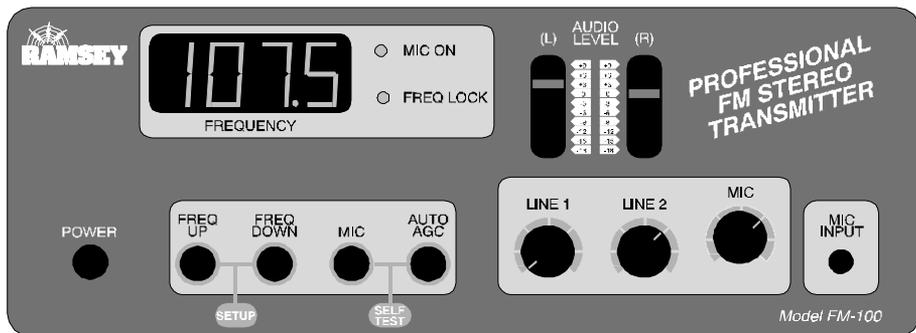


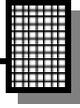
# PROFESSIONAL FM STEREO TRANSMITTER

Ramsey Electronics Model No. FM-100

*Now here's the ultimate radio transmitter for all of you home brew DJs out there! This all-in-one stereo transmitter has all the features you will ever need for transmitting for a school radio station, around your yard, or even around the block. With an optional high power module for out of the US transmitting, this is definitely a professional unit!*

- 2 Line inputs and one mic input-plus a built in mixer!
- PLL Crystal controlled for rock solid frequency
- Left and right channel peak hold indicators and large LED frequency display
- Built in power supply, just plug it in!
- 25mW output standard, optional 1W module for foreign country operation
- Auto AGC microphone muting function for cool talk overs
- Rugged steel enclosure for years of use





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**PARTIAL LIST OF AVAILABLE KITS****RAMSEY TRANSMITTER KITS**

- FM100 Professional FM Stereo Transmitter
- FM25 Synthesized Stereo FM Transmitter
- MR6 Model Rocket Tracking Transmitter
- TV6 Television Transmitter

**RAMSEY RECEIVER KITS**

- FR1 FM Broadcast Receiver
- AR1 Aircraft Band Receiver
- SR2 Shortwave Receiver
- SC1 Shortwave Converter

**RAMSEY HOBBY KITS**

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- SS70A Speech Scrambler
- BS1 "Bullshooter" Digital Voice Storage Unit
- AVS10 Automatic Sequential Video Switcher
- WCT20 Cable Wizard Cable Tracer
- LC1 Inductance-Capacitance Meter

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**RAMSEY MINI-KITS**

Many other kits are available for hobby, school, Scouts and just plain FUN. New kits are always under development. Write or call for our free Ramsey catalog.

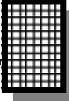
**FM-100 PROFESSIONAL STEREO TRANSMITTER INSTRUCTION MANUAL**

Ramsey Electronics publication No. MFM-100 Revision 1.1a

First printing: April, 1996 MRW

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## KIT ASSEMBLY AND INSTRUCTION MANUAL FOR

# FM-100 PROFESSIONAL STEREO TRANSMITTER

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## **INTRODUCTION TO THE FM-100**

First we will begin with a little history of stereo transmitters at Ramsey Electronics to give you some idea how we arrived at the FM-100 as our latest stereo transmitter. We have many people call us each day asking questions about our earlier versions of transmitters such as the FM-25 and the FM-10a. Most are questions concerning drifting, sound quality, and transmitting distance. The tunable FM-10a was a great product for a low-cost entry into the world of micropower transmitters. The FM-25 was the next step up allowing for a rock solid stable frequency just like professional stations. The latest step was to create a transmitter that not only has a rock solid frequency, but also all the features you would find in a commercial station.

Well, in answer to customer research and comment, here is the result of months of design and years of stereo transmitter experience. The FM-100 has all of the features needed to run a professional sounding radio station. It includes extensive audio filtering to prevent high frequency audio interference, AGC (Automatic Gain Control) with the microphone to prevent overloading distortion, a frequency display with easy frequency adjustment, 2 line inputs, 1 microphone input, PLL controlled, CD quality transmission, and more. In other words we pulled all the stops to bring you a top quality product that will satisfy even the most discriminating user.

Due to demand from our neighbors down south, and wherever it is legal, we have allowed for a special module to be added to give you a 1 watt RF output. Simply plug it right in with a minor adjustment, hook up a good antenna and bingo, you're on the air over miles.

We are happy to bring you this truly professional product that will give you many years of fun, reliable use, and enjoyment knowing that you have built it yourself.

## HOW DOES IT WORK?

Here is where we get into a little circuit analysis. If you just want to plug it in and start broadcasting, you can skip this section and read the FCC regulations section. Otherwise there is some insight into why and how this FM-100 works. We will use the schematic located at the center of the manual to analyze the circuit.

We will begin with the power supply since it is the most common circuit we will see. When you plug a working unit in, 110 VAC is applied across the primary winding of the transformer T1. This in turn induces 10 VAC across each secondary winding. The transformer included in your kit is rated for 500mA per winding, but we have connected two of them in parallel, allowing us to get 1 Amp at 10 VAC. This current is necessary when the high power module is added into the kit. The module draws a little more than 500mA when transmitting, which left no more current for the rest of the kit. The displays draw 10mA per segment, and there are a maximum of 29 of them lit at any time. That is another 290mA, making for a total of 790mA, not including the rest of the circuitry. As you can see, this project requires a little power to get on the air, so a substantial power supply is required for good operation.

The output AC of the transformer is fed to a bridge rectifier, where it is converted to about 12 VDC, and then smoothed out with C86 and C52, both 3300uF capacitors. These big capacitors were required to reduce ripple in the power supply to a minimum and therefore reducing 120Hz noise in the audio of the project.

To get a negative supply for the opamps, we make a negative voltage multiplier which taps some of the AC from the transformer. C89 passes AC, but not DC, allowing D7 and D6 to rectify the AC through the capacitor to a negative voltage. C55 then smoothes out the ripple.

Regulators are then used to completely smooth out any remaining ripple and other noises present on the power supply. The +12 volts is regulated to +5 volts by VR3, the +5 volts is then used for digital circuitry and some of the audio circuitry. The +12 volts is also regulated to +8 volts for most of the audio circuitry, and the major source of power for the high power module. The -12 volts is regulated to -8 volts for just the audio circuitry.

Now we will get on to the display circuit, and why we designed it this way. Keeping low noise in mind, we wanted a display that produced as little noise as possible. We determined that an LED display was our best choice for visibility, but we couldn't use display drivers that multiplexed. Multiplexing means that all of the digits are never on at the same time, but each are turned on in turn at a high enough rate so that to your eye it looks as if all are lit at the same time. The switching between the displays produced more noise than we wanted to have to deal with, so we chose a method where all the displays are constantly

lit. While this may not be the most efficient method of lighting a display, it is the least noisy. U3, the MM5451 is just a large serial shift register made for driving LED segments.

Well, the display wouldn't do much without a smart device to send it some meaningful data. In this case we are using a Motorola microcontroller (U4) to do the job for us. This microcontroller performs most of the operations on the unit such as checking for button presses, setting the transmitting frequency, muting audio lines at appropriate times, as well as updating the display.

When the frequency is changed, we access U2, a serially programmed PLL (Phase Locked Loop). When the frequency needs to be set, the information is sent serially to U2. This information is a string of binary data, (1's and 0's). In this way data is sent one bit at a time to U2. The frequency information takes 16 bits, and there are an additional 32 bits sent for the internal control of U2. You may think that all this would take a long time, but in fact the whole process from the time you press a frequency control switch until the data is completely sent is less than 1/100th of a second!

The PLL also takes the 6 MHz crystal frequency and divides it by 60 to obtain a stable reference frequency of 100KHz. How does it know to divide the crystal frequency by 60? That is part of the data that is sent from U4 each time a frequency button is pressed. To set the operating frequency of U6, we simply send U2 divide by N data to produce the desired frequency from the BA1404's VHF oscillator. The oscillator's frequency is divided by this value N, producing an output in the 100KHz region. The internal phase detector compares the highly accurate 100KHz reference with the divide-by-N output and controls the BA1404 oscillator so that the frequencies match precisely.

Using the example from above, a frequency of 95.3 MHz gives an N of 953, so the frequency from U3 is divided by 953 and then compared with the reference frequency of 100 KHz. If the desired frequency is less than the reference frequency U2 increases the output voltage on pin 13. This increases the voltage across diode D10, a varactor diode. As the voltage across the varactor increases, it causes a decrease in capacitance (Increasing reverse bias essentially increases the distance between the capacitor's plates by increasing the depletion region in the diode ( $C = kA/d$ ). The decrease in capacitance causes an increase in U6's RF oscillator ( $f_o = 1/[2\pi(LC)^{1/2}]$ ), bringing the FM-100's output frequency back on frequency. If the desired frequency is higher than the reference, pin 13 is driven low. If the frequency is just right then pin 13 becomes a high impedance, basically disconnecting it from the circuit so it will cause no change in the voltage on D10. The voltage changes on pin 13 are filtered by R8, C9, R7, and C11 to provide a steady, noise free tuning voltage for D10. In this way the output frequency of U6 is "locked" to that desired by the microcontroller. Meanwhile U4 is polling pin 11, the LD (Lock Detect) output of U2 to determine if the PLL can achieve a "lock" or not.

If you are a close observer, you will notice that U4 derives its clock signal from the PLL. The PLL has a nifty feature of a buffered divided crystal output to drive external devices such as microcontrollers. This is another part of the 32 bits we send to the microcontroller other than the divide by N info. When first powered on, the XCLK line is at the lowest possible divide by C frequency, which is  $6\text{MHz} / 16$  or 375KHz. This runs the microcontroller at a pretty slow rate until we can send out new information using a C of 4, giving us a clock of 1.5MHz. This clock frequency is not only used by the microcontroller U4, but also by U9 and U10, the switched capacitive filter circuitry that we will talk more about in a minute.

U1 is a serially accessed EEPROM, which stores our frequency settings for the next time we power up the FM-100. This prevents us from having to go through setting the proper frequency every time we turn off the FM-100. The frequency data is only set to the EEPROM when the user exits the setup mode, and a confirming beep from SP1 lets the user know it is written.

U6, the BA1404 FM stereo transmitter IC is what does all the work of creating your stereo subcarrier, and doctoring your audio signals for transmission. The BA1404 was originally designed to run from a couple of 1.5 volt batteries, so it was made to be run at a low voltage. We decided to use a 2.5 volt regulator (VR1) to give us the proper voltage at the greatest noise immunity from the power supply. The low level RF output of U6 is then fed to Q2 and surrounding parts to boost it to a more reasonable level for filtering. Since the RF output of the BA1404 is not the cleanest, much filtering is required to remove unwanted transmissions that are outside of the FM band.

The primary filter for the job is the bandpass filter consisting of C84, L5, L4, C82, L6, and C85. This has a lower cutoff at about 70MHz, and an upper cutoff at 120MHz. The output of this filter is sent to a class C amplifier consisting of Q1 and R32. This gives us a higher level output which is adequate for local broadcast. But before going to the antenna, we low pass filter the output at 110MHz. This gets rid of the unwanted upper harmonics that are very present in a class C amplifier. Harmonics are multiples of the primary frequency and the primary one we are trying to get rid of is the second harmonic ( $F \times 2$ ), which in our case winds up in the aircraft band. It is extremely important for us not to interfere with ANY other transmissions in ANY band. These filters will keep us from doing any harm outside our intended transmission band.

Now that we're done talking RF, we can get on with the audio. We will begin with the microphone amplifier. U7, a voice detector chip is used in this circuit. It has a couple features that we use in the FM-100 that really help us out. One feature is the AGC or Automatic Gain Control. This prevents us from overloading the audio circuitry by getting excited and yelling in the microphone. When the amplitude of the signal coming from the microphone increases, the gain of the microphone amp decreases, keeping its output relatively the same over varying input levels.

The second neat feature is the voice detection capability. Voice detection is used with the auto AGC feature of the FM-100. Essentially pin 8 of U7 goes high when there is a varying signal level seen on the microphone, as compared to the constant level of background noise. When pin 8 goes high, it turns JFETS Q5 and Q6 on which act like voltage controlled pots. The more they are turned on, the less resistance is seen from source to drain. This in turn mutes the audio from the line level inputs, allowing only the microphone to be heard when there is voice detection active.

U4, the microcontroller, has the ability to override this feature by setting the connection marked AUTOAGC high, thereby turning Q7 on, which disallows Q5 and Q6 from turning on. The microcontroller can also mute the microphone audio by setting the MUTE line high, thereby turning Q4 on, grounding out all the microphone audio. R21 and C37 smooth out the switching transitions so that there is very little popping heard that is apparent in most switches. This MUTE line is also used to turn on the microphone line when the speaker sounds a tone on the unit. This prevents the tone from being transmitted over the air.

In our description of the audio we will only be talking about the right channel circuitry in the FM-100, since the left channel is identical. Line level audio is applied to J5 or J6, and then on to R62 or R84. R62 and R84 control each line level's transmission volume. These levels are then summed in U8:A, so now both signals are present on pin 1 of U8. This signal is then sent through R63, which when combined with Q5 gives the voice detector circuitry the ability to mute the audio. The audio continues to U8:B, where it is summed with the microphone audio. The microphone audio level is controlled by R26, and is sent to both the left and the right channels. The microphone audio combined with the line level audio passes then on to U9, a switched capacitor filter.

U9 is an 8th order Butterworth switched capacitor low pass filter. It doesn't require reactive components like capacitors, inductors and resistors to set its operating frequency, instead its frequency is set by a clock reference. In this case it is 1.5MHz from the PLL that we discussed earlier. The actual operating frequency is then 1.5MHz divided by 100, or 15KHz. Anything over this frequency, like high frequency tones from cheap CD players and people with squeaky voices, is simply cut out to prevent interference with the stereo subcarrier in the BA1404.

U9 also has a built in op-amp which we use for our 75uS equalization. This equalization conforms with the standards for North America FM broadcast. The audio is then sent to U11:A for further low pass filtering. This filter gets rid of the 1.5MHz clock signal that may be present in the audio from the MAX291 (U9). Now we have nice clean audio all doctored up for serving across the airwaves. The audio is then sent to R23, which sets the relative audio level to be transmitted.

Part of the output of U11:A is observed for the level indicators. IC U11:B, D4, R54 and C60 comprise a peak hold detector. Part U11:B and D4 make up a real diode, meaning there is no .7 volt drop normally associated with a diode because it is accounted for in the feedback of the opamp. The “real diode” will charge C60 quickly on positive going signals, but it doesn’t discharge it. The discharge cycle is left up to R54. The larger the value, the longer in time the peak hold function is. The voltage on the peak hold is then observed by using a LM3915 bargraph display driver U12 and a ten segment bargraph. This part is pretty self explanatory, it’s really just a voltage meter with a log scale instead of a linear one.

The whole process of filtering, mixing and level detecting is repeated in the left channel as well. This completes the basic analog circuit description of the FM-100, but you may be interested in more detail of how it works. If so, there are many good books and magazines which deal with circuitry of this sort in smaller manageable circuits which can help you delve further in what is going on.

## MICROCONTROLLER DESCRIPTION

The coding of the microcontroller is set up for a simple process of changing frequency. As you will see, there is more than meets the eye, but it's not so complex when you give it a look.

We will start with two given conditions: 1) The unit is powered up, and 2) The unit has been set in setup mode. In this state the tens decimal point is blinking and your frequency may be changed.

1. User presses FREQ UP button.
2. Microcontroller stops scanning the LD (Lock Detect) line, sees what key the user has pressed.
3. It's a Frequency key, is the unit in setup mode?
4. Yes, increase the frequency value in RAM by 200KHz.
5. Send the appropriate divide by N to the PLL (U2) along with the rest of the required data.
6. Decode the display digits, then send the correct bits to the display.
7. Mute the microphone.
8. Send confirm beep.
9. Un-mute the microphone.
10. Wait for key release, if no key release after some time, repeat from step 4.
11. Continue polling LD and updating status indicators.

We hope all of this information helps you understand better what is going on in the FM-100, and will lead to some insight when you are having assembly troubles or something isn't working properly. Remember most projects like this are made up of many smaller ones, all you have to do is break them down to understand them better. Now on to building!!!

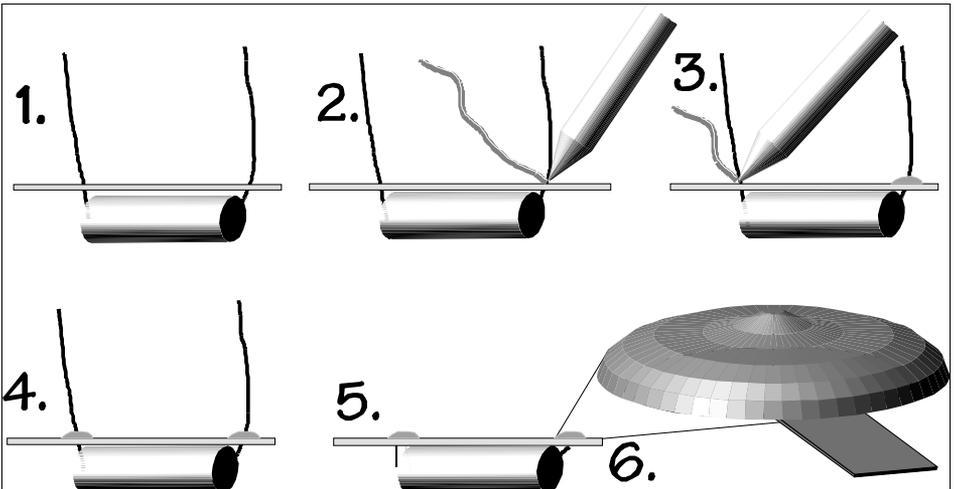
## RAMSEY “LEARN-AS-YOU-BUILD” ASSEMBLY STRATEGY

Be sure to read through all of the steps, and check the boxes as you go to be sure you didn't miss any important steps. Although you may be in a hurry to see results, before you switch on the power check all wiring and capacitors for proper orientation. Also check the board for any possible solder shorts, and/or cold solder joints. All of these mistakes could have detrimental effects on your kit - not to mention your ego!

### ***Kit building tips:***

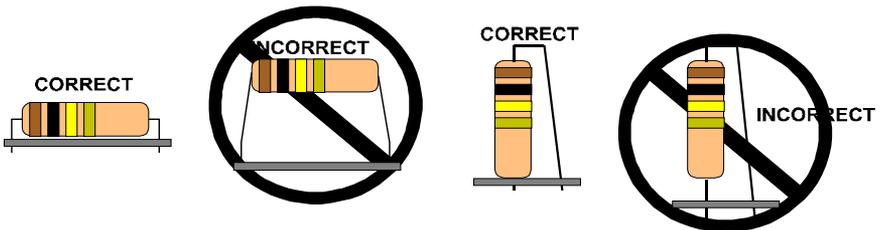
Use a good soldering technique - let your soldering iron tip gently heat the traces to which you are soldering, heating both wires and pads simultaneously. Apply the solder on the iron and the pad when the pad is hot enough to melt the solder. The finished joint should look like a drop of water on paper, somewhat soaked in.

Mount all electrical parts on the top side of the board provided. The top side is clearly marked with the word “TOP”, you can't miss it. This is the side that has little or no traces on it, but is covered with mostly copper. When parts are installed, the part is placed flat to the board, and the leads are bent on the backside of the board to prevent the part from falling out before soldering (1). The part is then soldered securely to the board (2-4), and the remaining lead length is then clipped off (5). Notice how the solder joint looks on close up (6).



Since this is a “professional” transmitter, we sincerely hope you put this together in a professional manner. This project will not work as well as you wished if you just slap it together without following good assembly techniques, and follow all instructions. No matter how clear we may think our manual is, if you have any questions give us a call at the factory instead of jumping to conclusions, we will be happy to help you with any problems.

This is a mixed signal project meaning there is digital, audio, and RF circuitry all in one unit. As with all RF circuitry, we want to mount the parts AS LOW AS POSSIBLE to the board. A 1/4” lead length on a resistor not mounted close to the board can act as an inductor or an antenna, causing all sorts of problems in your circuit. Be aware though that there are stand up components in your circuit. They don’t need to be squished to the board, but keep the portion of the resistor closest to the board mounted right on the board.



For each part, our word "Install" always means these steps:

- 1. Pick the correct part value to start with.
- 2. Insert it into the correct PC board location, making sure the part is mounted flush to the PC board unless otherwise noted.
- 3. Orient it correctly, follow the PC board drawing and the written directions for all parts - especially when there's a right way and a wrong way to solder it in. (Diode bands, electrolytic capacitor polarity, transistor shapes, dotted or notched ends of IC's, and so forth.)
- 4. Solder all connections unless directed otherwise. Use enough heat and solder flow for clean, shiny, completed connections.

Keeping this in mind, lets begin by sorting out our components and cross-checking them against the parts list to make sure we have received everything.

NOTE TO NEWCOMERS: If you are a first time kit builder you may find this manual easier to understand than you may have expected. Each part in the kit is checked off as you go, while a detailed description of each part is given. If you follow each step in the manual in order, and practice good soldering and kit building skills, the kit is next to fail-safe. If a problem does occur, the manual will lead you through step by step in the troubleshooting guide until you find the problem and are able to correct it.

## RAMSEY FM-100 PARTS LIST

### **Semiconductors**

- 1 MC145170 Serially programmed PLL (U2)
- 1 BA1404 Stereo generator IC (U6)
- 2 LF347 Quad low noise opamps (U11,8)
- 1 68HC705J2 Custom programmed microcontroller (U4) Marked FM-100
- 1 X2402 serial EEPROM (U1)
- 2 LM3915 Log bar-dot bargraph display drivers (U12,U5)
- 2 MAX291 8th order Butterworth lowpass switched capacitive filters (U9,10)
- 1 MC2830 Voice activated switch with AGC (U7)
- 1 MM5451 Serial shift register display driver (U3)
- 1 79L08 -8 volt voltage regulator (TO92 package) (VR4)
- 1 7808 +8 volt voltage regulator (TO-220 package) (VR2)
- 1 7805 +5 volt voltage regulator (TO-220 package) (VR3)
- 1 78L02 +2.5 volt voltage regulator (TO-92 package) (VR1)
- 2 10 segment bargraph displays (D11,12)
- 2 Small red LEDs (D2, 3)
- 2 Dual Common Anode LED displays (DS1, 2)
- 6 1N4002 rectifier diodes (Black with white stripe on one end) (D6,7,21,22,23,24)
- 5 1N4148 small signal switching diodes (small orange glass body with black stripe) (D1,4,5,8,9)
- 1 BB609 Varactor diode (black diode with green band) (D10)
- 3 BS170 N-Channel enhancement TMOS FETs (Q4,5,6)
- 2 2SC2498 or 2570 NPN UHF Bipolar transistors (Q1,2)
- 2 2N3904 NPN General purpose transistors (Q3,7)

### **Resistors**

- 1 10 ohm resistor (brown-black-black) (R9)
- 1 51 ohm resistor (green-brown-black) (R73)
- 1 100 ohm resistor (brown-black-brown) (R16)
- 3 270 ohm resistors (red-violet-brown) (R30,32,36)
- 2 330 ohm resistors (orange-orange-brown) (R1,4)
- 1 470 ohm resistor (yellow-violet-brown) (R11)
- 18 1K ohm resistors (brown-black-red) (R18,19,20,29,33,39,44,47,50,53,59,64,71,76,82,86,87,89)
- 3 4.7K ohm resistors (yellow-violet-red) (R42,61,69)
- 1 8.2K ohm resistor (gray-red-red) (R13)
- 23 10K ohm resistors (brown-black-orange) (R2,5,6,8,10,12,14,17,40,41,49,55,56,57,60,63,68,70,78,80,83,85,88)
- 4 15K ohm resistors (brown-green-orange) (R22,27,58,66)
- 2 22K ohm resistors (red-red-orange) (R31,65)
- 1 33K ohm resistors (orange-orange-orange) (R24)

- 7 47K ohm resistors (yellow-violet-orange) (R21,28,34,54,67,72,79)
- 4 75K ohm resistors (violet-green-orange) (R45,52,77,81)
- 4 100K ohm resistor (brown-black-yellow) (R7,51,75,91)
- 1 150K ohm resistor (brown-green-yellow) (R46)
- 1 220K ohm resistor (red-red-yellow) (R25)
- 3 1M ohm resistors (brown-black-green) (R3,38,48)

### **Ceramic capacitors**

- 1 5pF ceramic capacitor (marked 5 or 5K) (C15)
- 4 10pF ceramic capacitors (marked 10 or 10K) (C18,27,32,82)
- 2 27pF ceramic capacitors (marked 27 or 27K) (C1,2)
- 4 47pF ceramic capacitors (marked 47 or 47K) (C29,31,84,85)
- 1 75pF ceramic capacitor (marked 75 or 75K) (C30)
- 6 100pF ceramic capacitors (marked 100 or 101) (C13,40,46,64,70,91)
- 1 220pF ceramic capacitor (marked 220 or 221) (C34)
- 15 .001uF ceramic capacitors (marked .001 or 102) (C7,8,14,24,25,26,28,36,41,45,62,75,87,88,90)
- 2 .0047uF ceramic capacitors (marked .0047 or 472) (C61,74)
- 13 .01uF ceramic capacitors (marked .01, 10n, or 103) (C3,10,17,20,21,48,49,53,54,79,80,81,83)
- 6 .1uF ceramic capacitors (marked .1 or 104) (C4,9,22,51,66,68)

### **Electrolytic capacitors**

- 1 1uF electrolytic capacitor (C38)
- 1 2.2uF electrolytic capacitor (C12)
- 25 10uF electrolytic capacitors (C6,11,16,19,23,33,35,37,39,42,43,44,56,58,60,63,65,67,69,71,72,73,76,77,78)
- 2 47uF electrolytic capacitors (C47,59)
- 2 100uF electrolytic capacitors (C5,50)
- 2 1000uF electrolytic capacitors (C55,89)
- 2 3300uF electrolytic capacitors (C52,86)

### **Variable Resistors**

- 2 1K ohm trimmers (orange top marked 102) (R23,35)
- 1 10K ohm board mount pot (R26)
- 2 10K ohm dual pots (R62,84)
- 1 100K ohm trimmer (orange top marked 104) (R15)

### **Inductors**

- 1 adjustable shielded metal can coil or similar (L1)
- 4 40nH coils (small 4 turn air coils) (L2,3,5,6)
- 1 Small red torroid core (L4)
- 8" #26 enamel wire for winding (L4)

## Miscellaneous

- 1 38KHz crystal (Y2)
- 1 Mini speaker (SP1)
- 2 Stereo RCA jacks (J5,6)
- 1 6 pin Molex connector (J10)
- 1 4 pin Molex header (J11)
- 4 5 pin headers (J1,3,7,8)
- 5 DPDT Push button switches (S1,2,3,4,5)
- 1 20 pin IC socket
- 1 3.5mm phono jack (J4)
- 1 Whip antenna (ANT1)
- 1 18 pin IC socket
- 1 PC-20-500 Power transformer (T1)
- 1 Transformer mounting bracket
- 1 Heatsink (HS1)
- 1 6 MHz crystal (Y1)

## Case and knob parts

- 5 Push button switch caps
- 3 Set screw knobs
- 1 Bottom case half with pre-attached membrane panel
- 1 Top case half
- 14 4-40x1/4 board mounting screws
- 6 6-32x1/4 self tapping black case screws
- 2 4-40x5/8 self tapping machine screws
- 1 Fuse holder with hardware
- 1 1 Amp fuse
- 1 110 Volt line cord with plug and pre-installed Molex pins
- 1 Line cord grommet
- 1 Antenna grommet
- 4 Rubber leg pads
- 1 Chassis mount F connector and mounting nut
- 1 4" piece of hookup wire
- 7 4-40 Kepnuts

## Other Equipment (Not included)

- 1 Pencil type soldering iron (30-40 Watts) Don't use a solder gun!
- 1 Roll of fine 60/40 solder (less than .045" diameter)
- 1 Sensitive voltmeter or DMM
- 1 An FM radio for testing
- 1 Audio sources such as a tape deck, CD player, or microphone
- 1 Egg carton or grapefruit holder to sort out parts in.

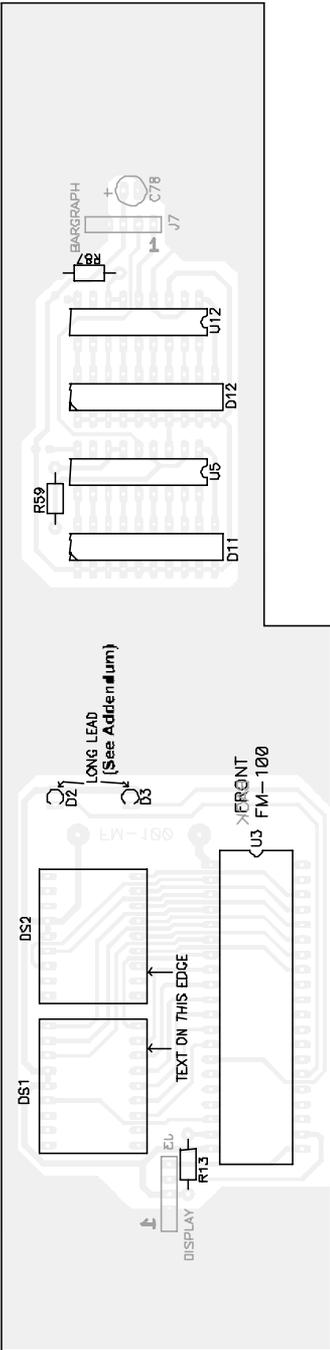
## **PROJECT ASSEMBLY**

Here we go! To make assembly easier and to stick by the “Learn As You Build” strategy, we will section off the project into different major circuit groups. We will begin with the smaller display board to perfect your assembly skills before we continue with the more crowded sections of the board. Following is a list of all the sections in the manual that we will be going into:

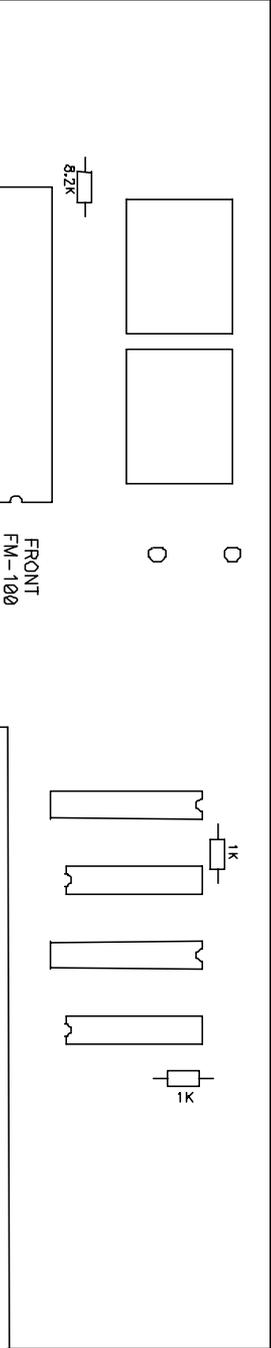
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# DISPLAY BOARD LAYOUT



Parts Values



Note: Gray components are on the reverse side of the board.

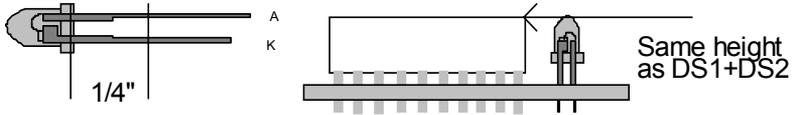
## A. DISPLAY BOARD

We will begin with the display board oriented in the direction shown. Be sure not to confuse the sides of the board where the parts go. On the board you will see the side marked FRONT, which is where most parts are mounted. We will begin with lower parts and work up to the higher ones. Don't use sockets for these parts since they need to fit between the front panel and the PC board.

- 1A. Install R87, a 1K ohm resistor (brown-black-red).
- 2A. Install R59, another 1K ohm resistor (brown-black-red).
- 3A. Install R13, a 8.2K ohm resistor (gray-red-red). This resistor sets the current to each of the display segments and LEDs driven from U3. Lowering the value of this resistor increases the brightness of the display, but then the display will draw more current. This resistor was selected for best brightness/current trade-off.
- 4A. Install U12, one of the LM3915 Log scale bargraph driver ICs. Make absolutely sure before soldering that you have installed all 18 pins into the appropriate holes. Also check the notch or dot indicating pin one is facing in the same direction as shown in the parts layout diagram. Solder all 18 pins, checking for solder bridges when done.
- 5A. Install U5, the other LM3915 Log scale bargraph driver. Again make sure all 18 pins are through the board and that the IC is in the correct orientation.
- 6A. Install U3, the MM5451 40 pin IC. Again make sure the notch is in the same direction as shown in the parts layout, and that all 40 pins are through the board before soldering. This IC drives all the individual segments of the display without multiplexing it.
- 7A. Install D12, one of the ten segment bargraph displays. You will notice a small divot or notch on one corner of the bargraph indicating where pin 1 is. This will be installed in the same orientation as the notch in the parts layout diagram. Solder all 20 pins.
- 8A. Install D11, the other 10 segment bargraph display. Make sure to align this in the same way as before and solder all 20 pins.
- 9A. Install DS2, one of the two digit displays. Notice how there isn't any indication of pin 1 on these. In this case we want to orient the lettering on the one side towards U3, so that when looking at the display, the lettering is facing downward. Solder all 18 pins.
- 10A. Install DS1, the other two digit display. Again orient the lettering

towards U3 before soldering all 18 pins.

- 11A. Install D2, one of the small red LEDs. You will notice that if you look



straight at the LED there is a flat side. This indicates the Cathode side of the LED. The Cathode side is also indicated by the shorter of the two leads. Make sure to install the flat side or the shorter lead in the same way as shown in your diagram. They only light up if they are installed correctly. Before soldering though, this and the next LED are the only parts that we do not mound flush to the PC board. In this case we want to mount them so the lens of the LED is at the same height as DS1 and DS2. These LEDs will eventually be lining up with holes in the front panel. Once the height is set, bend the leads to hold the LED in place, then solder.

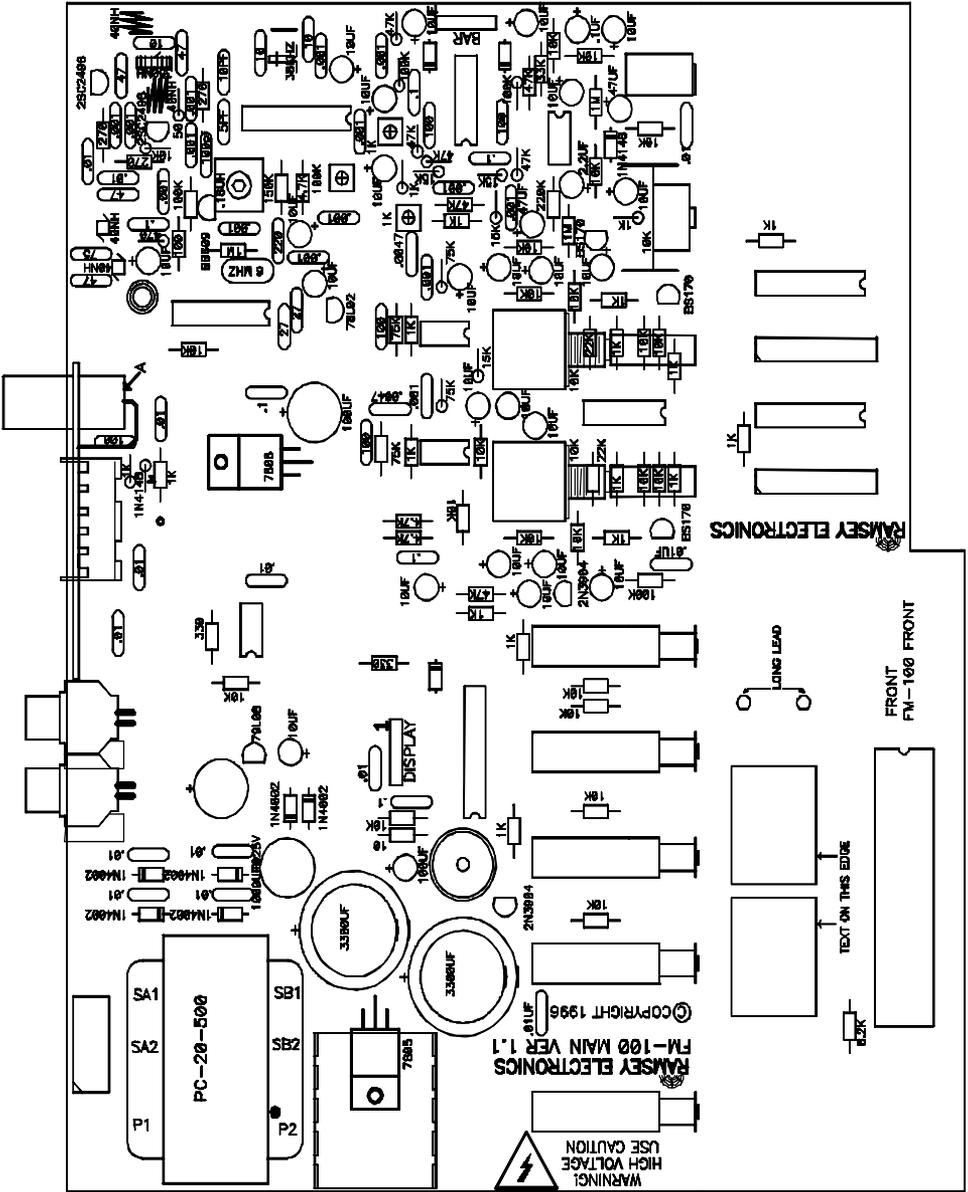
- 12A. Install D3 in the same fashion, making sure it is at the same height and orientation as in the previous step.

Now would be a good time to check all of your solder connections for opens and solder bridges on the back side of the board. Now we are moving on to install jumper connections and a capacitor on the back side of the board. The parts on the back side of the board are marked in gray instead of black.

- 13A. Install J3, a five pin jumper block, short leads go into the board. Again make sure you are putting them in the opposite side of the board from where the rest of the parts are located. This jack is where the numeric display gets its power and the data for display values.
- 14A. Install J7, another five pin jumper block. This is where the power for the bargraphs is applied and the signal levels for the bargraphs are sent.
- 15A. Install C78, a 10uF electrolytic capacitor. Notice this is the first capacitor of this type. You want to be sure that you pay close attention to the polarity markings on this part. In most cases the negative (-) side is marked on the capacitor, while the positive side (+) is marked on the parts layout. If you fail to mount this component correctly, the part can fail as well as prevent proper operation of your project. We will be installing many more of these later in the project so be sure and remember this!

Cool! We have just completed the display board and we are almost ready to move on. First we want to check our display board to make sure there are no solder bridges or cold solder joints. Next check orientation of your parts for correct installation.

# MAIN BOARD PART VALUES



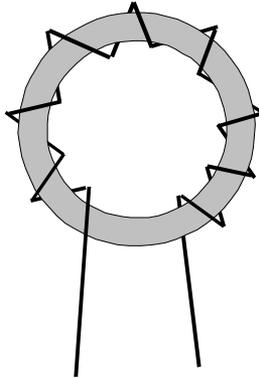


## B. PART PREPARATION

Well, there isn't a heck of a lot to do in these next couple of stages, but these steps will help the rest of the kit go smoothly if we get them over with now.

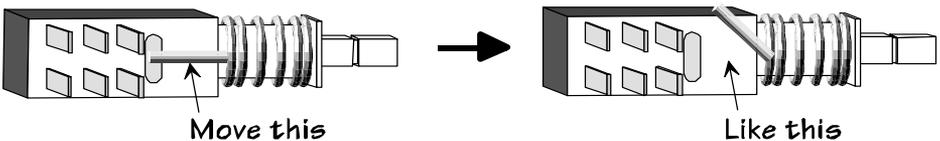
### 1.) Create L4:

Using the small red torroid core and the piece of enameled wire provided with your kit, make a coil consisting of 9 turns. To do this simply thread the wire through the torroid core 9 times as shown here. When done winding, use a hot soldering iron and fresh solder to tin the ends of the wire. This takes a little heat and patience, but the enamel will burn off without any need for scraping. Set this part aside for section H.



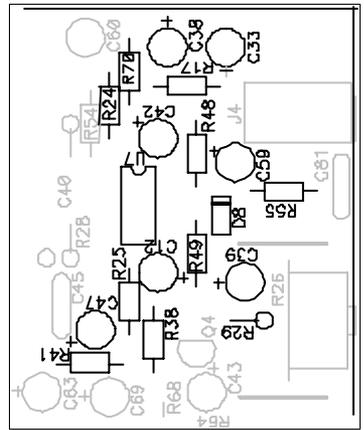
### 2.) S1,2,3,5 Switch Modification:

We want to modify all but one of the switches to be momentary contact instead of latching switches. To do this there is a little metal latching mechanism on the front top of the switch. The end of the metal latch furthest from the button end is gently lifted up and out to the side, while the other end remains in place to keep the spring there.



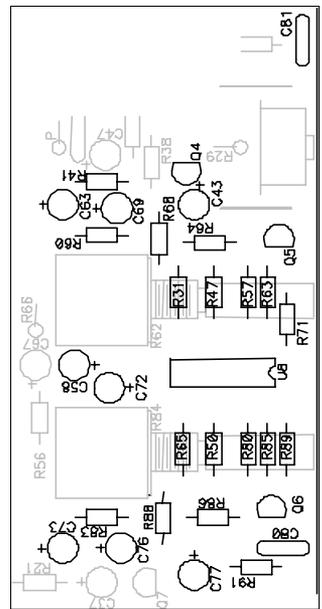
## C. MICROPHONE AMPLIFIER

- 1C. Orient the board in the same direction as shown in the parts layout diagram.
- 2C. Install R24, a 33K ohm resistor (orange-orange-orange).
- 3C. Install R70, a 10K ohm resistor (brown-black-orange)
- 4C. Install R17, a 10K ohm resistor (brown-black-orange)
- 5C. Install R48, a 1M ohm resistor (brown-black-green).
- 6C. Install U7, the MC2830 voice detector IC. Make sure the part is oriented correctly before soldering, and that all 8 pins are through the board.
- 7C. Install R49, a 10K ohm resistor (brown-black-orange).
- 8C. Install D8, a 1N4148 type diode (small glass orange body with black stripe). Make sure the striped end that indicates the cathode is oriented in the same direction as shown in the layout.
- 9C. Install R55, a 10K ohm resistor (brown-black-orange).
- 10C. Install R41, another 10K ohm resistor (brown-black-orange).
- 11C. Install R25, a 220K ohm resistor (red-red-yellow).
- 12C. Install R38, a 1M ohm resistor (brown-black-green).
- 13C. Install R29, a 1K ohm resistor (brown-black-red). Note that this part stands upright.
- 14C. Install C38, a 1uF electrolytic capacitor. Make sure that it is installed with the correct polarity. Make sure the stripe indicating the negative side is on the other side from where positive is marked on the PC board.
- 15C. Install C33, a 10uF electrolytic capacitor. Check polarity!
- 16C. Install C42, a 10uF electrolytic capacitor. Polarity!
- 17C. Install C59, a 47uF electrolytic capacitor. Again check polarity!
- 18C. Install C39, a 10uF electrolytic capacitor. Orientation!
- 19C. Install C12, a 2.2uF electrolytic capacitor. Polarity again!
- 20C. Install C47, a 47uF electrolytic capacitor.



## D. AUDIO MIXER

- 1D. Install R83, a 10K ohm resistor (brown-black-orange).
- 2D. Install R88, another 10K ohm resistor (brown-black-orange)
- 3D. Install R86, a 1K ohm resistor (brown-black-red)
- 4D. Install R91, a 100K ohm resistor (brown-black-yellow).
- 5D. Install R65, a 22K ohm resistor (red-red-orange).
- 6D. Install R50, a 1K ohm resistor (brown-black-red).
- 7D. Install R80, a 10K ohm resistor (brown-black-orange).
- 8D. Install R85, a 10K ohm resistor (brown-black-orange).
- 9D. Install R89, a 1K ohm resistor (brown-black-red).
- 10D. Install R31, a 22K ohm resistor (red-red-orange).
- 11D. Install R47, a 1K ohm resistor (brown-black-red).
- 12D. Install R57, a 10K ohm resistor (brown-black-orange).
- 13D. Install R63, a 10K ohm resistor (brown-black-orange).
- 14D. Install R71, a 1K ohm resistor (brown-black-red).
- 15D. Install R64, a 1K ohm resistor (brown-black-red).
- 16D. Install R68, a 10K ohm resistor (brown-black-orange).
- 17D. Install R60, a 10K ohm resistor (brown-black-orange).
- 18D. Install C63, a 10uF electrolytic capacitor. Make sure to check polarity for all electrolytics!
- 19D. Install C69, a 10uF electrolytic capacitor.
- 20D. Install C43, a 10uF electrolytic capacitor.
- 21D. Install Q4, a BS170 FET. When looking at this part, you will notice that the center lead is bent slightly opposite of how we are going to install



it. Don't let this confuse you, so make sure the flat side of the transistor is in the same orientation as shown in the parts layout.

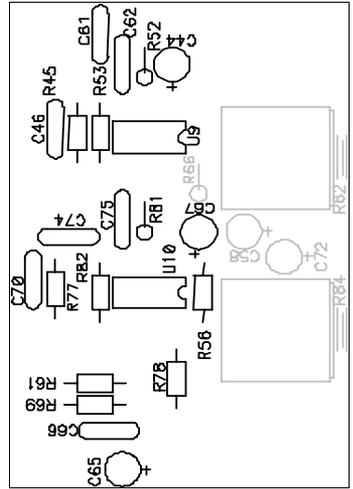
- 22D. Install C81, a .01uF ceramic capacitor (marked .01, 10n, or 103). This cap is used to filter out noise on the gates of Q5 and Q6.
- 23D. Install Q5, another BS170 FET. Make sure and mount the flat side in the same orientation as shown in the layout.
- 24D. Install U8, one of the LF347 quad low noise opamps. Make sure the dot or tab indicating pin 1 is installed in the same orientation as the tab shown in the layout. Solder all 14 pins while making sure each pin has been inserted into the board.
- 25D. Install C58, a 10uF electrolytic capacitor. Check polarity!
- 26D. Install C72, another 10uF electrolytic capacitor.
- 27D. Install C73, yet another 10uF electrolytic capacitor.
- 28D. Install C76, even another 10uF electrolytic capacitor.
- 29D. Install C77, a 10uF electrolytic capacitor.
- 30D. Install C80, a .01uF ceramic capacitor (marked .01, 10n, or 103).
- 31D. Install Q6, the last of the BS170 FETs. Again make sure that the flat side is installed in the same orientation as shown in the layout.

Now it's time to move on to the next section of our project, but maybe you want to take an eyeball break first. Not including the pots that will be used for control, the mixer and microphone sections are now complete. This would be a good time to go through and check your work for good assembly practice. Check for solder bridges, cold solder joints, and improperly oriented devices. A common practice among engineers and techs at the factory when you can't find a mistake is to get up, take a short break and come back with a new perspective. You would be surprised how many problems you can find when you do this. Sort of like getting up and leaving one marriage for a fresh, new perspective?

Onward!

## E. SWITCHED CAPACITOR FILTERS

- 1E. Locate the center of the board where this group of parts is to go.
- 2E. Install R45, a 75K ohm resistor (violet-green-orange).
- 3E. Install R53, a 1K ohm resistor (brown-black-red).
- 4E. Install R52, a 75K ohm resistor (violet-green-orange). This part stands upright.
- 5E. Install R81, a 75K ohm resistor (violet-green-orange). Another stand-up.
- 6E. Install R66, a 15K ohm resistor (brown-green-orange). This resistor isn't actually associated with this section but it forms part of the active lowpass filter in the next section. Another stand-up.
- 7E. Install R77, a 75K ohm resistor (violet-green-orange).
- 8E. Install R82, a 1K ohm resistor (brown-black-red).
- 9E. Install R61, a 4.7K ohm resistor (yellow-violet-red).
- 10E. Install R69, another 4.7K ohm resistor (yellow-violet red). This resistor and R61 form a voltage divider for the MAX291 ICs opamps since they need to run from the +5 volt supply. The divider creates 2.5 volts which is the center voltage around the audio signal coming in.
- 11E. Install R78, a 10K ohm resistor (brown-black-orange).
- 12E. Install R56, a 10K ohm resistor (brown-black-orange).
- 13E. Install U10, one of the MAX291 filter chips. Make sure the part is oriented correctly before soldering. Also make sure all eight pins are through the board before soldering. It is a common mistake to install an IC with one of the pins folded under the IC instead of through a hole.
- 14E. Install U9, the other MAX291 filter chip. Again check orientation and the pins before soldering.
- 15E. Install C46, a 100pF ceramic capacitor (marked 100 or 101).
- 16E. Install C61, a .0047uF ceramic capacitor (marked .0047 or 472).
- 17E. Install C62, a .001uF ceramic capacitor (marked 102 or .001).

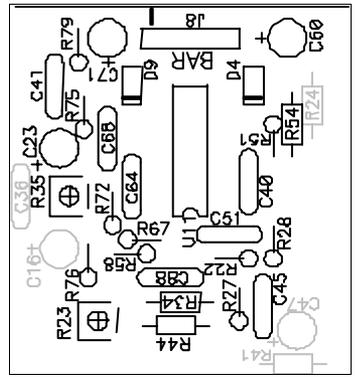


- 18E. Install C44, a 10uF electrolytic capacitor, check the polarity before soldering!
- 19E. Install C67, a 10uF electrolytic capacitor (polarity).
- 20E. Install C75, a .001uF ceramic capacitor (marked 102 or .001).
- 21E. Install C74, a .0047uF ceramic capacitor (marked .0047 or 472).
- 22E. Install C70, a 100pF ceramic capacitor (marked 100 or 101).
- 23E. Install C66, a .1uF ceramic capacitor (marked .1 or 104).
- 24E. Install C65, a 10uF electrolytic capacitor. Check its installation!

Check you work up to this point to be sure you didn't mess up. It is much easier to check you work in small manageable groups than all at once. Again check for solder bridges and cold solder joints. Especially check around the pins of the ICs for solder bridges since it is a common occurrence.

## F. PEAK HOLD AND ACTIVE FILTERS

- 1F. Install R79, a 47K ohm resistor (yellow-violet-orange). Stands upright.
- 2F. Install R75, a 100K ohm resistor (brown-black-yellow). Stands upright.
- 3F. Install R72, a 47K ohm resistor (yellow-violet-orange). Stands upright.
- 4F. Install R76, a 1K ohm resistor (brown-black-red). Stands upright.
- 5F. Install R67, a 47K ohm resistor (yellow-violet-orange). Stands upright.
- 6F. Install R58, a 15K ohm resistor (brown-green-orange). Stands upright.
- 7F. Install R34, a 47K ohm resistor (yellow-violet-orange).
- 8F. Install R44, a 1K ohm resistor (brown-black-red).
- 9F. Install R27, a 15K ohm resistor (brown-green-orange). Stands upright.
- 10F. Install R22, another 15K ohm resistor (brown-green-orange). Stands upright.
- 11F. Install R28, a 47K ohm resistor (yellow-violet-orange). Stands upright.
- 12F. Install R51, a 100K ohm resistor (brown-black-yellow). Stands upright.
- 13F. Install R54, a 47K ohm resistor (yellow-violet-orange).
- 14F. Install D9, a 1N4148 type diode (orange glass body with black stripe on one end). Make sure this diode is installed in the correct way with the stripe on the same end as shown in the parts layout diagram. This diode and its surrounding circuitry rectifies the audio signal into a DC level. Then C71 holds this level for a long duration. The resistance of R79 then determines how long C71 holds its charge, the less the value, the less time C71 holds its charge. This is seen in the bargraph meters when you have a single pulse like a drum beat. C71 and R79 set the time it takes for the meter to go from full scale down to zero so that your eyes can see the pulses better.
- 15F. Install D4, another 1N4148 type diode (orange glass body with black stripe on one end). Again check orientation before soldering. This is the rectifier for the other channel.



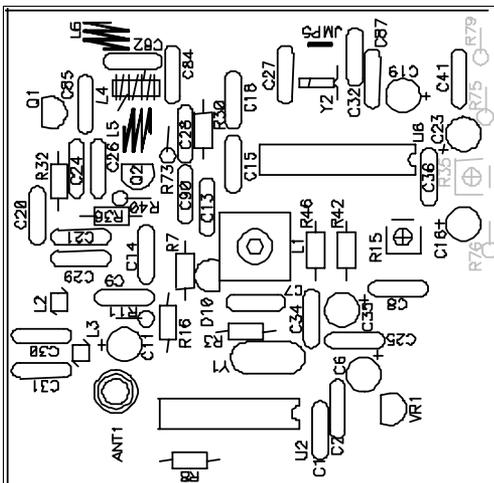
- 16F. Install J8, a 5 pin jumper header. Make sure and leave the longer leads facing up, with the shorter ends soldered to the board. This is where the connection is made to the front panel.
- 17F. Install C71, a 10uF electrolytic capacitor. Check polarity!
- 18F. Install C60, another 10uF electrolytic capacitor.
- 19F. Install C68, a .1uF ceramic capacitor (marked .1 or 104).
- 20F. Install C64, a 100pF ceramic capacitor (marked 100 or 101).
- 21F. Install C51, a .1uF ceramic capacitor (marked .1 or 104).
- 22F. Install C40, a 100pF ceramic capacitor (marked 100 or 101).
- 23F. Install C88, a .001uF ceramic capacitor (marked 102 or .001).
- 24F. Install C45, a .001uF ceramic capacitor (marked 102 or .001).
- 25F. Install U11, a LF347 low noise opamp. Make sure and orient it in the same direction as shown in the parts layout. Also check for all 14 pins to be through the board before soldering.
- 26F. Install R23, one of the 1K ohm trim pots (orange Philips top marked 102).
- 27F. Install R35, the remaining 1K ohm trim pot (orange Philips top marked 102).

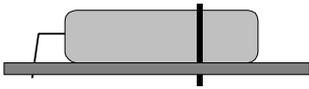
Well, that's it for the peak hold circuits and the 15KHz low pass filter. Quick and painless, wasn't it? We have to go back now and check all our work to make sure that we didn't install anything in the wrong way or have any soldering errors such as bridges and cold solder joints. When you're done, go grab a soda (preferably caffeinated) and give yourself an eyeball break.

Our next section is the toughest of the whole kit, so make sure you have all of your skills primed and ready for the true test!

## G. TRANSMITTER

This is where we definitely want to have clean soldering skills and proper mechanical mounting of parts. If you need a review, shoot back to the start of the manual in the “STRATEGY” section for tips. Make sure all your parts are flush to the board and not waving in the breeze. You will not only lose performance if parts aren’t installed correctly, but your kit may not work at all. Have patience and follow all directions and you should have no trouble at all!



- 1G. Install JMP5 using a scrap piece of lead wire. Leave the jumper “loop” about 1/4” above the board to allow you to cut it out later. If you wish to operate the FM-100 in mono, this is the jumper you would cut.
- 2G. Install Y2, the 38KHz crystal found taped to a piece of paper. Before mounting, bend the leads so that they don’t short to ground when installed. We want to install the part in a lay-down fashion so that we can strap the part to the board with a jumper so that it is secured in place. Lay it down in the orientation shown, then use a scrap piece of lead to make a loop over the crystal to hold it tightly to the board. You can’t miss the two holes where this loop is mounted to.
- 3G. Install the 18 pin IC socket. Make sure all the leads are though the board before soldering. Install U6, the BA1404 stereo generator IC, making sure that the part is installed in the correct orientation.
- 4G. Install R46, a 150K ohm resistor (brown-green-yellow).
- 5G. Install R42, a 4.7K ohm resistor (yellow-violet-red).
- 6G. Install R15, a 100K ohm trim pot (orange Philips top marked 104). This will adjust the MPX balance of the internal workings of the BA1404. Normally this control is at center position.
- 7G. Install R3, a 1M ohm resistor (brown-black-green). This resistor helps Y1 begin to oscillate when the unit is first turned on by biasing an internal inverter in U2 into a linear range.
- 8G. Install R7, a 100K ohm resistor (brown-black-yellow).

- 9G. Install R16, a 100 ohm resistor (brown-black-brown).
- 10G. Install R11, a 470 ohm stand up resistor (yellow-violet brown). Be sure to install it exactly as shown in the parts layout. We will be using the exposed end later during testing procedures.
- 11G. Install R36, a 270 ohm resistor (red-violet-brown).
- 12G. Install R40, a 10K ohm stand up resistor (brown-black-orange).
- 13G. Install R32, another 270 ohm resistor (red-violet-brown).
- 14G. Install R73, a 51 ohm stand up resistor (green-brown-black). This resistor is used on the RF output of U6 to give the BA1404 a resistive load to drive.
- 15G. Install R30, a 270 ohm resistor (red-violet-brown).
- 16G. Install U2, the MC145170 PLL. Make sure that the dot or tab indicating pin 1 is in the same direction as shown in the parts layout diagram. Solder all 16 pins.
- 17G. Install R8, a 10K ohm resistor (brown-black-orange).
- 18G. Flip the board over and find the hole where the whip antenna mounts. Insert the antenna screw (4-40X1/4) into the hole so that the threads are pointing to the parts side of the board. Use ample heat to solder the screw in place. You may scrape off some of the screw's plating to make it solder better.
- 19G. Install L3, one of the 4 turn 40nH coils.
- 20G. Install L2, another 4 turn 40nH coil.
- 21G. Install L5, yet another 4 turn 40nH coils.
- 22G. Install L6, the last 4 turn 40nH coil.
- 23G. Install L4, the custom wound coil that you made earlier. Make sure to mount this part low to the board and that you are soldering to the copper of the wire and not the insulation.
- 24G. Install C31, a 47pF ceramic capacitor (marked 47 or 47K).
- 25G. Install C30, a 75pF ceramic capacitor (marked 75 or 75K).
- 26G. Install C29, a 47pF ceramic capacitor (marked 47 or 47K).
- 27G. Install C9, a .1uF ceramic capacitor (marked .1 or 104).
- 28G Install C14, a .001uF ceramic capacitor (marked .001, or 102).

- 29G. Install C21, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 30G. Install C20, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 31G. Install C24, a .001uF ceramic capacitor (marked .001 or 102).
- 32G. Install C26, a .001uF ceramic capacitor (marked .001 or 102).
- 33G. Install C85, a 47pF ceramic capacitor (marked 47 or 47K).
- 34G. Install C82, a 10pF ceramic capacitor (marked 10 or 10K).
- 35G. Install C84, a 47pF ceramic capacitor (marked 47 or 47K).
- 36G. Install C28, a .001uF ceramic capacitor (marked 102 or .001).
- 37G. Install C90, a .001uF ceramic capacitor (marked 102 or .001).
- 38G. Install C13, a 100pF ceramic capacitor (marked 100 or 101).
- 39G. Install C18, a 10pF ceramic capacitor (marked 10 or 10K).
- 40G. Install C15, a 5pF ceramic capacitor (marked 5 or 5K).
- 41G. Install C27, a 10pF ceramic capacitor (marked 10 or 10K).
- 42G. Install C32, a 10pF ceramic capacitor (marked 10 or 10K).
- 43G. Install C87, a .001uF ceramic capacitor (marked .001 or 102).
- 44G. Install C19, a 10uF electrolytic capacitor. Make sure and check its correct polarity before soldering!
- 45G. Install C41, a .001uF ceramic capacitor (marked .001 or 102).
- 46G. Install C23, a 10uF electrolytic capacitor. Check polarity!
- 47G. Install C36, a .001uF ceramic capacitor (marked .001 or 102).
- 48G. Install C16 a 10uF electrolytic capacitor. Again orientation!
- 49G. Install C8, a .001uF ceramic capacitor (marked .001 or 102).
- 50G. Install C35, a 10uF electrolytic capacitor. Check to be sure it's in the right way.
- 51G. Install C25, a .001uF ceramic capacitor (marked .001 or 102).
- 52G. Install C6, a 10uF electrolytic capacitor. Polarity!
- 53G. Install C1, a 27pF ceramic capacitor (marked 27 or 27K).
- 54G. Install C2, another 27pF ceramic capacitor (marked 27 or 27K).

These capacitors give the crystal the proper loading so that it operates on the correct frequency. In the FM band, our crystal can be off by as much as .01% and most tuners will pick it up just fine. As this crystal is set up, it will be within .001%, which is 10X better, and that's without tuning!

- 55G. Install C34, a 220pF ceramic capacitor (marked 220K or 221).
- 56G. Install C7, a .001uF ceramic capacitor (marked .001 or 102).
- 57G. Install C11, a 10uF electrolytic capacitor. Check polarity!!!
- 58G. Install D10, the BB609 varactor diode (black diode with a green band). The PC board silkscreen for this part looks like a transistor so you'll need to be careful to get the orientation right when installing this varactor diode. The banded cathode end should be placed in the hole closest to C13. Adjusting the voltage across this diode allows the PLL to do its job. When in use, this diode is reverse biased so it actually acts as a capacitor. When the voltage across the diode is high, the depletion layer internal to the diode gets wider. This causes the capacitance to lower so that the oscillator changes frequency.
- 59G. Install Q2, one of the 2SC2498 UHF transistors. Make darn sure the flat side is oriented as shown in the parts layout diagram. Notice because these are not a standard transistor, the pin-out is not C-B-E like with 2N3904 transistors, instead it is B-E-C (Base Emitter Collector).
- 60G. Install Q1, the other 2SC2498 UHF transistor. Again make sure the flat side is in the correct direction.
- 61G. Install VR1, the 78L02 2.5 volt regulator. Be sure the flat side is in the right direction before soldering. This regulator only powers the BA1404.
- 62G. Install L1, the shielded metal canned coil. Solder both the mounting lugs and the two connections. Be careful that you don't bend over one of the connections before it goes through the board, these are a pain in the neck to desolder.
- 63G. Install Y1, the 6.00MHz crystal (Silver metal can marked 6.00). Make sure and mount this part flush to the board.

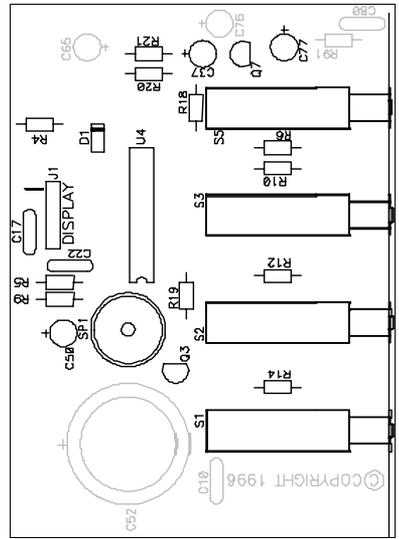
Whew! That was a lot of steps. Definitely check all of your work up to this point for mistakes in orientation. Double check all of your electrolytic capacitors to be sure the positive symbols are on the opposite side of the negative stripe. Also make sure there are no solder bridges or cold solder joints.

If there are no problems up to this point it is time to move on! Now we are on to easier stuff with less steps. But still be careful of your assembly, you wouldn't want to get this far and then make a mistake causing the project not to work. With soldering iron in hand, on to the next section!

## H. MICROCONTROLLER

This section is a little vague in what's entailed. The microcontroller really controls the entire circuit, but this section deals with the parts which are fairly exclusive to the controller itself. We'll wait until later to install the switches because they get in the way while we're installing the rest of the parts.

- 1H. Install R21, a 47K ohm resistor (yellow-violet-orange).
- 2H. Install R20, a 1K ohm resistor (brown-black-red).
- 3H. Install R18, a 1K ohm resistor (brown-black-red).
- 4H. Install R6, a 10K ohm resistor (brown-black-orange).
- 5H. Install R10, a 10K ohm resistor (brown-black-orange).
- 6H. Install R12, another 10K ohm resistor (brown-black-orange).
- 7H. Install R14, yet another 10K ohm resistor (brown-black-orange).
- 8H. Install R19, a 1K ohm resistor (brown-black-red).
- 9H. Install Q3, a 2N3904 switching transistor. Make sure when installing that the flat side is facing in the same direction as shown in the layout.
- 10H. Install SP1, the mini speaker. Make sure the + terminal of the speaker is facing towards C50, but away from Q3. This is where confirming tones are sounded when a button is depressed.
- 11H. Install the 20 pin IC socket for U4. If the socket has a notch in one end, install it at the same end the layout shows to prevent confusion later.
- 12H. Install R9, a 10 ohm resistor (brown-black-black). This resistor limits the volume of the speaker.
- 13H. Install R5, a 10K ohm resistor (brown-black-orange).
- 14H. Install C22, a .1uF ceramic capacitor (marked .1 or 104).
- 15H. Install C17, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 16H. Install J1, a 5 pin jumper header. Make sure the shorter ends are installed into the board. This will be the connection to the digit display.

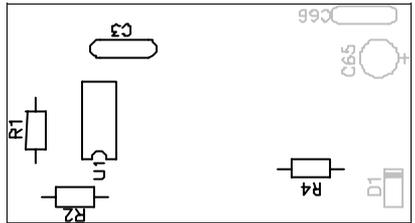


- 17H. Install D1, a 1N4148 type diode (orange glass body with black stripe on one end). Install it in the same orientation as shown in the parts layout diagram.
- 18H. Install U4, the IC with the sticker FM-100 into the socket. If your chip has a dot or notch, orient as shown in the parts layout diagram. If your chip has a large “1” on one end, this end is oriented as though it were a notch. It should be placed at the end of the socket closest to R19. This is the “brains” of your project, keeping track of all the button presses, the frequency lock, and the rest of the circuit. Be sure all 20 pins are firmly in the socket and none are bent under.
- 19H. Install C37, a 10uF electrolytic capacitor (Check polarity!).
- 20H. Install Q7, a 2N3904 type transistor. Make sure and mount the flat side in the same orientation as shown in the parts layout diagram.

Now is another good time to check all of your work for soldering and installation problems before we move on to the EEPROM circuit.

## I. EEPROM

EEPROM is where the operating frequency last used is stored so that the next time you power up the unit, it goes right back to that frequency. It sure beats having to remember the frequency and have to re-enter it each time you power it up!



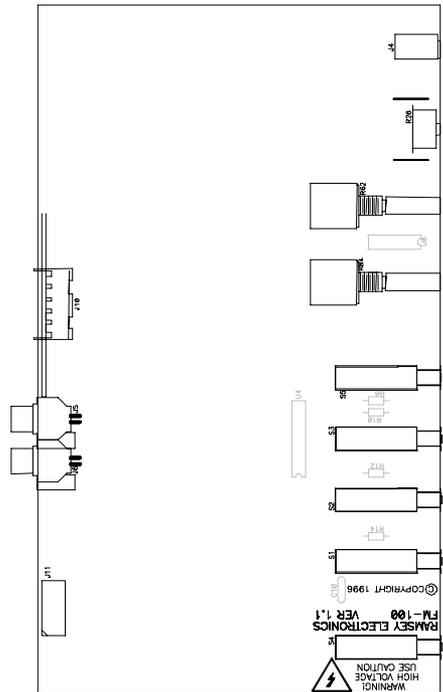
- 1I. Install R1, a 330 ohm resistor (orange-orange-brown).
- 2I. Install R2, a 10K ohm resistor (brown-black-orange).
- 3I. Install R4, a 330 ohm resistor (orange-orange-brown).
- 4I. Install C3, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 5I. Install U1, the X2402 EEPROM IC. Make sure that the notch or dot is installed in the same orientation as shown in the parts layout diagram.

The resistors in this part of the circuit prevent bus contention when the microcontroller and the EEPROM are talking back and forth. The EEPROM uses a two wire serial interface. The data line goes between an input and output depending if you are writing or reading data from the EEPROM. Since the microcontroller doesn't entirely know when the EEPROM is switching between input and output, we don't want to drive an output with an output by accident. The resistors prevent an output from driving another output directly.

## J. JACK AND SWITCHES:

Now our project will begin to look complete as we install the jacks and switches. We only have one component section to go after we complete this, so be sure not to lessen the effort you put into making a nice neat project out of this.

- 1J. Install S4, an unmodified switch that we left alone in section B. Make sure when mounting all of your switches that they are pressed firmly to the board so that they will align properly in the case holes when completed.
- 2J. Install S1, the FREQUENCY UP switch. This is one of the modified switches.
- 3J. Install S2, the FREQUENCY DOWN switch.
- 4J. Install S3, the MIC IN switch.
- 5J. Install S5, the AUTO AGC switch.
- 6J. Install R84, one of the dual 10K ohm potentiometers. Install this part so that its shaft is perfectly parallel to the PC board before soldering. It is easy enough to reheat the pads and adjust the pots so they align properly to the holes if you make a mistake.
- 7J. Install R62, the other dual 10K ohm potentiometer. Make sure the post is parallel with the PC board before soldering.
- 8J. Install R26, the single 10K ohm potentiometer. Solder all three pins as well as solder the two mounting lugs as well.
- 9J. Install J4, the microphone jack. Solder all 5 pins.
- 10J. Install J10, the six pin Molex connector. Make sure and mount the short ends in the PC board. Also notice that the board layout shows only the female connector of the 1 watt module, not the male connector that we are installing.
- 11J. Install J5, one of the stereo RCA jacks. Make sure and mount these so the back is square in relation to the PC board and that the jack is mounted flush to the PC board.



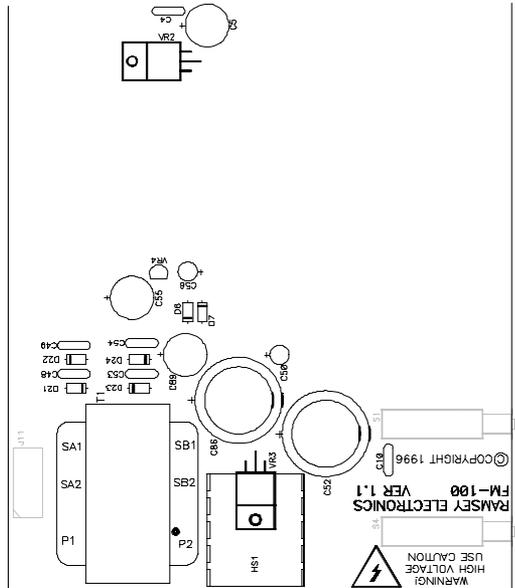
- 12J. Install J6, the other stereo RCA jack. When installing, make sure it is installed to nicely meet up with J5 and that it is flush with the PC board as well.
- 13J. Install J11, a four pin Molex header connector. Make sure the short ends are the ones installed in the PC board.

That takes care of all of the jacks and switches. Now we want to give the FM-100 a thorough check over with the most picky eye that you possess. We have installed many parts up to this point in time and chances are you have made a mistake somewhere. Even the best of kit assemblers are known to make mistakes when putting their kits together, and feel pretty ridiculous when they get their kit back from repair with a solder bridge fixed or a part installed backwards (whoops!). We just want to make sure you don't need to send back this for something easily repaired yourself. To assist you in checking your project out, have an associate check your work for you, you may be surprised what they point out for you!

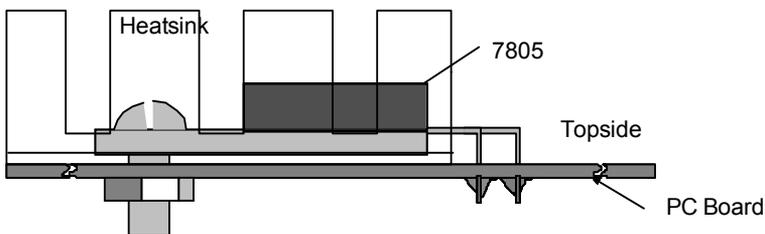
## K. POWER SUPPLY

Oh yes! the final section of our project and then on to testing and playing! Don't rush now, this section has many parts that are very critical in orientation, especially the large electrolytic capacitors. If they are installed in reverse, the electrolyte in the capacitor begins to boil creating a grand amount of pressure inside a metal can part. Even though they have stress relief on the tops, they still tend to explode like a firecracker. After all this work we certainly don't want that to happen!

- 1K. Install D21, a 1N4002 type rectifier diode (black body with white stripe on one end or larger orange body with thick leads and black stripe). Make sure the end with the stripe is installed in the same orientation as shown.
- 2K. Install D22, another 1N4002 type rectifier diode. Again make sure the striped end is installed correctly.
- 3K. Install D23, a 1N4002 type rectifier diode (orientation!).
- 4K. Install D24, another 1N4002 type rectifier diode (line end installed correctly?) The four diodes we installed form a bridge rectifier providing us with a DC voltage from an AC source.
- 5K. Install C48, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 6K. Install C49, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 7K. Install C53, a .01uF ceramic capacitor (marked .01, 10n or 103).
- 8K. Install C54, another .01uF ceramic capacitor (marked .01, 10n or 103). These four diodes that we just installed prevent 60Hz hum in a high noise environment like a transmitter. When the diodes are busy switching on and off during an AC cycle, the RF impedance of the power supply changes slightly, causing amplitude modulation in the RF on the power supply (there is always going to be some present in varying degrees). This RF modulation is detected in some circuits like opamps and the BA1404 causing 60Hz hum and other noises. The capacitors reduce the problem dramatically when placed across each diode.



- ❑ 9K. Install D6, a 1N4002 type diode. Make sure the striped end is installed correctly!
- ❑ 10K. Install D7, the last 1N4002 type rectifier diode. Again check the striped end for correct installation.
- ❑ 11K. Install VR4, the 79L08 -8 volt regulator. Make sure the flat side of the part is oriented as shown. This part “smoothes” out the raw DC from C55.
- ❑ 12K. Install C56, a 10uF electrolytic capacitor. Make sure the negative side of the capacitor is installed on the opposite side of where the positive side marked on the board is.
- ❑ 13K. Install C55, a 1000uF electrolytic capacitor. (Watch polarity!)
- ❑ 14K Install C89, another 1000uF electrolytic capacitor. (Polarity) The last group of parts have formed a negative voltage multiplier to give us our minus supply for the opamps.
- ❑ 15K. Install C50, a 100uF electrolytic capacitor. Again check the polarity before installing.



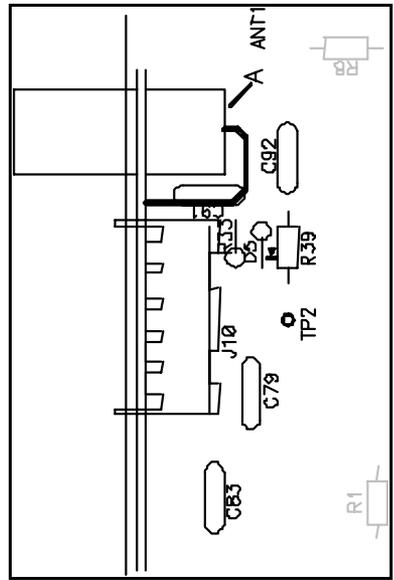
- ❑ 16K. Install VR3, the 7805 +5 volt power regulator. We want to mount this flat to the board as shown in the diagram. The tab side of the part should be facing the board. Install HS1 between the tab and the PC board. Make sure the heatsink is installed so that it doesn't hit the leads of the regulator. Use a 4-40x1/4 screw and a lock nut to secure the regulator, heatsink and board together.
- ❑ 17K. Install C10, a .01uF ceramic capacitor (marked 103, .01 or 10n).
- ❑ 18K. Install T1, the power transformer (PC-20-500). Notice how the label of the transformer has an orientation dot on one corner. A corresponding dot is located on the PC board silk screen for T1. When installing T1, ensure that the dot on the transformer is oriented to the same corner as indicated on the board. Make sure you install this correctly! If installed wrong, you will destroy your entire kit! You may need to bend the leads around a little before installing in the board. Make sure all six pins are through before soldering.

- 19K. Install C86, a 3300uF electrolytic capacitor. Notice how there are three holes available for the negative side of the capacitor. Only one of these needs to be used by the capacitor. These holes just make allowances for various lead spacings, just use the best fit. Make sure and check polarity!
- 20K. Install C52, the other 3300uF electrolytic capacitor. Again make sure the part is installed in the correct orientation.
- 21K. Install VR2, the 7808 +8 volt power regulator. Before soldering, bend the part over while installed in its holes. Make sure the tab does not short to the trace above it. Use a 4-40x1/4 screw and lock nut to hold the regulator tightly to the board. The copper of the PC board works well as a heat sink for this part.
- 22K. Install C4, a .1uF ceramic capacitor (marked .1 or 104)
- 23K. Install C5, a 100uF electrolytic capacitor (Watch polarity!).
- 24K. Install the transformer bracket over T1. Use four 4-40x1/4 screws and 4 lock nuts on the top side of the board to hold the transformer in place. Be sure to place the lock nuts on the top side of the board. **If tightened on the bottom they may short out the power line!**
- 25K. Locate a 4" piece of hookup wire . Strip back and tin each end about 1/4".
- 26K. Insert and solder one end into the hold marked 'A' near the antenna screw. The other end will attach to the rear panel mounted antenna jack.

Again check all of your work up to this point, especially the orientation of all of the parts in the power supply section. Now we will install the parts for the 1 watt module.

## L. 1 WATT MODULE

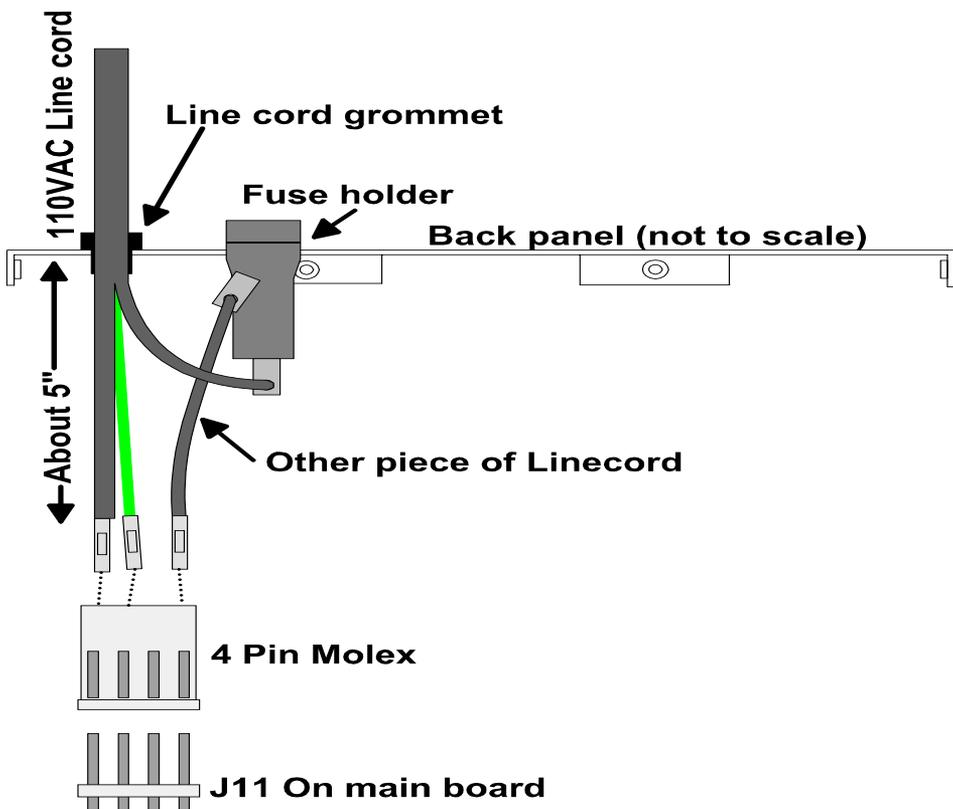
- 1L. Note the position of C92 on the PC board. Do not install any part in this position.
- 2L. Install R33, a 1K ohm stand up resistor (brown-black-red).
- 3L. install D5, a 1N4148 type diode (small glass orange body with black stripe on one end). Make sure and mount the stripe in the same direction as shown in the parts layout.
- 4L. Install R39, a 1K ohm resistor (brown-black-red).
- 5L. Install C91, a 100pF ceramic capacitor (marked 100 or 101).
- 6L. Install C79, a .01uF ceramic capacitor (marked 103, .01 or 10n).
- 7L. Install C83, a .01uF ceramic capacitor (marked 103, .01 or 10n).
- 8L. Using a scrap piece of component wire, install a wire in the hole marked TP2. Make sure this wire is long enough to connect a DMM meter probe to.



This section of parts will not be needed until you install the 1 watt module. Check all of your parts for correct installation and clean solder connections.

## M. REAR PANEL WIRING

- 1M. Find the parts indicated in the diagram.
- 2M. Insert rubber grommet into the line cord hole, this will be used as a strain relief.
- 3M. Thread the line cord through the grommet in the back panel. Make sure the plug end is on the silk screen side of the panel, and the Molex end of the line cord is on the non-silk screen side (inside the case).



- 4M. Your 110VAC line cord has three wires; black, white, and green. The black wire does not have a factory installed Molex pin on it; this is the HOT side of the power connection. Strip and tin the end of the black wire.
- 5M. Locate the female Molex connector and insert the white linecord wire, as shown, into the jack. You will notice there is a small catch tab on one side of the pin. Insert the pin into the Molex jack so the tab faces the side with the slotted holes. You should hear a small “click” when installed properly.
- 6M. Install the center green wire and pin into either of the center holes of the Molex jack. Make sure it clicks into place. Both the center holes are connected together on the PC board.
- 7M. Install the 3” piece of line cord wire with Molex pin attached into the other side of the Molex jack.
- 8M. Install the fuse holder in the back of the case so that the cap is on the

silkscreened side of the panel. Mount the plastic nut between the silk screened side of the case and the cap. Make sure the plastic nut is tightened well on the inside so it doesn't become loose later.

- 9M. Bend the pre-tinned end of the 3" piece into a quarter loop so that it holds onto the solder tab of the fuse holder for soldering. Solder the wire to the end tab of the fuse holder.
- 10M. Bend the end of the black wire tinned in step 4M into a quarter loop so that it holds to the side tab of the fuse holder. Solder this wire to the side tab of the fuse holder.
- 11M. Thread about 3" of the line cord through the back so there is some wire length to play with inside the case.
- 12M. Make sure the fuse is installed in the fuse holder.
- 13M. Plug in the Molex plug onto the Molex strip J11.
- 14M. Locate the chassis mount F connector. Mount it to the rear panel using the included hardware.
- 15M. Solder the wire from point 'A' on the PC board to the center pin of the F connector.

That should take care of that! We are almost ready to plug it in the wall and give her a run. But first we want to check everything we have done up to this point very closely. Especially the circuitry involved with the 110 VAC connections. Check and double check your wiring against that shown in the diagram. Also make sure that the two high voltage connections are to either side of the Molex plug, and not in the center. The green wire of the line cord is Earth ground, not a high voltage connector and can be connected to either of the center pins.

Be very careful around these connections, because when we plug it in, it will be live! Especially be careful of the power switch S1, the top pins on the switch are connected directly to the ones mounted in the PC board, so 110VAC will be present on those also. When we have finished checking out the project, you may coat these connections with insulating glue such as epoxy or silicone glues such as tub sealant.

## **N. FRONT PANEL ASSEMBLY**

- 1N. Align the front panel PC board with the holes in the front panel assembly.
- 2N. Check the LEDs for proper installation height and positioning. If they are misaligned, now is a good time to correct that.
- 3N. Using 3 of the the 4-40x1/4 screws, mount the board securely to the front panel.
- 4N. Admire your work up to this point. (WOW!)

## **O. PC BOARD MOUNTING AND CASING**

To make testing of the PC board easier, it is convenient to have the PC board mounted to the bottom of the case. This keeps down the possibility of wires crossing or metal objects shorting out across the back of the PC board.

- 1O. Mount the main board to the bottom of the case making sure the holes line up with the standoffs in the bottom. Note that you will be installing 5 board screws; the screw under the power switch is not used.
- 2O. Using one of the pre-made 5 wire jumper connectors, connect from J8 to J7. Make sure pin 1 of J7 is connected to pin 1 of J8. To check this you can see what pins are connected to the ground plane.
- 3O. Using the other 5 wire jumper connector, connect from J1 to J3. Again make sure that pin 1 of J3 is connected to pin 1 of J1.
- 4O. Connect the 4 pin Molex connector from the rear panel to J11 on the main board. You can then set the cover in place without having to screw it down until your initial tests are made.

Now we are getting somewhere! Is it ever tempting to plug it in. But wait, flip the page first!

## P. FINAL TESTING AND CALIBRATION

We're almost ready to plug it in. We will need the following equipment to give it a true test.

- A DMM or voltmeter.
  - A sound source such as a CD player or tape deck.
  - A microphone with the appropriate jack.
  - A receiver (preferably digital tuner).
  - The tuning tool sent with your kit.
- 
- 1P. Adjust R15, R23 and R35 to their center positions.
  - 2P. Make sure the power switch is off. Plug in your FM-100 to 110 volts.
  - 3P. Turn on the FM-100. All of the digits of the display should light, the speaker will beep, and then go to some frequency.
  - 4P. The FREQ LOCK light may or may not light. We will get to that later.
  - 5P. Press both frequency buttons at the same time. You should get a confirming tone and the 10's decimal point should blink indicating setup mode.
  - 6P. Press FREQ UP until the display shows 107.9 MHz if it does not already.
  - 7P. Connect your voltmeter between the exposed part of R11 and ground. Adjust L1 with your tuning tool until you see about 4.8 volts present.
  - 8P. Step FREQ UP to get to 88.1MHz and check the voltage on R11 for about 0.3 volts
  - 9P. At this point the FREQ LOCK LED should be lit continuously.
  - 10P. Now is a time to choose a frequency. Consult the "Choosing a Frequency" section of the manual for this.
  - 11P. When you have set your frequency, press both FREQ keys. You should hear three short beeps to confirm the data has been written.
  - 12P. Turn off the power, wait ten seconds and turn it back on. Verify that the unit comes up to the correct frequency and that the FREQ LOCK LED lights.
  - 13P. Tune your receiver to the same channel you have chosen. Verify that there is a signal present and that the stereo light on the tuner is on.

- 14P. Plug your microphone into the microphone jack, and crank up the microphone gain.
- 15P. Press the MIC button, verify the MIC LED turns on.
- 16P. Talk into the microphone; you should hear sound from the receiver and the LED meters should indicate sound.
- 17P. Connect your sound source to either J5 or J6, the stereo RCA jacks.
- 18P. Play some tunes through the unit and make sure the controls on the front are working.
- 19P. Press the AUTO AGC button once, the MIC ON LED should blink rapidly. This indicates that the AUTO AGC mute function is enabled.
- 20P. Talk into the microphone and verify that the music mutes while you talk.
- 21P. Press the AUTO AGC button again to turn it off. Talk into the microphone and verify your voice is now mixed with un-muted music.
- 22P. The LED meters should be indicating the music level at this point.
- 23P. Adjust R23 and R35 so that the volume of your station on the receiver is less than or the same as other commercial stations and that the balance is set well. The LED displays at this point should be at an average of 0dB.
- 24P. Adjust R15 until the audio quality is good and in stereo. You will need to use your audiophile judgment for this. Generally, leaving R15 in the center of rotation is good.
- 25P. Any troubles? Consult the troubleshooting section. It will help you know where to look for mistakes.

## Q. FINAL CASE UP

- 1Q. Install the antenna grommet so the antenna does not short to the case.
- 2Q. Install the top case half using the self tapping case screws.
- 3Q. Install one small sheet metal screw into each of the holes for the RCA jacks on the back panel. This prevents physical damage to the RCA jacks.
- 4Q. Use the four sticky pad feet on the bottom of the case in each corner.
- 5Q. Install all five switch buttons on the end of each switch.
- 6Q. Use the set screw knobs on both of the line level controls, and on the microphone control.

You are finished! Now enjoy your project. Remember your FCC rules and regulations before broadcasting.

## TROUBLESHOOTING

PROBLEM: Nothing happens at all when I turn it on.

SOLUTION: Check your fuse. If it is blown you will want to check section L for rear panel wiring or section K for the power supply. Use a volt meter to check your power supply voltages. Verify that there is +8, +5, and -8 volts on the outputs of the regulators. Also check U2 pin 3 for a 1.5MHz clock signal.

PROBLEM: Everything works, but only some or no lights light up on the front.

SOLUTION: Check section A and make sure you put your LED displays in the correct way. Also check your 5 wire jumpers for correct installation.

PROBLEM: I can't get the FREQ LOCK LED to light and I can't pick up the signal on the receiver.

SOLUTION: You will definitely want to check your parts placement in section G for misplaced components. Check the voltage on R11, if it is less than 0.2 or greater than 4.8 and L1 doesn't have any effect then the VCO may not be oscillating. Make sure the crystal is 6.00MHz. Check around Q2 and D10. Also check C11 for proper orientation.

PROBLEM: One channel out completely, other one sounds OK.

SOLUTION: More than likely a short somewhere in any one of the audio sections. These are usually a bugger to find without a signal tracer or an oscilloscope. Inject a signal into both sides and trace through the circuit. Compare one channel to the other all the way through the circuit until one side is not present. You can bet you can now locate the problem.

PROBLEM: Very distorted sound.

SOLUTION: Turn down your level controls. If that does not help, check your power supply voltages. If a negative or positive supply is not there, the signal will be lousy.

PROBLEM: Transformer gets hot.

SOLUTION: Ignore it. Transformers are made to run hot at their maximum ratings and we are running close to it with our unit. Don't worry, we have given it many long term tests to make sure it doesn't burn the house down! Of course if it does singe your hand, there may be a problem in the power supply. Give it a check, especially the capacitor and regulator orientation.

PROBLEM: Lots of AC hum in the audio on the tuner.

SOLUTION: Again check your power supply. If there is a heavy load due to a faulty circuit somewhere, the power regulators won't regulate, letting raw DC into the audio circuits.

PROBLEM: Still lots of AC hum in the audio.

**SOLUTION:** Make sure it's not coming from your other components in combination with this unit. Some components don't deal with RF very well. We once had a CD player that wouldn't even play with low power RF nearby. Try using ferrite beads around the audio connectors. You can find the beads in computer accessory magazines and electronic magazines.

**PROBLEM:** Unit doesn't store last frequency.

**SOLUTION:** Don't forget to get out of setup mode to set the frequency before shutting off the power. If that's not it, make sure U1 has been installed correctly (check section I).

**PROBLEM:** Unit doesn't transmit very far, less than 100'.

**SOLUTION:** Try spreading out the windings of L2 and L3 a little. This will lessen their inductance, changing the lowpass filter. Otherwise check assembly in section G.

**PROBLEM:** I just can't get the @#!%\$@!! to work! It's Ramsey's fault.

**SOLUTION:** Give us a buzz at (716) 924-4560. While some problems can be answered on the phone, others cannot. Read the warranty information in the manual for information on how to send your unit in. Upon its return it will be fully functional according to our specifications.

### **CHOOSING AN OPERATING FREQUENCY:**

[A] It really is NOT sufficient to just "check" the FM band for an empty frequency, using the FM portable radio closest at hand. It is your responsibility to carefully research what FM stations can be listened to with a good system within the transmitting range of your FM-100. This is especially important in the low end of the FM broadcast band (88-92 MHz), where there are numerous medium power National Public Radio stations. You may not be aware of these stations but your neighbors may be receiving them, using a good receiver and outdoor antenna. Interfering with such reception is a direct violation of federal law. The most reliable way of finding a truly open frequency on the FM band is to check the band with a very good FM receiving system using an external antenna. If you do not have access to such a radio, most modern car radios (with exterior antenna) are very sensitive and usable to help you know what stations your neighbors really can be receiving on a particular frequency.

[B] In choosing an operating frequency, remember that most "digital-tuning" receivers, whether portable, mobile or hi-fi, are designed to tune in 200 KHz increments and therefore might not receive well a signal operating between these pre-tuned standard broadcasting frequencies. In order to comply with Part 15 of FCC regulations, it is your responsibility to determine carefully that your operation will not cause interference to broadcast reception. Please study Appendix A of this manual before using your FM-100.

## **ADJUSTING YOUR FM-100 TRANSMITTER:**

Keep all tests very brief until you have carefully chosen an open operating frequency in the FM broadcast band.

### **1. Transmitting Frequency:**

After finding a suitable "open" frequency in the 88-108 MHz FM band, adjust the frequency by first getting the FM-100 into setup mode by pressing both **FREQ** keys at the same time. Then use **FREQ UP** and **FREQ DOWN** keys until you hear the carrier frequency on a nearby FM radio. No audio input is needed to make this first adjustment, you can simply listen for a "quieting" in the normal background noise "hiss."

The modulation sensitivity of your FM-100 will vary from one end of the broadcast band to the other. This is explained by the characteristic curve of the varactor diode. In order to maintain the proper 75KHz deviation, your front panel level control should be set so that the audio level meters read as follows:

- 88.1 MHz to 92.9 MHz. . . . . +6 on meter
- 93.1 MHz to 99.9 MHz. . . . . 0 on meter
- 100.1 MHz to 107.9 MHz. . . . . -3 on meter

### **2. Audio Connection:**

Hooking up an audio source to your FM-100 is really quite simple. However, there are some general rules:

- A terribly distorted sound is a sign of too much audio level. Simply rotate the level potentiometers, R23 and R35, CCW to reduce the level. Make sure you rotate each one about the same amount to maintain proper stereo balance.
- Stereo LP turntables are low-level output and will require the use of a preamplifier for proper audio input to the FM-100.
- NEVER connect the FM-100 audio inputs to speaker outputs of a high power stereo system; such a connection will destroy the IC chips.

### **3. Stereo balance:**

Adjust R15 for correct stereo transmitting balance. If you are not transmitting in stereo adjust R15 to its center position. The better your ear for music and your understanding of quality audio devices and interconnections, the better will be the performance of your FM-100.

## **USING THE FM-100 WITHIN THE HOME:**

A most practical use for the FM-100 would be to connect it to the main stereo system within a large home so that whatever is playing on the main system can also be tuned-in on portable FM radios in other rooms, the garage or in the yard. This connection consists of using shielded audio cables to connect the auxiliary "line audio" output of your cassette deck, CD player or other stereo device to the audio inputs of the FM-100. Consult the literature that came with your stereo equipment.

Even if you intend use of the FM-100 for your own home and family, it is still your responsibility, in accordance with Part 15 of the FCC Rules, to ensure that this operation does not cause interference to your neighbors.

## **EXPERIMENTAL "BROADCASTING" PROJECTS:**

To use the FM-100 successfully as a "broadcasting" service to interested listeners in a school or immediate neighborhood, most of your effort will be concentrated on smoothly "managing" or mixing the audio signals fed into the transmitter input. Operation of the transmitter itself consists simply of the following:

1. Correct construction and adjustment.
2. Carefully checking for an open frequency between 88-108 MHz in accordance with FCC Rules, Part 15.
3. Setting up a suitable antenna.
4. Connecting the audio source to the Left and Right input jacks.
5. Turning on the transmitter while you intend to be "on the air" and turning it off when you are finished.

## **ANTENNA IDEAS:**

Although use of the included whip antenna is recommended, you may want to use an external antenna to get a more uniform coverage. Use an external antenna mounted on the rear F connector to expand your coverage.

Ramsey Electronics now offers an antenna called the "Tru-Match FM Broadcast Antenna". This antenna has been specifically tested and designed for the FM-series of micropower transmitters, and will help you get the most out of these products. When you call ask for the TM-100 antenna, and its cost is \$39.95.

A simple, yet very effective, antenna for the FM-100 consists of a "dipole", set up either horizontally or vertically, and connected to the transmitter output jack through a few feet of coaxial cable (either RG-58, RG-59 or miniature RG-174, available at Radio Shack and other sources). Correct dipole lengths for major sections of the 88-108 MHz band are:

88 MHz, each side: 2.7 feet; 5.4 feet total

98 MHz, each side: 2.4 feet; 4.8 feet total

108 MHz, each side: 2.2 feet; 4.4 feet total

You can see that there is not a great difference in antenna length from 88 to 108 MHz. Some antenna designers have the view that an "approximate" dipole such as 2.5 ft. on a side will do fine, while others believe it is worth the effort to calculate the length for your exact frequency, using the simple formula of Length (of one side, in feet) =  $234/\text{Frequency in MHz}$ .

If the dipole is installed vertically, the end connected to the center conductor of the coax should be the upper (higher) end. If young children will be around the set-up, a flexible wire antenna is preferable, rather than rigid tubing.

A "ground plane" antenna can be quite effective. A ground plane consists of one vertical element, the same length as one side of a dipole, connected to the center conductor of the coax. Four "radials" are connected to the shielded side of the coax at a 90 to 135 degree angle to the vertical element. The dipole formula is also used to calculate the length of the radial; since radials should be slightly longer than the main element, use 240 rather than 234 in your calculations.

If you are equipped to make the field strength measurements required by Part 15 FCC rules, and if you think it would be best to aim or "focus" your signal in a narrower direction, you can consult an antenna handbook and design a suitable gain antenna. See Appendix A concerning FCC field strength limitations. An FM- VHF TV receiving antenna could be modified for such a purpose.

Ham radio books and magazines are filled with antenna principles and ideas which can be adapted to your application. Also, you may wish to look at Radio Shack book No. 62-1083 on antennas.

## **ANTENNA ALTERNATIVES:**

If your situation involves a single large building or multi-level home where reception from the FM-100 antenna may tend to be uneven because of walls and other VHF path obstacles, you might set up the FM-100's output in a "carrier-current" configuration. If you know how, then do so - safely. If not, you can show your FM-100 and this book to a licensed radio engineer and negotiate with that person for a safe installation which will feed your signal through interior wiring of your home or building. Do not attempt such an installation unless you know exactly what to do and not to do. Also, because such an installation is beyond the original purpose of this kit and the safety standards intended for all Ramsey kits, and because we have not tested the FM-100 in such an installation, we cannot provide further details for such an installation.

## **USING YOUR FM-100**

- **Setting the frequency:**

- [1] Press both **FREQ UP** and **FREQ DOWN** at the same time. You should hear a confirming low then high tone. The 10's digit decimal point should blink.
- [2] Press and hold a **FREQ** button; the frequency should scroll through the values.
- [3] When frequency is acceptable, press both **FREQ UP** and **FREQ DOWN**. You will hear three short quick beeps to let you know the data is written to non-volatile memory.

- **Turning on the microphone:**

- [1] Make sure a microphone is plugged into the appropriate jack.
- [2] Pre-set the gain level of the microphone before coming on the air. This will prevent the audio level of your voice varying every time you come on.
- [3] Use the **MIC** button to toggle between on and off.

- **Turning on AUTO AGC**

- [1] Press the **AUTO AGC** button, when the **MIC ON LED** is lit, it will blink rapidly to indicate **AGC** mode is selected.
- [2] You can toggle this mode whether the **MIC** is on or off.
- [3] Press the **AUTO AGC** button again to disable it.

- **Testing the display:**

- [1] Press both **MIC** and **AUTO AGC** at the same time.
- [2] All of the display **LEDs** light to help you troubleshoot any display problems
- [3] Press both keys again to return to normal mode.

- **Volume levels:**

- [1] Make sure music source peaks remain below +3dB. Any more level and you introduce distortion.
- [2] You should be able to set the microphone **AGC** once and leave it alone, just using the **MIC** switch to turn it on and off.

## **APPENDIX A: FCC RULES AND INFORMATION**

*The Rules of the FCC (Federal Communications Commission) and your kit built FM Stereo Transmitter.*

An basic introduction of applicable FCC regulations. This basic introduction is just that: basic and introductory. A complete and thorough explanation of the FCC rules requires a reading of the regulations contained in the "Code of Federal Regulations, Part 15." To order your copy of FCC rules part 15, call the US Government, Superintendent of Documents, at 202-512-3238, or fax at 202-512-2250. To order the correct document, ask for "CFR Title 17: Parts 1 to 19." The cost is \$24.00, Master Card and Visa accepted.

It is the policy of Ramsey Electronics, Inc., that knowing and observing the lawful use of all kits is a first responsibility of our kit user-builders. We do not endorse any unlawful use of any of our kits, and we do try to give you as much common sense help about normal and lawful use as we can. Further, it is the policy of Ramsey Electronics, Inc., to cooperate with all applicable federal regulations in the design and marketing of our electronics kit products. Finally, we urge all of our overseas customers to observe the regulations of their own national telecommunications authorities.

In all instances, compliance with FCC rules in the operation of what the FCC terms an "intentional radiator" is always the responsibility of the user of such an "intentional radiator".

### **In the United States, this is how the FCC regards your transmitter kit:**

Licensed FM broadcast stations and their listeners have ALL the rights! Your use of a device such as the FM-100 kit MAY have some limited privileges in locally-unused band space.

Unlicensed operation of small transmitting devices is discussed in "Part 15" of the FCC Rules. These Rules are published in 100 "Parts," covering everything imaginable concerning the topic of "Telecommunications." The six books containing the FCC Rules are section 47 of the complete Code of Federal Regulations, which you are likely to find in the Reference section of your Public Library. If you have questions about the legal operation of your FM-100 or any other kit or home-built device which emits RF energy, it is your responsibility to study the FCC regulations. It is best if YOU read (and consult with a lawyer if you are in doubt) the rules and do not bother the understaffed and busy FCC employees with questions that are clearly answered in the rules.

Here are the primary "dos and don'ts" picked from the current FCC Rules, as of May, 1990. This is only a **brief look** at the rules and should not be construed to be the absolute complete legal interpretation! It is up to you to operate within the proper FCC rules and Ramsey Electronics, Inc. cannot be held responsible for any violation thereof.

1. In the past, no "two-way communications" use of the 88-108 MHz FM broadcast band was permitted. This prohibition does not appear in the current edition of Part 15. Previous editions of Part 15 discussed "wireless microphones" (such as Ramsey FM-1, FM-4, etc.), while the June 23, 1989, revision eliminates this discussion in favor of more detail regarding computer and TV peripherals and other modern electronic conveniences. However, it is not immediately clear that the 1989 revision of the FCC Rules Part 15 necessarily "cancels" previous regulations. Laws and rules tend to remain in force unless they are specifically repealed. Also, FCC Rule 15.37 discusses "Transitional Provisions for Compliance with the Rules," and states in item (c): "There are no restrictions on the operation or marketing of equipment complying with the regulations in effect prior to June 23, 1989."

2. It is the sole responsibility of the builder-user of any FM broadcast-band device to research and fully avoid any and all interference to licensed FM broadcast transmission and reception. This instruction manual gives you practical advice on how to do a good job of finding a clear frequency, if one is available.

3. For some frequency bands, the FCC sets 100 milliwatts (0.1 watt) as the maximum permitted power output for unlicensed, home-built transmitting devices, and that the combined length of your antenna and feedline (coaxial cable or other) must not exceed 10 feet. The technical standards for 88-108 MHz are very different, primarily concerned with band width and RF field strength.

4. FCC Rules do not differ for "stereo" or "monaural" transmissions.

5. Broadcasting on the grounds of a school (AM emissions only) is specifically permitted and encouraged between 525 and 1705 KHz under Part 15.221. Use our AM-1 AM radio broadcast kit for this use.

6. FCC Rule No. 15.239 specifically addresses operation in the 88-108 MHz FM broadcast band for which your FM-100 transmitter kit is designed. However, this Rule does not, by itself, tell you everything you need to know about using a device of this kind. Therefore, we are noting a series of Part 15 regulations which should be observed:

- a. The transmitter must NEVER be tuned to a frequency above 108 MHz, specifically the band 108-121.94 MHz, FCC Rule 15.205 lists this band as restricted, due to potential interference with aircraft navigation equipment.
- b. The "bandwidth" of your transmission is limited to 200 KHz, centered on the actual operating frequency. Since 200 KHz is enough spectrum space for several different FM stations, this is a "generous" limitation designed to accommodate cruder FM devices. Properly built and adjusted, the FM-100 kit operates well within this limit. In fact, its signal should sound no "wider" than any other FM station when listening on an ordinary FM radio.
- c. FCC Rule 15.215(a) says: "Unless otherwise stated, there are no restrictions as to the types of operations permitted under these sections." This general provision appears to leave you free to use your FM stereo transmitter in a manner similar to operations of an FM broadcasting station, or to use it for any other non-interfering, practical application.
- d. FCC Rule 15.5: General conditions of operation: "(b) Operation...is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical equipment, or by an incidental radiator. (c) The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference."
- e. The most specific FCC regulation of 88-108 MHz FM Broadcast band unlicensed operation is that the "field strength" of the signal must not exceed 250 microvolts/meter at a distance of 3 meters from the transmitter (FCC rule 15.239). If you have any concern about this emission limit, have your device checked by a technician with accurate measuring equipment. Remember that the "field strength" of a signal is determined as much by the antenna as by the RF output of the transmitter itself.

<b>DISTANCE FROM TRANSMITTER ANTENNA</b>			
<b>METERS</b>	<b>FEET</b>	<b>FIELD STRENGTH (<math>\mu\text{V}</math>)</b>	<b>TOTAL RECEPTION AREA</b>
<b>3</b>	10	250	314 FT
<b>6</b>	20	125	1256 FT
<b>12</b>	39	63	4800 FT
<b>24</b>	78	31	19113 FT
<b>48</b>	157	15	1.8 ACRES
<b>96</b>	315	7.5	7.2 ACRES
<b>192</b>	630	3.8	28.6 ACRES
<b>384</b>	1260	1.9	11.4 ACRES
<b>768</b>	2520	.95	458 ACRES
<b>1536</b>	5036	.5	1830 ACRES

### **APPENDIX B: UNDERSTANDING LEGAL "FIELD STRENGTH"**

A "microvolt" is one-millionth of one volt and designated " $\mu\text{V}$ " in the following explanations.

The new FCC Part 15 Rules specify a maximum "Field Strength" of your transmitted signal. Since it is unlikely that you have the equipment to carry out accurate field strength measurements in microvolts, it is useful to understand at least the theory of field strength so that you can understand both what you can expect from such transmitters, and what limits the FCC intends.

Previous limits on non-licensed FM-broadcast band devices were defined as a maximum field strength of  $40\mu\text{V}$  per meter measured at a distance of 15 meters. The June 1989 revised rule specifies a maximum of  $250\mu\text{V}$  per meter, but measured at 3 meters from your antenna. Both limitations are the same in practice. " $250\mu\text{V}$  per meter" means that an accurate field-strength meter with a 1-meter antenna may indicate a maximum signal field strength of  $250\mu\text{V}$  (In contrast, non-licensed operation from 26.96 to 27.28 MHz is limited to a field strength of 10,000  $\mu\text{V}$  per meter at 3 meters).

In all cases, the field strength of a signal decreases in direct proportion to the distance away from the antenna. Power decreases by the square of distance: for every doubling in distance, the signal power is quartered, but the field strength voltage is only halved. Using this theory, we can construct a simple chart to show the maximum permitted performance of a non-licensed FM band transmitter. The theoretical figures assume a simple 1 meter receiving antenna in all cases and do not take into consideration that reception can be greatly enhanced with larger, multi-element antennas and preamplifiers. In the following chart, the field strength (theoretical minimum) gets even stronger as you move from the edge of these circular boundaries toward the antenna:

This "exercise in meters and microvolts" demonstrates that the FCC clearly intends to limit the theoretical range of non-licensed devices operating in this band. It also shows the potential for causing interference at a home down the street from you. But it also shows that you can legally put out quite a good signal over wider areas than you might have imagined.

For other kinds of radio services, the FCC restricts such factors as transmitter power or antenna height, which cannot really limit the possible "range" of a transmission under good conditions. By restricting the maximum field strength at a specific distance from your antenna, the FCC clearly plans for your signal to "die out" at a specific distance from your antenna, no matter what kind of transmitter power or extra-gain antenna you are using. On the other hand, the FCC standards do make it legal and possible for you to broadcast on a school campus, campground or local neighborhood, as long as you do not cause interference to broadcast reception.

### ***"Why talk about acres"?***

There are three reasons to translate our look at "field strength" into "acres".

- (1) The first one is easy: the numbers would get too cumbersome if we discussed your possible signal coverage in terms of square feet or square meters.
- (2) It's very easy to see that your signal can easily and legally serve a school campus or wilderness campground.
- (3) And, if we remember that typical urban single-family home sites run from 1/4 to 1/2 acre on the average, it should become extremely clear that your obligation to avoid interfering with broadcast reception can easily involve hundreds of homes, before adding apartments!

In fact, the most significant distance in the above chart is the 1.9  $\mu\text{V}$  signal strength permissible at 1260 feet (about 1/4 mile), covering a circular area of

about 114 acres. A quick glance at stereo FM receiver specifications shows typical sensitivity of 1.7  $\mu\text{V}$  before considering high-gain antennas or preamplifiers. Your non-licensed signal can provide serious competition to a public broadcast station fifty miles away, a station which someone in your neighborhood may have set up a special antenna to enjoy.

Calibrated "field strength meters" such as described in the ARRL Radio Amateur's Handbook can detect signals down to about 100 microvolts. To measure RF field strength below such a level, professional or laboratory equipment and sensitive receivers are required. A "sensitive" receiver responds to a signal of 1 or even .5 microvolt "delivered" to the receiver input by antenna. If the antenna is not good, the receiver cannot respond to the presence of fractions of a microvolt of RF energy.

## **SUMMARY**

The present edition of Part 15 of the FCC rules does not provide detailed guidance on ALL aspects of using a low-power transmitter such as the FM-100. The main point is that you may not cause any interference whatsoever to licensed broadcast services and that you must be willing to put up with any interference that you may experience.

### **Lawful use suggestions for the FM-100**

1. Build and adjust this kit strictly according to the published instructions.
2. Use the whip antenna supplied.
3. Do not modify your kit in any way.
4. Check your intended operating frequency very carefully, as clearly explained in this instruction manual, to ensure you will not cause interference to reception of licensed broadcasting.
5. If you receive ANY complaint about your transmissions interfering with broadcast reception, stop or change your operation IMMEDIATELY.
6. If you are contacted by the FCC regarding use of this device, cooperate fully and promptly.
7. Do your own homework and research to understand and comply with present and future FCC rulings concerning devices of this kind.
8. Do not use made-up "station call signs" to identify your transmissions. Only the FCC has the authority to issue such call signs. Use some other way to identify your transmitting activity, such as "This is Stereo 90.5, Seabreeze School Student Music Radio," and so forth.
9. Identify the location and purpose of your transmissions from time to time. This is common courtesy toward other persons who may hear your signal. The FCC is toughest about clandestine transmissions which cost time and money to track down.
10. Do not assume that the mere fact that you purchased this kit gives you any specific right to use it for any purpose beyond generating a low-level RF signal which is barely detectable beyond the perimeter of your personal dwelling space.

Finally, the FCC Rules call for the posting of printed notices on devices

intended for non-licensed operation under Part 15 Rules. You will find such notices written up for the front or back of the instruction manual for nearly any computer or video accessory that you have seen in recent months. Consult the Part 15 Rules for the exact wording of such notices. Following is a text for such a notice which responds to FCC rule making intentions:

**NOTICE:**

The radio-frequency "intentional radiator" device which may be constructed from kit parts supplied by us is intended and designed by Ramsey Electronics, Inc. to conform to applicable provisions of Part 15 of FCC Rules. The individual kit-builder and all users of this device assume responsibility for lawful uses conforming to FCC Part 15 Rules. Operation is subject to the following two conditions:

- [1] This device may not cause harmful interference, and
- [2] this device must accept any interference received, including interference that may cause undesired operation.

## **Final comment**

A well-informed person will see today's FCC Rules to be evolving and progressively less-restrictive. Even though today's technology is far more complex than what was possible at the time of the Communications Act of 1934, the FCC rules are becoming more relaxed, giving radio experimenters more and more opportunities to explore many frequency bands, using many communications modes, with no need for a formal license of any kind. A thorough study of Part 15 of the FCC Rules, which is completely beyond the purpose of this kit manual, will show you many legal uses of radio transmitting devices which do not require licensing, either amateur or commercial.

To provide more personal and club radio-learning opportunities, and to cut down on administrative costs, today's FCC permits far more non-licensed activity than at any time in previous history. On the other hand, today's FCC enforcement actions get bigger fines and real prison terms for scofflaws! From CB (now 3 bands of it, for varying applications) to easy entry-level Amateur Radio with long-term licensing, to numerous unlicensed Part 15 operations, the FCC is beginning to look out for the interest and good plans and intentions of private citizens and school-community groups as never before in radio communications history. Learn the rules...observe them...and have fun in radio!

If you enjoyed this Ramsey kit, there's plenty more to choose from in our catalog - write or call today!

## **The Ramsey Kit Warranty**

**Please read carefully BEFORE calling or writing in about your kit. Most problems can be solved without contacting the factory.**

Notice that this is not a "fine print" warranty. We want you to understand your rights and ours too! All Ramsey kits will work if assembled properly. The very fact that your kit includes this new manual is your assurance that a team of knowledgeable people have field-tested several "copies" of this kit straight from the Ramsey Inventory. If you need help, please read through your manual carefully. All information required to properly build and test your kit is contained within the pages!

**1. DEFECTIVE PARTS:** It's always easy to blame a part for a problem in your kit, Before you conclude that a part may be bad, thoroughly check your work. Today's semiconductors and passive components have reached incredibly high reliability levels, and it's sad to say that our human construction skills have not! But on rare occasions a sour component can slip through. All our kit parts carry the Ramsey Electronics Warranty that they are free from defects for a full ninety (90) days from the date of purchase. Defective parts will be replaced promptly at our expense. If you suspect any part to be defective, please mail it to our factory for testing and replacement. Please send only the defective part(s), not the entire kit. The part(s) MUST be returned to us in suitable condition for testing. Please be aware that testing can usually determine if the part was truly defective or damaged by assembly or usage. Don't be afraid of telling us that you 'blew-it', we're all human and in most cases, replacement parts are very reasonably priced.

**2. MISSING PARTS:** Before assuming a part value is incorrect, check the parts listing carefully to see if it is a critical value such as a specific coil or IC, or whether a RANGE of values is suitable (such as "100 to 500 uF"). Often times, common sense will solve a mysterious missing part problem. If you're missing five 10K ohm resistors and received five extra 1K resistors, you can pretty much be assured that the '1K ohm' resistors are actually the 'missing' 10 K parts ("Hum-m-m, I guess the 'red' band really does look orange!") Ramsey Electronics project kits are packed with pride in the USA. If you believe we packed an incorrect part or omitted a part clearly indicated in your assembly manual as supplied with the basic kit by Ramsey, please write or call us with information on the part you need and proof of kit purchase.

### **3. FACTORY REPAIR OF ASSEMBLED KITS:**

To qualify for Ramsey Electronics factory repair, kits MUST:

1. NOT be assembled with acid core solder or flux.
2. NOT be modified in any manner.
3. BE returned in fully-assembled form, not partially assembled.
4. BE accompanied by the proper repair fee. No repair will be undertaken until we have received the MINIMUM repair fee (1 hour labor) of \$49.00, or authorization to charge it to your credit card account.
5. INCLUDE a description of the problem and legible return address. DO NOT send a separate letter; include all correspondence with the unit. Please do not include your own hardware such as non-Ramsey cabinets, knobs, cables, external battery packs and the like. Ramsey Electronics, Inc., reserves the right to refuse repair on ANY item in which we find excessive problems or damage due to construction methods. To assist customers in such situations, Ramsey Electronics, Inc., reserves the right to solve their needs on a case-by-case basis.

The repair is \$49.00 per hour, regardless of the cost of the kit. Please understand that our technicians are not volunteers and that set-up, testing, diagnosis, repair and repacking and paperwork can take nearly an hour of paid employee time on even a simple kit. Of course, if we find that a part was defective in manufacture, there will be no charge to repair your kit (But please realize that our technicians know the difference between a defective part and parts burned out or damaged through improper use or assembly).

**4. REFUNDS:** You are given ten (10) days to examine our products. If you are not satisfied, you may return your unassembled kit with all the parts and instructions and proof of purchase to the factory for a full refund. The return package should be packed securely. Insurance is recommended. Please do not cause needless delays, read all information carefully.

# PROFESSIONAL FM STEREO TRANSMITTER KIT

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### REQUIRED TOOLS

- Soldering Iron Ramsey #RTS06, (Radio Shack #RS64-2072)
- Thin Rosin Core Solder Ramsey #RTS12, (RS64-025)
- Needle Nose Pliers Ramsey #RTS05, (RS64-1844)
- Small Diagonal Cutters Ramsey #RTS04, (RS64-1845)
- <OR> Complete Soldering Tool Set (RS64-2801)

### ADDITIONAL SUGGESTED ITEMS

- Soldering Iron Holder/Cleaner (RS64-2078)
- Holder for PC Board/Parts Ramsey #RTS13, (RS64-2094)
- Desoldering Braid Ramsey #RTS08, (RS-2090)

Price: \$10.00

Ramsey Publication No. MFM-100

Assembly and Instruction manual for:

**RAMSEY MODEL NO. FM-100**



<b><u>TOTAL SOLDER POINTS</u></b> 897
<b><u>ESTIMATED ASSEMBLY TIME</u></b>
Beginner .....24 hrs
Intermediate .....18 hrs
Advanced .....10 hrs

