rod. The antenna coil is adjusted correctly when the first action of either end of the magic wand reduces the signal amplitude as the wand is brought closer to the antenna. (It is possible that the first action is to increase the signal, but then as you bring it closer, the signal decreases again. It is the first action that counts.)

9b.) Re-tune the signal to 1400 kHz, 1.0 V p-p (with the 5.6 Ω resistor), sine wave output. Tune in the 1400 kHz generator on the radio. Be sure you have tuned it in by disconnecting the patch cord from the front of the signal generator and checking for a much weaker signal. Then tune the AM antenna trimmer capacitor (See Figure 25 in the Elenco manual) for maximum response on as shown on the oscilloscope (monitoring TP3). When the adjustment is close, increase the sensitivity of the adjustment by reducing the signal generator's output voltage and tweaking the antenna trimmer capacitor again.

Adjustments 7a and 7b interact with each other. Repeat them in turn until you converge on settings of the antenna coil and the antenna trimmer capacitor that give maximum results at both 600 and 1400 kHz. Remember to keep your hand a few inches away from the AM antenna as you monitor the results of your adjustments. (Your hand will de-tune the antenna circuits.)

Figure 1, Correct use of the magic wand is to move it along the axis of the coil.

Recheck both oscillator tracking adjustments (page 6). The antenna tracking and oscillator tracking adjustments can slightly interact with each other under some conditions. If the oscillator tracking needs a final tweak, do so but then do not go back and readjust the antenna tracking. It might be slightly off, but it is more important that the oscillator tracking is accurate. Minor tuning errors in the antenna tracking will not noticeably reduce the radio's performance. If you do go back and tweak the antenna tracking, then also go back and check the oscillator tracking and adjust it if needed.

The AM adjustments are now complete and the AM section should work perfectly. Take the radio outdoors for a final "performance check." At night you should be able to pick up distant stations, such as KOA, 850 kHz, Denver (news/talk); WLS, 890 kHz, Chicago (news/talk); and KMNV, 1400 kHz, St. Paul (Spanish language).

Section 6 FM Ratio Detector Alignment after soldering

1.) Visual inspection Look for cold solder connections and solder bridges. If there are any questionable solder joints, fix them immediately instead of hoping for good connections.

2.) *Power Test* Adjust section A of the power supply to 9.5 V, 10 mA. The meter on the power supply is accurate enough for this adjustment. (But 10 mA probably is only one minor division of the meter's scale, so be sure it is zeroed correctly!) The current limit is needed to protect the transistors in case of a wiring error. Be sure the power switch on the radio is set to "off," then connect the radio to the section A of the power supply. Observe the voltmeter on the power supply—it should remain at 9.5 V. Set the radio for FM, then turn the radio on. The voltmeter on the power supply might take a momentary dip, but is should quickly stabilize again at 9.5 V. If the kit passes this test, set section B of the power supply to 9.5 V, 500 mA, then connect the radio to section B of the power supply to operate it at normal current levels for the rest of the tests.

3.) *Bias Tests* Make these tests with the radio turned on, volume at minimum, no station tuned in. (If enough of the radio is built to tune a station in.) First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Then check TP15. It should be 0 V.

Then check the emitter of Q6. It should be at 0.7 volt, plus or minus a few tenths.

4.) *Disable the FM Oscillator* If Q2 is installed, use an e-z-hook-to-e-z-hook patch cord to connect the base of Q2 to the emitter of Q2.

5.) *Function Generator Setup*:
The goal of this setup process is to produce a sinusoidal signal that has a frequency that increases slowly as time goes by. It should start at 10.7 MHz – 0.075 MHz = 10.625 MHz. Over a period of 1/50 of a second it should linearly increase in frequency to 10.7 MHz + 0.075 MHz = 10.775 MHz. Each 1/50 of a second the sweep of the frequency range should repeat. This is called a *swept sinusoidal signal*. Note that the center frequency is 10.7 MHz and the frequency deviates ±75 kHz. The total *span* of the frequency range is 150 kHz. Conceptually, the signal would look something like Figure 1 below if it were displayed on an oscilloscope. However, the signal shown in Figure 1 is for much lower frequencies. The signal needed to align the radio will have too many cycles in 1/50 of a second to plot in a meaningful way.

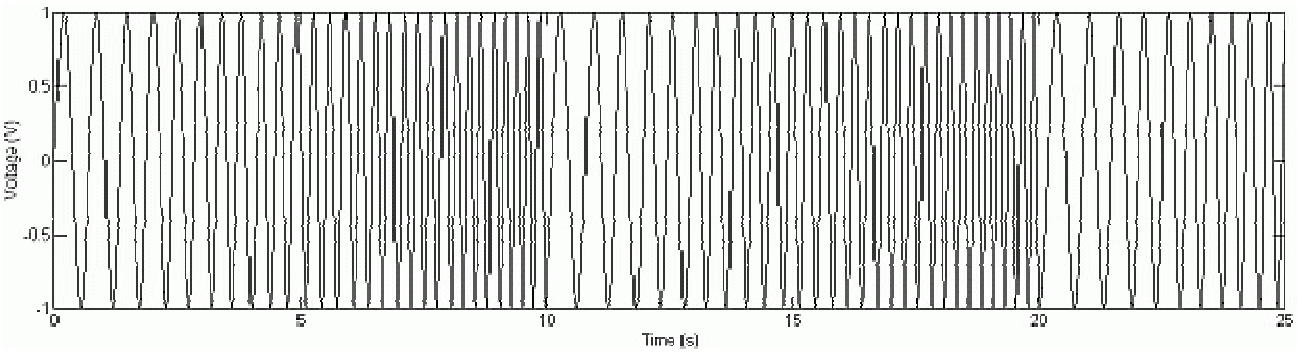


Figure 1, A swept sinusoidal signal. This one sweeps from about 1 Hz to about 4 Hz at a 0.1 Hz rate. It has a center frequency of about 3 Hz, a deviation of 1.5 Hz, and a span of 3 Hz. This waveform has a duty factor of 100% meaning that the frequency is always increasing (except for the instants when it drops back to about 1 Hz.

Setup Procedure:
Disconnect everything from the signal generator and power the signal generator up. Press SHIFT, RS-232 to set the signal generator to default settings. (This is like giving it a reset.)

Now press LIN S to specify that you want a linearly swept signal. The LIN S indicator in the MOD/SWP area of the display illuminates. (Now buttons that set the sweep parameters will be active. Some other buttons, like FREQ, will be inactive.) Check to be sure the sinusoid waveshape indicator is illuminated near the top of the display. If not, use FUNC to set it. Now press MOD ON to enable the sweep generator.

Press AMPL and then 0.2 and then Vpp.

Then press and release SHIFT, and then SYM (SWP CF). Then press 10.7 MHz. (Sets the center frequency.)

Press SPAN and then 150 kHz. (Sets the frequency deviation constant to ±75 kHz.)

Press RATE and then 50 Hz. (Sets the fundamental frequency of the audio modulation—a saw-tooth wave)

Pres SYM and then 90%. (Sets the duty time of the rising slope of the saw-tooth audio modulation.)

Confidence Check on the Signal Generator Setup
Connect a BNC cable to the MAIN output. Put a "50 ohm terminator and 0.1 μF AC coupler," a home-made part from now on called the "coupler," on the other end of the BNC cable. Connect the oscilloscope probe to the output of the coupler (red to probe tip, black to ground clip) to view the signal. Press AUTOSET. You should see about five cycles of the signal. Confirm that the amplitude is about 0.1 V peak (0.2 Vpp). Slow down the sweep to 250 ns/div. The sinusoids to the left and right of center should look thicker. This confirms that the setup of the signal generator is probably correct. Then disconnect the oscilloscope from the coupler.

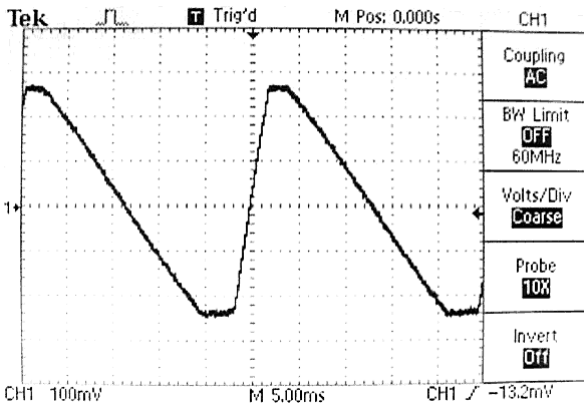
6.) *Connecting the Signal Generator*:
From the coupler, connect the black e-z-hook to TP15 and the red e-z-hook to the emitter of Q6

7.) *Oscilloscope Setup for Alignment of the FM Ratio Detector*
Move the oscilloscope probe to the top lead of C23. Set the oscilloscope for 100 mV/division deflection, 5.00 ms sweep, AC coupling.

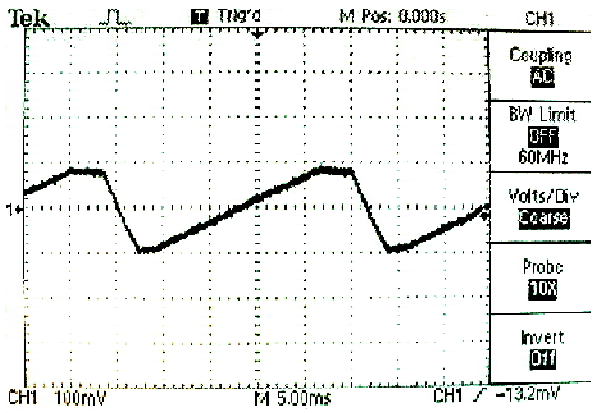
8.) If Q2 is installed, use an e-z-hook-to-e-z-hook jumper to disable it by shorting the base to the emitter. Turn the radio on and set the AM/FM switch to FM. The volume should be set low or at a minimum position. (Loud sounds could overload the amplifier and reduce accuracy.)

9.) *FM Ratio Detector Alignment* This adjustment has two goals—maximum gain and best linearity. The gain has two local maxima. Only one of those is a global maximum. This procedure insures that you find the global maximum.

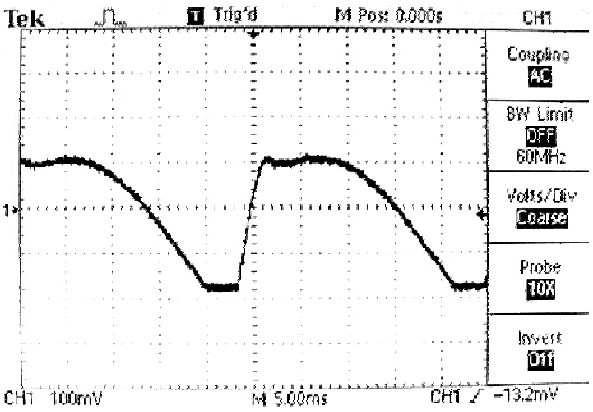
Adjust T4 (pink) to find the maximum as shown on the oscilloscope. This should bring the waveform up into the range of 50 – 900 mV p-p. The waveform should be triangular but will likely be highly distorted, possibly not even recognizable as a triangle wave. Now adjust T5 (blue) to get a maximum. Figure 1(c) below is a typical example of what to initially expect, but almost any waveshape is possible. The rising edge of the waveform should have the steepest slope, as shown in Figure 1(c). If the steepest slope is on the falling slope (Figure 1(b) or a distorted version of that), you found a non-global maximum. Adjust T5 (blue) typically about a half to a full turn one way or the other to move the maximum slope to the rising edge of the waveform, then repeat the adjustment of the pink core to get maximum amplitude. Finally, adjust T5, (blue), for best linearity. Pay attention to the straightness of the long line on the waveform (falling slope). Hold a straight edge up to the oscilloscope screen (a screwdriver works fine for this) and adjust T5 (blue) for the straightest line. This minimizes distortion in the FM audio and should not compromise the amplitude of the waveform much if the pink core was previously adjusted correctly. Good linearity is most important. Amplitude is a secondary goal. After T5 (blue) is adjusted for linearity, if you go back and re-touch T4 (pink) then check the linearity again. Make linearity the final criterion.



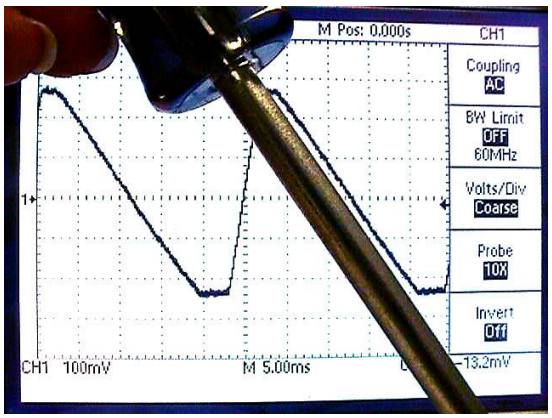
(a) Typical good result



(b) The non-global maximum.
This is bad. Adust T5 (blue) to correct.



(c) Not linear. Adjust T5 (blue).



(d) Final check for linearity

Figure 2—Example oscillographs for aligning the FM ratio detector.

Sections 7 and 8, FM IF Amplifier Alignment, after soldering.

1.) *Visual inspection* Look for cold solder connections and solder bridges.

2.) *Power Test* With the power supply adjusted as shown above in section 1, connect the radio to section A of the power supply and check for normal voltage, then reconnect to section B.

3.) *Bias Tests* Make these tests with the radio turned on, volume at minimum, no station tuned in. (If enough of the radio is built to tune a station in.) First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Then check TP15. It should be 0 V.

Then check the emitter of Q5. It should be at 0.7 V, plus or minus a few tenths.

4.) *Set up the signal generator* the same as for Section 6, except change the output amplitude setting from 0.2 Vpp to 0.01 Vpp. Connect the red e-z-hook of the home-made coupler to TP10 (and the black ground to TP15).

5.) *Set up the oscilloscope* for 100 mV/div, 5.00 ms/div, AC coupling (the same as for Section 6) and connect the probe tip as before to the top of C23 Also connect the probe's ground clip to TP15.

6.) *Disable the FM Oscillator* If Q2 is installed, use an e-z-hook-to-e-z-hook patch cord to connect the base of Q2 to the emitter of Q2.

7.) *2nd FM IF Coarse Alignment*. Adjust T3 (right green) for a maximum on the oscilloscope

8.) *1st FM IF Coarse Alignment*. Move the coupler's output (red e-z-hook) to the base of Q4. Adjust T2 (left green) to maximize the amplitude of the wave shown on the oscilloscope.

Section 9, FM Oscillator and RF Amplifier Alignment, after soldering.

1.) *Visual inspection* Look for cold solder connections and solder bridges. If there are any questionable solder joints, fix them immediately instead of hoping for good connections.

2.) *Disconnect* the signal generator and the oscilloscope from the radio, if either or both are connected. Also entirely remove the jumper wire from Q2, if it is there. The radio might tune in stations at this point. Ignore that.

3.) *Power Test* With the power supply adjusted as shown above in section 1, connect the radio to section A of the power supply and check for normal voltage, then reconnect to section B.

4.) *Bias Tests* Make these tests with the radio turned on, AM/FM switch to FM, volume at minimum, no station tuned in. (If enough of the radio is built to tune a station in.) First confirm that the power supply is correctly set to 9.5 V and that the radio has a good ground. Do this by touching the DMM's red probe to the power tab (on/off switch) at the bottom of the volume control—it should be 9.5 V. Also check TP 15. It should be 0 V. Then check these voltages:

Emitter of Q3, 1.5 V, ±0.5 V.

Emitter of Q2, 3.0 V, ±1.5V. (The emitter voltage of Q3 varies as the tuning dial is adjusted.)

5.) *Set up the signal generator* the same as for Section 6, except change the output amplitude setting from 0.2 Vpp to 0.01 Vpp. Connect the red e-z-hook of the home-made coupler to TP13 (and the black ground to TP15).

6.) *Set up the oscilloscope* for 500 mV/div, 5.00 ms/div, AC coupling and connect the probe tip to TP11. Also connect the probe's ground clip to TP15. The oscilloscope should show a fat black band of a signal.

7.) *Mixer Output Course Alignment*. Adust T1 (orange) for a maximum on the oscilloscope.

8.) I.F. Strip Fine Tuning. Move the oscilloscope probe to the base of Q6. Connect a BNC patch cord from the function generator's MOD output to the oscilloscope's EXT TRIG input. Use the trigger menu on the oscilloscope to select the Source as "Ext". Adjust the Trigger level if necessary for a stable display. A trigger level of about 200 mV will usually work well. Set the oscilloscope for about 200 mV/div, 5.00 ms/div. Now repeatedly tweak the adjustments (make only small adjustments) for T3 (right green), T2 (left green) and T1

(orange) in that order to try to level the envelope of the signal to a constant. A secondary goal is to maximize the amplitude of the signal displayed on the oscilloscope, but a flat envelope is more important. Do not return to an adjustment more than three times. Do not make large adjustments. Too many fine adjustments can cause the center frequency of various stages to drift away from 10.7 MHz (in opposing directions).

9.) If there is no knob on the tuning capacitor, put a borrowed test knob on for convenience. (Turn the capacitor's shaft fully clockwise, then the AM section of the dial goes on top.)

10.) *Function Generator Setup for FM Oscillator Alignment*

Create a loop antenna from a BNC plug to female banana plug adapter and a piece of jumper wire about four to six inches long. Connect the wire as a short circuit across the adapter. (If the loop is too long or too short the antenna might not work well.) Connect a BNC tee to channel one of the oscilloscope. Connect the antenna to one side of the tee. Connect a BNC patch cord from the other side of the tee to the COUNTER input of the function generator.

Set the oscilloscope for a 1X probe, DC coupling, 50 mV div, 5 ns/div. Enable the counter on the function generator by pressing and releasing SHIFT and then GATE. The GATE indicator should illuminate in the display. (Repeat this later when you want to toggle the counter feature off again.) Set the counter/timer for 0.01 s gate time by pressing just GATE repeatedly until the 0.01s indicator is illuminated.

Remove all connections, probes, jumpers, etc. from the radio. Turn the radio on, volume at minimum, AM/FM switch to FM and the tuning dial fully counterclockwise.

Lay the loop of your antenna down on the circuit board of the radio so that it surrounds C9, Q2, L3 (the inductor above Q2), Q1 and some of the other parts nearby. Watch the oscilloscope and move the loop antenna to get a strong signal. A signal of more than 50 mV peak-to-peak should be possible. After that has been achieved, note the location of the loop antenna so that you can remove it and put it back in a good location without much effort. Now move the loop antenna underneath the circuit board in about the same place as it was when it was above the board. Note a location there that also picks up a strong signal.

With a strong signal from the loop antenna the GATE indicator on the function generator should be flashing and a frequency should be displayed. Adjusting the tuning dial should change the displayed frequency.

11.) *FM Local Oscillator Tuning*.

11a.) *L3 Adjustment*. Turn the tuning dial fully counterclockwise to its stop and then adjust L3 by spreading the coils apart so that the counter displays a frequency of **98.5 ± 0.2 MHz**. (87.8 + 10.7 = 98.5 MHz Thus the dial will tune down to 87.8 MHz at its limit. That is 0.3 MHz beyond the lowest possible station at 88.1 MHz. to give some margin.) Typically, you need about 0.5 or 1 mm between each turn of L3. If you spread L3 too much, you can push it back together a bit as needed. Figure 3 (next page) shows what L3 typically looks like after adjustment.

11b.) *Oscillator trimmer capacitor adjustment.* Turn the tuning dial fully clockwise to its stop and then adjust the FM oscillator trimmer capacitor so that the counter displays a frequency of **118.9 ± 0.2 MHz**. (108.2 + 10.7 = 118.9 MHz Thus the dial will tune up to 108.2 MHz at its limit. That is 0.3 MHz beyond the highest possible station at 107.9 MHz. to give some margin.) This adjustment is best done with a non-magnetic tool. If you use a magnetic tool, be sure the frequency is correct when the tool is removed from the capacitor.

11c.) Steps 11a and 11b interact with each other. Repeat them in turn until you get correct results at both ends of the dial.

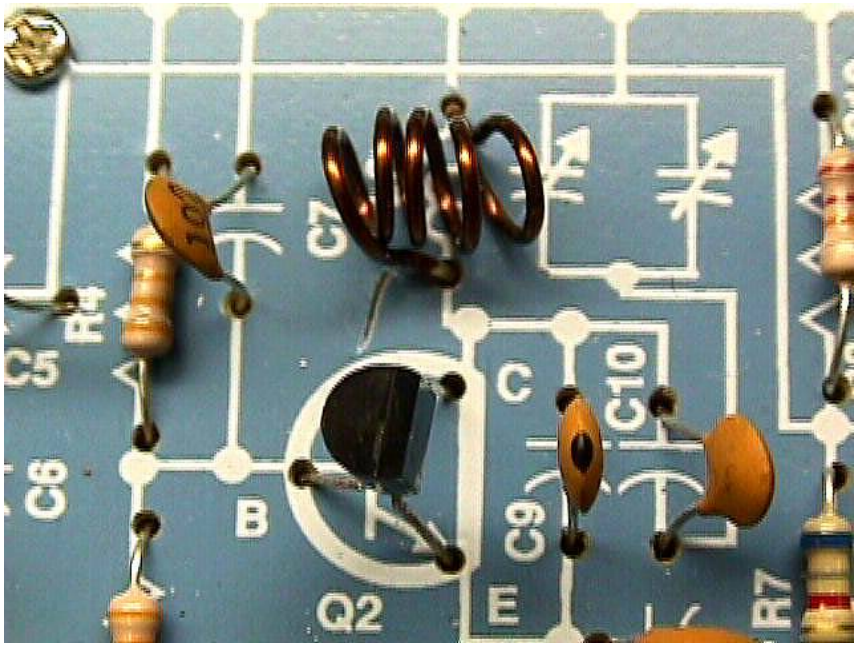


Figure 3. This is what L3 typically looks like after spreading it out for tuning.

12.) *FM RF Amplifier Tuning*.

Fully extend the FM antenna and aim it straight up from the circuit board. Keep your hands and other large objects (e.g. a computer monitor) away from the antenna during the next adjustments. (Especially, do not hold the radio by the antenna.)

12a.) Turn the radio's tuning dial to about 90 but make sure no station is tuned in (or near being tuned in). Turn up the volume control until you hear noise. If you cannot hear noise through the speaker use an earphone or use an oscilloscope connected to the speaker. Adjust L1 by spreading it apart to the point that maximizes the noise. If the noise gets loud, turn down the volume so that the amount of noise is not limited by the output power capability of the audio amplifier.

12b.) Turn the radio's tuning dial to about 106 but make sure no station is tuned in. Adjust the FM Antenna trimmer on the back of the tuning capacitor to maximize the noise.

12c.) Steps 7b and 7c interact with each other. Repeat them in turn until noise is maximized at both 90 and 106 (about) on the radio's dial.

13.) *Final adjustments*.

Steps 8b on page 5 (AM oscillator tracking) and 11b on page 11 (FM oscillator tracking) may interact with each other slightly. Check them again and adjust them only if necessary. If large adjustments are needed you will then need to repeat steps 8a (page 5) and 11a (page 11) too, so only make adjustments if they are out-of-specification. It's best to be tolerant of minor deviations from ideal at this time unless you have lots of time for fiddling with improvements that are probably imperceptible in normal use.

Finally, remove the temporary tuning dial and apply your own dial and label. (Optional: before removing the backing from your label, punch a hole right in the center so the mounting screw will not be covered by the label.)

The FM section is now fully tuned and should work well. When the radio is outdoors you should be able to pick up all local stations, for example one of the weaker stations that you should be able to get is KWIT, 90.3 MHz, Sioux City.