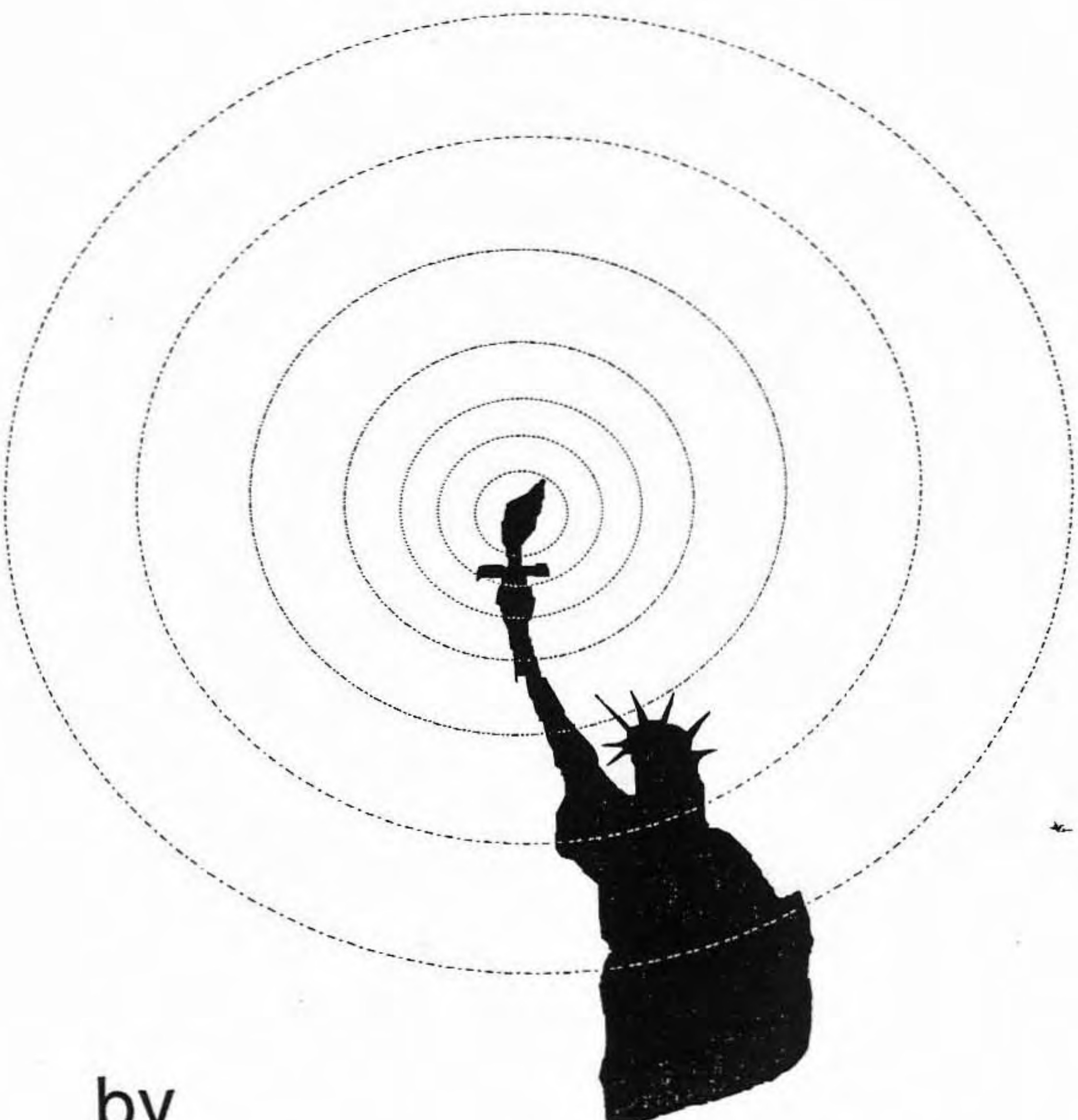
FM MicroPower Radio



by

Mycal

FM Micro Power Radio Guide

Disclaimer

The author has taken great care to see that the information contained here is accurate, but takes no responsibility for its accuracy. Also, some of the procedures described may be illegal to use on the open airwaves. It is the readers responsibility to consult the FCC or other relevant government body before use. This book is meant for informational purposes only.

Preface

This book was written to add to the public knowledge the information necessary to create and operate a micro power FM radio station. It is not intended to help someone break a law or cause interference with other radio operators and services. It is intended as a starting point or a guide to educate ones self in the correct construction and operation of a micro power radio station. Many of the current newspapers, radio and TV stations are being bought up and controlled by just a few large corporations, micro power radio could soon be one of the only avenues of expression for the average person.

The biggest problem facing the micro power radio movement is the limited availability of high quality radio equipment. For the average U.S. citizen, it is easier to get an AK-47 than a radio transmitter suitable for micro power radio. This book tries to remedy that by offering easy to build projects and lots of sources useful to the micro power radio enthusiast.

So if you have seen Pump Up The Volume fifteen times and dreams of being the voice of the North Dorm, or you are sick of the media censorship in your area and want to offer an alternative voice, look no further. With the help of this document, you can soon be armed with an RF cannon able to blast electro- magnetic waves into the air of your community.

Version Info

This document is currently under development. Any ideas, comments, or information relevant to this subject would greatly be appreciated.

The information contained in this document is the result of many hours of experimentation. I have burned many parts trying out different designs, and spent many hours reading radio electronics books and trying to figure out what they meant. So don't get discouraged if you don't get it to work the first time, they usually won't. Try to understand how things work, it will make your life much easier when you want to improve or change a circuit.

Included in this document are recommendations on equipment to have, basic radio station design, antenna design, amplifier design, legalities and part 15, ideas on programming and a section on how to avoid trouble.

Comments can be directed to :

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(edited 2005 when scanned)

DIY MASS MEDIA

Tired of selective and biased coverage of the news in your area? Bored with the same old top-40 radio stations? Tired of tuning up and down the FM band to find something worthwhile? Ready to take matters into your own hands, but don't have an extra $100,000 to finance your own radio station? Have no fear, the micro-power radio movement is here, and it's time for you to get involved!

Micro-power radio has been called "freecasting," "pirate radio," and more recently, "sandbox radio." Throughout Europe and Africa, it has played an important part in informing and entertaining the public with alternatives not available from government-controlled media sources. Now in the United States, micro radio is becoming increasingly important. Large corporations are buying up every last independent broadcast media outlets and pressuring the government to increase regulations to keep new players out of the game. This has stifled alternative thought on the airwaves.

Micro-power radio is true community radio because its signal only reaches a small geographic are. Depending on the power output, a micro-power station can reach from 1/4 of a mile to 10 miles or more. Coverage could be an apartment complex, a college campus, or a small town. And because of the capture effect of FM and the low power of micro-power broadcasts, another micro-power station in a neighboring community broadcasting on the same frequency would cause little interference. Micro radio is to commercial radio as newsletters are to slick magazines.

IS IT LEGAL?

Well...no, if you want to be technical about it. The FCC tightened up its licensing requirements in 1980 because of the lobbing efforts of commercial broadcasters and The Corporation for Public Broadcasting (your 'public radio' friends at NPR). Since then, the minimum price to get on the air has risen to $50,000--not counting operating expenses. These costs make broadcasting too expensive for individuals. Micro-power has changed all that: a compleat station can be assembled for a few hundred dollars, or a bare-bones station for less than a hundred.

One goal of the micro-power movement is to force the FCC to reinstate low-power radio licenses. Similar actions in Europe and Canada have been successful: Canada now issues micro-power licenses; Italy has totally deregulated radio, permitting anyone with a transmitter to broadcast; and England now allows non-government stations. All these gains were made by micro-power stations and their ever-increasing listenership.

Groups like San Francisco Liberation Radio and Free Radio Berkeley have been running high-profile stations, openly challenging the FCC to take them to court. So far the FCC has done little but file notices of apparent violations. In Springfield, Illinois, Black Liberation Radio has been broadcasting for five years, 3 of them after the FCC fined the station $750 (which has not been paid).

Many other micro-power stations have been running for years with little interference from the FCC. Not to say that the FCC doesn't frown on these broadcasts; but in most cases, they won't go after a micro-power broadcaster unless there has been a complaint, usually about interference with commercial stations. The micro-power movement stresses careful consideration when selecting a broadcast frequency, along with care to use only equipment producing "clean" signals.

ROLL YOUR OWN RADIO

Radio can be better with micro-power radio stations that serve a community, not a 200-mile region. Get involved! Here's a brief explanation of what you'll need to start your own micro-power radio station:

- A group of committed people who get along well and have plenty of time and energy.
- A format (presuming you have something worth saying).
- A site to transmit from.
- A Frequency that is on an open FM channel.
- A transmitter built from kits (or sometimes surplus parts).
- An antenna built or modified from amateur radio suppliers.
- Odds and ends.

One person could operate a micro-power station alone--but the time and effort to produce a show, setup the equipment, and do the actual broadcast requires lots of work. Having a small group of like-minded people greatly enhances the operation of the station, offering more ideas for programming and more hands for equipment setup/teardown. Also, the ream effort required to put together a radio show is on of the reasons that chaos doesn't break out on the airwaves!

Find a site. If you're broadcasting a powerful signal (or worry the politicos in your area won't appreciate your denouncing them as fascists), you may want to select a place that offers a fast getaway. A dormitory roof or any other high location works great for micro stations, but even antennas mounted to wooden poles jammed outside of a window have been known to work. A broadcast site must offer convenience, central location to your listenership--and protection from the FCC, if necessary.

Before your first broadcast, find an open space on the airwaves. On the FM band, channels are spaced every 200kHz, from 87.9 MHz to 107.9 MHz. (You'll notice on most digital tuners that the frequency changes by jumps of 200kHz. For example : 87.9 MHz will become 88.1 MHz when the 'up' button is pressed.) Care must be taken not to broadcast above 108MHz; this space is used by aircraft, and you could cause a safety risk if you interfere with aircraft communication. In the best of worlds, you would want at least one clear channel between the frequency you choose and the next station. In most urban centers, this is impossible. Best bets are the channels that lie between 87.9 and 92.1 Mhz--but be careful not to broadcast over faint, low power commercial or public stations.

Hardest to find will be the transmitter. Although it's possible to buy an old FM transmitter from the pre-1980 legal micro-power days, you'll probably have to build your own.* Don't worry: it's not as hard as it sounds. Several companies produce kits based on the BA1404 monolithic FM stereo transmitter chips. These kits are very simple to assemble and produce high quality stereo signals.

Antennas are one of the easiest pieces to acquire or build, but are also the items most micro-power radio operators skimp on. Big mistake! The antenna is one of the most important parts of the station. With a poor antenna, your range will be limited and you risk interfering with other stations, even if all your other equipment is very high quality. Antennas for FM micro-power radio stations can be made out of a couple pieces of wire, adapted from amateur radio antennas, or purchased outright from your local Radio Shack. Read up: the ARRL Handbook (also known as the amateur radio bible) contains everything you'll want to know about antennas--and just about every thing else technically involved in a micro-power radio station. Highly recommended!

There are a few other things you will probably need for your station: a soldering iron; basic knowledge of electronics to assemble the transmitter; a power source (a car battery or a CB radio power supply works great); an SWR meter to measure how much power your transmitter is producing and reaching your antenna; and a good digital receiver or a frequency counter to ensure your transmitter stays at the right frequency. And of course, wire, audio patch cords, and coaxial cables to connect everything together.

That is basically all you need to get on the air and take back the airwaves from the giant megacorps. Read up and turn on your own micro-power radio cannon. With micro-power radio, you can score a victory for truth and liberty, without censorship or control. And don't forget the killer music.

FCC and the LAW

It is unclear in the law weather or not the FCC really has legal jurisdiction over unlicensed broadcasters that broadcast signals that don't cross state boundaries. Most people give the FCC the benefit of the doubt since they are a government agency and have much more ammunition than the average unlicensed broadcaster. Much like taxpayers and the IRS. But as you shall see later the FCC's jurisdiction may be resolved in the near future.

Unlicensed operation of transmitting devices is discussed in "Part 15" of the FCC Rules. These Rules are published in a maximum of 100 "Parts," covering all aspects of telecommunications. A compleat set of these rules should be available at your local Public Library. If you have questions about the legalities of operating any of the projects in this book that are not covered here or are unclear, please consult these Regulations.

Part 15 covers "wireless microphones" and "unlicensed broadcast band" transmitters for a number of different frequencies. While Part 15 allows 100 milliwatts output power for unlicensed, home-built transmitting devices, on the FM broadcast band your allowable power output is measured in a different way.

On the FM broadcast band you are not allowed to transmit a signal that would cause a field strength greater than 250 microvolts (uV) at a distance of 3 meters from the antenna. You may be asking yourself "what does this mean in real terms?" The answer is a difficult one to answer. You could have transmitter that generates 100mw running into one antenna that is legal and have another transmitter that generates 10mw into another antenna that is twice or more this legal limit. This depends mostly on how efficient your antenna and feedline are.

It is the Authors opinion that these regulations regarding FM broadcast band field strength could of been written by Machiavelli himself. Most of the "bugs", FM broadcaster kits, and Mr. Microphones that are available on the open market today can easily exceed these regulations. To be able to follow this regulation you would need a calibrated field strength meter that could measure field strengths accurately down to about 100 uV, and use it every time you broadcast, even with your Radio Shack Mr. Microphone.

Other regulations for the FM broadcast band include :

- The transmitter must NEVER be tuned to a frequency above 108 MHz. FCC Rule 15.205 lists the frequency range between 108 to 121.94 as restricted, due to potential interference with aircraft navigation equipment.
- The bandwidth (or amount of spectrum your transmission can occupy) of your transmission is limited to 200 kHz centered on the actual operating frequency. This is plenty of room for a stereo signal and several subcarriers.
- 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.

There is much more in the Part 15 Rules. FM broadcast band usage is specifically addressed in Rule No. 15.239. Please consult the rules for more info.

FCC and Reality

The FCC, at least at the time of the writing of this book, is not a gestapo type government entity like the IRS. Mostly they are your typical government licensing agency concerned in what is perceived the "greater good" for the "people" of our country. They have no law enforcement ability by themselves and rely mostly on enforcing there regulations by fines, usually to licensed radio operations that could have there licence taken away for failure to comply to regulations or pay fines.

In the case of unlicensed broadcasters things get a little more tricky. The FCC's recourse is to take a fined unlicensed broadcaster to civil court. This rarely happens. In most cases the unlicensed broadcaster stops broadcasting and pays the fine or broadcaster stops broadcasting and doesn't pay the fine. In the latter case the FCC rarely goes after the broadcaster for the fine and the whole matter is dropped.

The FCC doesn't drive the streets at night looking for unlicensed broadcasters. In almost all cases the FCC will not go after an unlicensed broadcaster unless there has been complaints about the broadcaster. Most of these complaints are generated from people that the unlicensed broadcaster is interfering with. There have also been a few cases where legitimate broadcasters complain about unlicensed broadcasters because they were taking to many listeners away.

The FCC does have vans that resemble small moterhomes that they use for enforcement of there regulations, but these vans are usually used for licensed enforcement. For unlicensed enforcement the FCC usually uses there specially modified station wagons. These cars have specially fitted fiberglass roofs with antennas mounted in them. Both the vans and the cars, contrary to popular belief, usually have no antennas hanging off them. All the antennas are encased in the body or in plastic containers on there roofs.

FCC and Recent Busts

Since the micro power radio movement has been gaining lots of momentum lately, there has been a corresponding number of people served with "notices of apparent violation", which basically mean "We (the FCC) know/think you are broadcasting illegally". The fines levied have been much higher than have been issued in the past for unlicensed operation.

There has been one crowning difference between the most recent "busts" an the older ones. This is that the unlicensed operators have been running high profile radio stations. While there has been many documented cases in t he past of college students running for years with there low profile station without a peep out of the FCC, these guys are thumbing there noses at the FCC, the licensed broadcasters, and the government. High profile, media campaigns, and anti-establishment broadcasts are prevalent. And like any government agency, the FCC wants to make an example out of these broadcasters before "more disruption" occurs. In short they are trying to put the cap back in the bottle before the genie gets out.

These high profile stations, Black Liberation Radio, KAPW, Free Radio Berkeley and San Francisco Liberation Radio have lined up to do battle with the FCC the all American way, with lawyers. It will be interesting to see if these suits will resolve any of the questions about the FCC's jurisdiction, and the status of unlicensed broadcasting.

Fundamentals of FM Audio

Depending on the kind and quality you desire in your broadcasts, a lot can be done with the audio signal before trying to modulate that transmitter with it. To be able to broadcast a stereo signal you must create a stereo composite to be applied to the transmitter. If you want to have that warm full sound of a professional station you can compress the audio signal. Other audio options like limiters, pre-emphasis networks, and filters can also have dramatic effects on how you 'sound' on the audiences receiver.

Stereo Composite Generation

When stereo was introduced it was designed to offer the same program quality as before to the millions of existing monophonic systems and offer stereo to the new receivers. What is done is to generate two separate audio channels. The main channel (L+R) is the sum of both the Left and Right channels. The channel is transmitted as standard audio (0-15kHz). A monophonic receiver will receive this and get the sum of the Left and Right information, not loosing an information. Another channel is also generated. This channel is the difference between the Left and the Right channel (L-R). This is done by subtracting the two channels. If the channels are identical in content, as in a monophonic source, the difference signal will be zero. This channel modulates a subcarrier at 38kHz and the 38kHz subcarrier is transmitted along with the main audio. A monophonic receiver will ignore this channel. The 38kHz subcarrier is suppressed to allow more information to be carried in the channels sidebands and a pilot synchronism signal is transmitted instead at half the frequency of where the 38kHz subcarrier is suppose to be. This 19kHz pilot carrier is used to turn on the receiver stereo decoder and used to reassemble the 38kHz subcarrier in the receiver. Once the signal is in the recever the Stereo Decoder extracts the L+R and L-R signals and recovers the original left and right signals by :

(L+R) + (L-R) = 2L -and-

(L+R) - (L-R) = 2R

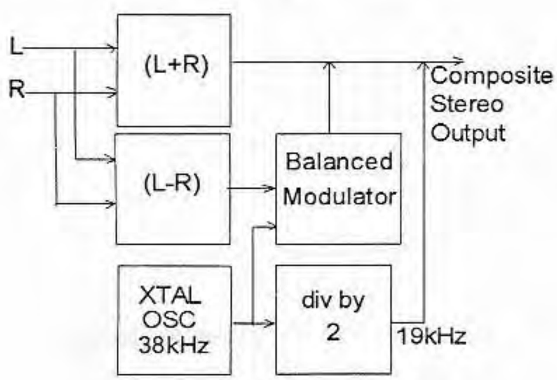


FIG.

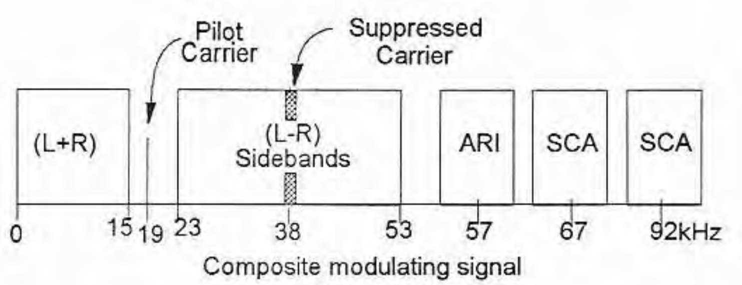


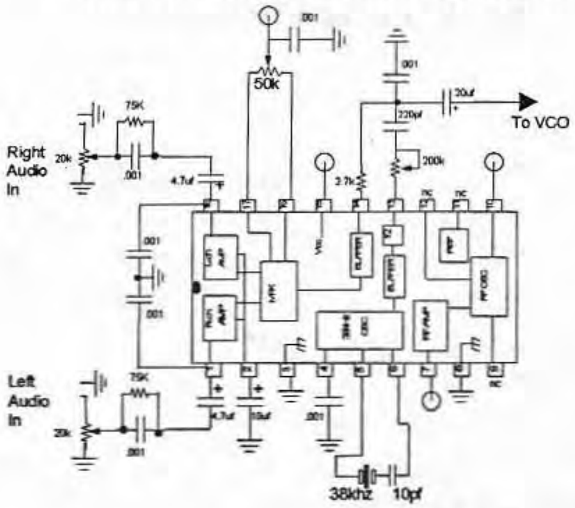
Figure X

Figure X-1 shows a block diagram of a stereo encoder and Figure X-2 shows the layout of a composite stereo signal. Notice that there are three other pieces to the stereo composite signal. These are "hidden" channels used for a number of different things. The SCA (Secondary Communications Authorization) channel is by far the most popular at this time with the 67kHz channel accounting for about 90% of all the SCA broadcasts out there. Often found on the SCA channels is commercial free muzac that department stores use. The ARI subcarrier is a new service called Automobile Radio Information mainly used to give road information to motorists.

Not all commercial radio stations transmit these signals, and they are unheard of in the micro power radio scene.

Recently Rolm, a electronic chip manufacturer, has developed a stereo transmitter on a chip. Known as a BA1404, it is available at many electronics part suppliers at about two dollars apiece in single quantity. It was developed to connect CD players to car stereos but has also showed up in many low cost stereo broadcaster kits. When used with a 38kHz crystal it can produce a fairly nice stereo composite signal that can be fed into a separate transmitter or be fed into its own oscillator and FM amp. Shown in Figure X-X is an example of the BA1404 used to generate a stereo composite signal to be feed into a VCO. Note the 75uS pre-emphasis network on the right and left audio audio inputs (see next section.) The 50k variable resistor is the left-right balance control and the 200k variable resistor is the 19kHz pilot level control. It should be noted that the BA1404 operates on 1.5 to 3 volts. Operating it with more than 3.5 volts may damage the chip.

Stereo Composite Generator



Pre-Emphasis

In a typical audio signal the high frequency sounds have less energy than the low ones and so produce less deviation of the carrier. This makes the high frequency sounds more susceptible to noise when received. To avoid this high frequency energy is boosted before being transmitted.

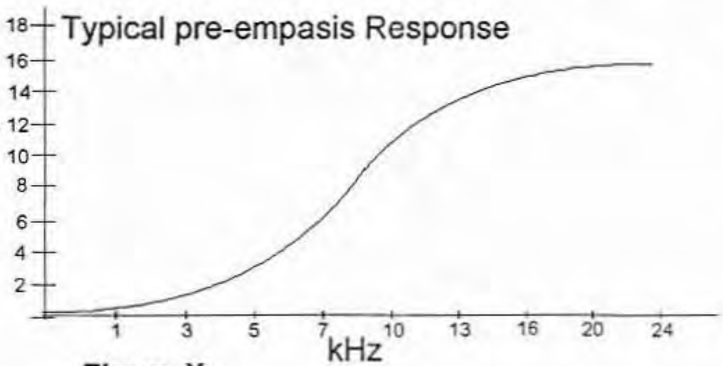


Figure X

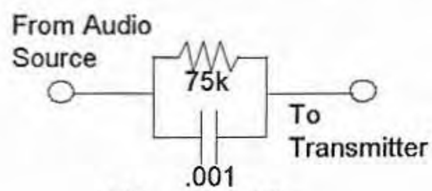


Figure X

This is called *pre-emphasis*. In the receiver the frequencies are cut by the same amount, this is called *de-emphasis*. The end result of pre-emphasis and de-emphasis is that the overall frequency response stays flat, but the background noise is reduced a lot.

Pre-emphasis and de-emphasis networks are characterized by their *time constant*. In the United States the standard is 75uS (micro seconds), but in Europe it is 50uS, and the de-emphasis networks are built in all of todays FM revievers. In a mono transmitter the pre-emphasis network can be built into the front end of the exciter. For a stereo transmitter the network must be installed before the stereo composite generator and there must be a network for each channel.

running a stereo composite signal into a pre-emphasis network would boost the L-R and pilot carrier information and would produce a very bad signal on a receiver.

The passive resistor/capacitor pre-emphasis networks that are typically used actually don't boost the high frequency energy, but cut down the low frequency energy. This equates to a loss of about 14dB for the low frequency energy. The end result is the same as boosting the high frequency signals, as the ratios of the difference between the low frequency and high frequency energy levels are equivalent and can be reconstructed correctly by the receiver de-emphasis network.

Simple resistor-capacitor networks like shown in Figure X-X can be calculated by multiplying the resistor value in Kilo-Ohms by the capacitor value in Farads this will give you the time constant in seconds. To calculate the examples time constant we would multiply 75 by $1x10^{-6}$ which would give us $75x10^{-6}$ seconds or 75uS the United States pre-empasis standard. Changing the 75 K resistor to a 50 K resistor would give us a network that would match the European standard.

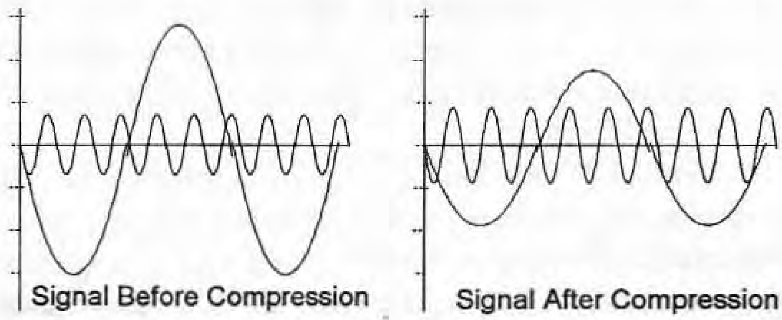


Figure X

Compressor

It is a compressors job to compress the dynamic range of an audio signal. The term 'dynamic range' means the difference between the softest and loudest passages the audio system can handle. Typically CD players can handle a very wide dynamic range, up to 96dB, while tape players have a dynamic range of about 50dB, and FM broadcast audio systems usually weigh in at 45dB of dynamic range. Compressing dynamic range has the end result of making soft passages louder and and loud passages softer. In figure ' ' as signal is show before and after compression. The large amplitude signal is compressed down and the small amplitude signal is boosted, thus the difference or dynamic range of the signal is smaller. Compressing works best when you are matching audio systems like CD players with FM broadcast audio systems or tape recorders. If a compressor is not used high level signals can be severely clipped and low level signals can be lost down in the noise of the audio system. Another effect compression will have is to make a transmitter seem 'louder' than a transmitter using no compression, but using too much compression can make a transmitter sound worse by sounding 'loud' all the time, offering little variance in signal levels.

Since the dynamic range of a tape deck is almost equal to that of a FM broadcast audio system no compression is recommended from tape sources. Another downside of compressing the output of a tape deck is that the noise from the tape deck will be amplified making the audio sound much worse. Compression does work well on the recording end of tape decks, and is recommended when recording programs for later broadcast.

Several Analog Integrated Circuits from Signetics, called compandors can be used to construct compressors. These are the NE570, NE571, and NE572 devices.

Limiter

Limiters are used to stop a signal's amplitude going over a certain level. In FM, the larger the signals amplitude the more bandwidth the transmitted signal takes. If an FM transmitter is over modulated (with large amplitude signals,) its frequency can shift too much, causing interference with other transmitting stations. This over modulation also sounds very bad on receivers designed to handle only certain amount of bandwidth. Limiters protect the transmitter from receiving audio signals over a certain amplitude and can protect the transmitter from over modulation. Figure ' ' shows a signal before and after going through a limiter. The large amplitude signal is compressed down to the limiters limit value while the smaller amplitude signal is uneffected.

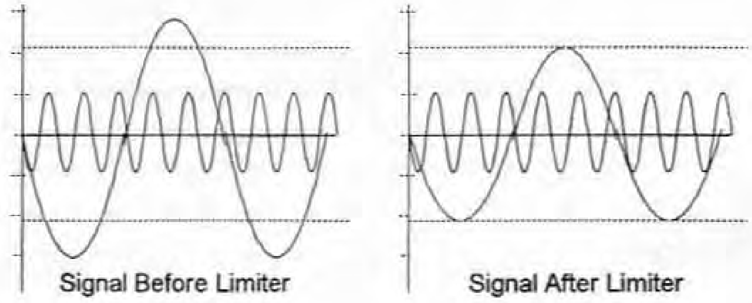


Figure X

Some CD's are louder than others just as some voices are louder than others, even with careful adjusting of the mixing console it is easy to overdrive, thus over modulate the transmitter. Accidents like dropping the mike or running the needle over the record can also cause large amplitude signals to reach your transmitter, unless of course you are using a limiter. Limiters like compressors can be built around compandor IC's.

Low Pass Filtering

If you look at Figure ' ' you will notice that the main channel (L+R) has a range from 0 to 15 kHz, and that the suppressed carrier sidebands are each 15 kHz in length. This is the maximum frequency response of a FM system. It is desirable to run the audio into a low pass filter with a cutoff of 15 kHz so that higher frequency audio doesn't interfere with the stereo pilot or cause excessive sidebands in the stereo subcarrier. Even if you are broadcasting a monophonic signal, high frequencies can effect a stereo receiver causing 'false' stereo by turning on the stereo decoder with energy that falls around 19kHz. Figure ' ' shows a typical filter response used for conditioning audio signals to be feed into a transmitter. If a stereo signal is being transmitted 2 filters, one for each channel is needed.

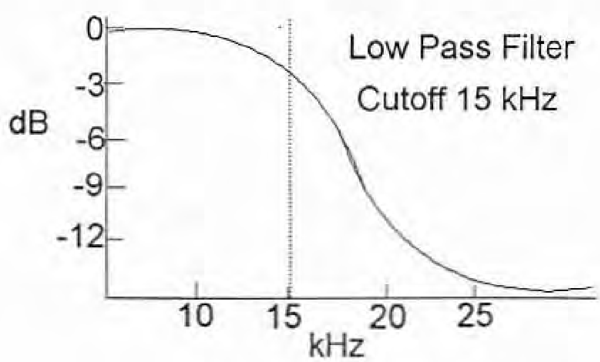


Figure X

Antennas

A good antenna is the backbone of a radio station. A Lot of power into a poor antenna will seldom produce more solid coverage than a small amount of power into a good antenna. Included here are some basic designs that will offer good overall performance for a variety of different space requirements.

Feedlines

Most modern day radio equipment operates with 50 ohm impedance cable and antennas. For antenna design in this section we will follow this convention as close as we can. Use 50 ohm coax cable for all transmission of RF energy in your radio station. There are many different kinds of 50 ohm cable, it is used extensively in CB and Amateur radio, and used for Ethernet computer networks. It can be found at most Radio Shacks and electronic stores. The Figure at left shows some popular 50 cables and the loss at 100 ft. Loss is shown in dB. Every 3dB is 2 times (see section on dB), so if we had 10 watts of output power and ran it through 100ft of RG-8A/U we would only have about 5 watts reaching the antenna. So, for low power stations, short feedlines are almost a must! I would keep all runs under 50 feet if possible, less than 30 would be ideal. I have seen several cases where pirates have mounted their low power transmitter in a weather proof box at the base of their antenna, and feed the AF and the power up the tower. to the transmitter. This is extream, but works well for super low power transmitters with no amplifier.

Line Loss Of Popular Cables @ 100Mhz Per 100 ft
RG-58U - 4.5dB
RG-8A/U - 3.2dB
1/2" hard line - .8dB

SWR

SWR ,or Standing Wave Ratio, signifies how well your antenna is matched to the rest of your feed system. Meters that will measure SWR are readily available. The most inexpensive costs about $19 at Radio Shack. The ones at Radio Shack are for CB radios which operate at 30Mhz but will be fairly accurate at measuring SWR well over 100Mhz. These meters usually also have a setting to measure power output, while not accurate at 100Mhz, they will still give you an idea of power output and are useful for tuning up a transmitter/amplifier. I highly recommend you acquire at least the most inexpensive SWR meter that has a power setting. It is invaluable in tuning up an antenna system.

If an antenna exhibits a high SWR, that means that a percentage of the power feeding it is being reflected back into the feed system,. This is not desirable. The Table here shows the percentage of power reflected for several SWR values. I would in all cases try to keep the SWR under 2.0:1. This is not possible in all conditions, but should be strived for.

Percentage of power reflected	VSWR
.0	1.0:1
.8	1.2:1
5.0	1.6:1
11.0	2.0:1
20.0	2.6:1

Antenna Design

A quarter wavelength of the operating frequency is an important measurement when designing simple dipole and vertical antennas. 1/4 wave length is equal to 234 divided by the frequency in Mhz. For Example at 88Mhz, 1/4 wave length would be equal to 2.7 feet. The following is a description of the figures on the following page. These are some innovative antenna designs that are ideal for covert FM broadcast band use.

Figure 1 shows a simple dipole, each element is cut to a 1/4 wave. This is the most basic antenna. You may be familiar with wire dipoles commonly inlaid into automobile windows, or included with stereo receivers. It exhibits about a 70 ohm impedance when more than about 15 feet off the ground at FM broadcast band frequencies. Using a gamma match (FIG. 3) can make this antenna 50 ohms.

Figure 2 shows a 1/4 wave groundplane antenna, it is my favorite for omni-directional broadcasting. Popular on the CB radio band. Good all around performance and a 50 ohm impedance make this an antenna you can't go wrong with. The groundplane elements of the antenna should be just a bit longer than the radiator (hence longer than 1/4 wave), so use element type B when cutting these elements.

Figure 4 is an example of a vertical dipole used out a window of a tall building. This is a perfect antenna for the dorm or apartment dweller. Can be used in vertical polarity as shown, or rotated into a horizontal position. Experimenting with both is recommended. When operating in the vertical position the gamma match side should be the top side. One will usually out perform the other depending on building material used in the building and height off the ground. Figure 3 shows a close up view of the dorm antenna. A gamma match is used to match the dipole to the 50 ohm feedline. This increases the efficiency of the antenna. All construction of antennas on this page use brazing rods available from your local welding shop, buy the longest rods you can find. The center of the coax is connected to a short rod (7 inches long, 1 inch inserted in dowel) that is inserted into the wood dowel about 3/4-1 inch away from the antenna radiator. A metal clip connects this short rod to the antenna radiator (see figure 7). This clip should be able to slide up and down the two rods, this is to be done to match the antenna to 50 ohms, or 1.0:1 SWR (or as close as you can get it). In the case of the radiator two rods were fused together with a torch to make a rod that was A+A long (see element cutting chart). When tuning up this antenna place the clip about 3 inches away from the dowel. place antenna at least 3 feet (if not more) away from all objects and apply RF energy from your transmitter and check SWR (you will probably need at least 100mw of output power to do this). Move the clip 1/2" either direction and measure SWR again, if it goes up you went the wrong way, if it goes down your moving the right direction. Try for the lowest SWR reading. You may want to make the rod a little bigger than A+A so you can trim it down with a pair of wire cutters, this will also help you 'match' your antenna.

Figure 6 shows the construction of a groundplane antenna. A 2 inch diameter wood dowel is used as a base. A whole is drilled down its center, and the bottom is cut out a bit to accommodate the top of a UHF connector (used in CB and other radios). A 2 x 2 inch of metal is used to connect the UHF connector (ground side) to the ground plane radials. Holes should be drilled at an angle to accommodate the radials so that the radials are 135 degrees from the radiator. Drill the metal so it will accommodate the UHF connector and the groundplane radials when up against the dowel. Connect the UHF connector to the metal plate with solder or screws, making sure that the center of the UHF connector is not touching the metal plate (ground). Slide the radiator (main radial) down the center of the dowel so it sticks through the dowel several inches and solder it to the center of the UHF connector. Shoot some glue in the holes that are going to accept the ground plane radials. Slide the plate up so it touches the dowel and align the holes for the ground plane radials. Insert the radials. Let the glue dry and then solder the radials to the metal plate. Tune antenna with SWR meter. Start with radials just a bit longer and trim down 1/8th of an inch at a time until lowest SWR appears.

Figure 7 shows the construction of a gamma match for the dipole antenna. Two small rectangles of sheet metal are drilled in the center and a machine screw sandwiches them together compressing on the gamma match rod and the radiator. A wingnut helps for fast adjustment. Copper circuit board, or any other highly conductive material could be used in place of the sheet metal. I know of people that solder a UHF connectors ground side to the radiator and solder its 'hot' side to the gamma match rod. This enables them to use connectors on the ends of the coax cable, thus creating a much cleaner antenna.

Figure 8 shows several ideas when it comes to mounting antennas. A) shows a groundplane antenna used as an out the window dorm style antenna. B) shows a typical mounting of a groundplane antenna with metal straps, or duct tape, or ... C) shows a horizontal dipole on the top of a pole or dowel. A dipole could also be supported between two structures.

It should also be noted that an antenna is tuned to a particular frequency. If one day you will be broadcasting on 100 Mhz and the next day 106 Mhz you will not have a match on both frequencies. The two choices are to A) tune your antenna to 103 Mhz (a happy medium) or B) use two separate antennas. Remember, when broadcasting low power, every little bit helps.

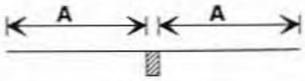
On the Road

Two-meter ham radio antenna are well suited for mobile operation of FM broadcast band transmitters. Most have a little Alan wrench set screw that holds the radiator in place. Simply remove the stock radiator and replace it with a brazing rod of length A (see figure 5). Tune up by simply cutting the rod down in size or loosening the set screw and raise or lower the rod and tighten back up in between SWR mesurements. With a mobile setup you can broadcast all night long from a very high location (ideal for good coverage) and see the magic vans coming for miles.

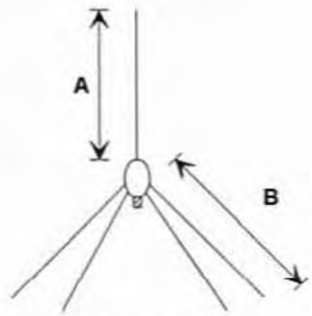
In Closing

There are enough ideas here to get you started. But there are many more antenna designs. Some that offer gain (increased output in desirable directions), or are highly directional (broadcasting only in one direction). Consult the ARRL Handbook form many more ideas and better explanations of some of these ideas and designs shown here..

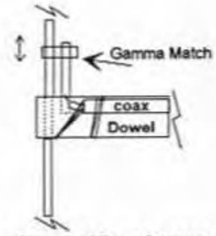
Antennas



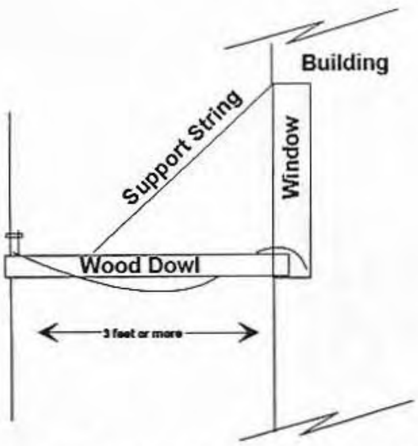
1/4 di-pole
FIG. 1



1/4 wave vertical
FIG. 2



Close up of Dorm Antenna
FIG. 3



Improvised Dorm or City Building Antenna
FIG. 4

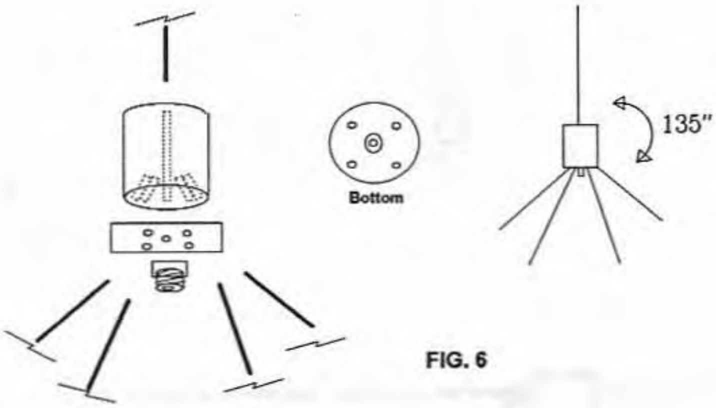


FIG. 6

Gamma Match

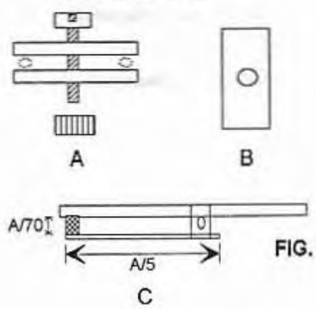


FIG. 5

A = 234/Frequency in Mhz
B = 240/Frequency in Mhz

Element Cutting Chart		
Freq. in Mhz	**A**	**B**
87.9	2.66ft	2.73ft
89.1	2.63ft	2.69ft
90.5	2.59ft	2.65ft
91.9	2.55ft	2.61ft
93.3	2.51ft	2.57ft
95.9	2.44ft	2.50ft
97.5	2.40ft	2.46ft
99.5	2.35ft	2.41ft
101.5	2.30ft	2.36ft
103.5	2.26ft	2.30ft
105.5	2.21ft	2.27ft
106.1	2.20ft	2.26ft
107.1	2.18ft	2.24ft

FIG. 7

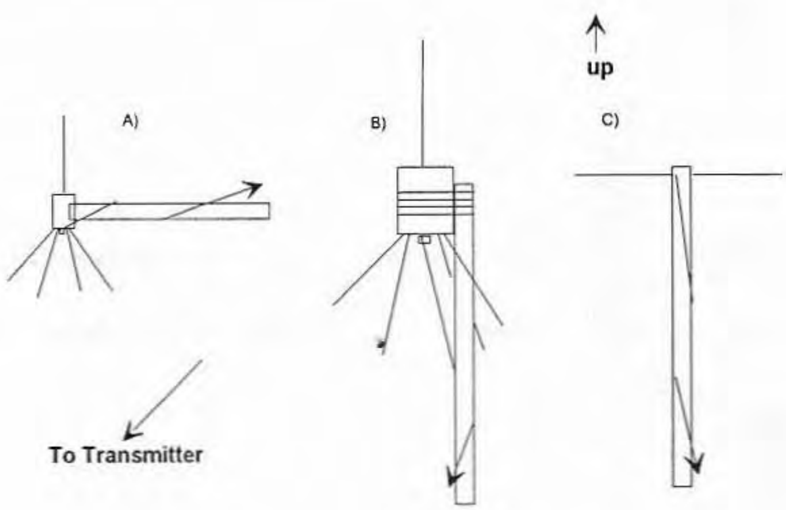
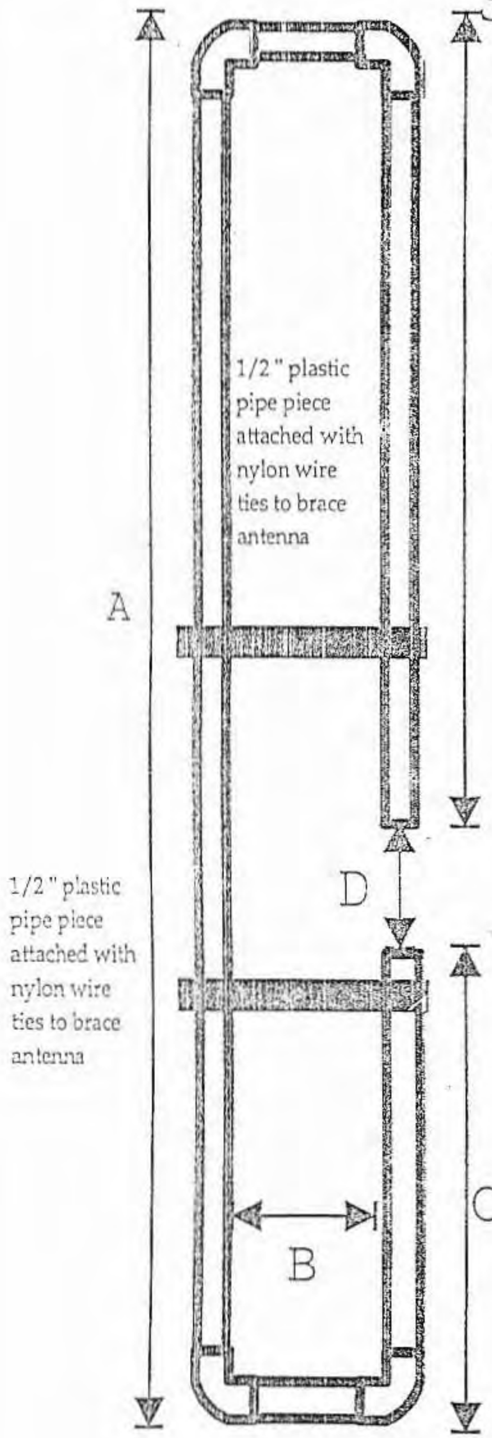


FIG. 8

SLIM JIM ANTENNA



Made from 1/2 " copper pipe & elbow fittings soldered together. Use propane torch and copper pipe solder. Press fit all connections after polishing and applying flux to all pipe ends and lay flat on concrete surface to solder. Hang the end over a curb to solder it or rest entire assembly on bricks. Be sure it is flat & parallel prior to soldering.

Tap point for coaxial cableconnection is between 11/2to 3 inches from the bottom. The cable shield is attached to C and the center conductor is attached to A. A VHF power meter with an SWR scale is needed for optimum tuning which is accomplished by moving the tap points up or down and checking the meter for lowest SWR. Turnon the transmitter, take a reading and note it. Turn off transmitter and move the tap points 1/2" up or down. If the reading is lower keeping repeating 1/4" movements in the same direction (reverse direction if reading is higher) until the lowest reading is obtained. See the next page for attachment details.

Cutting Table

$A = 5610/f + 2805/f$

$B = (144/f) * 1.5$

$C = 2805/f$

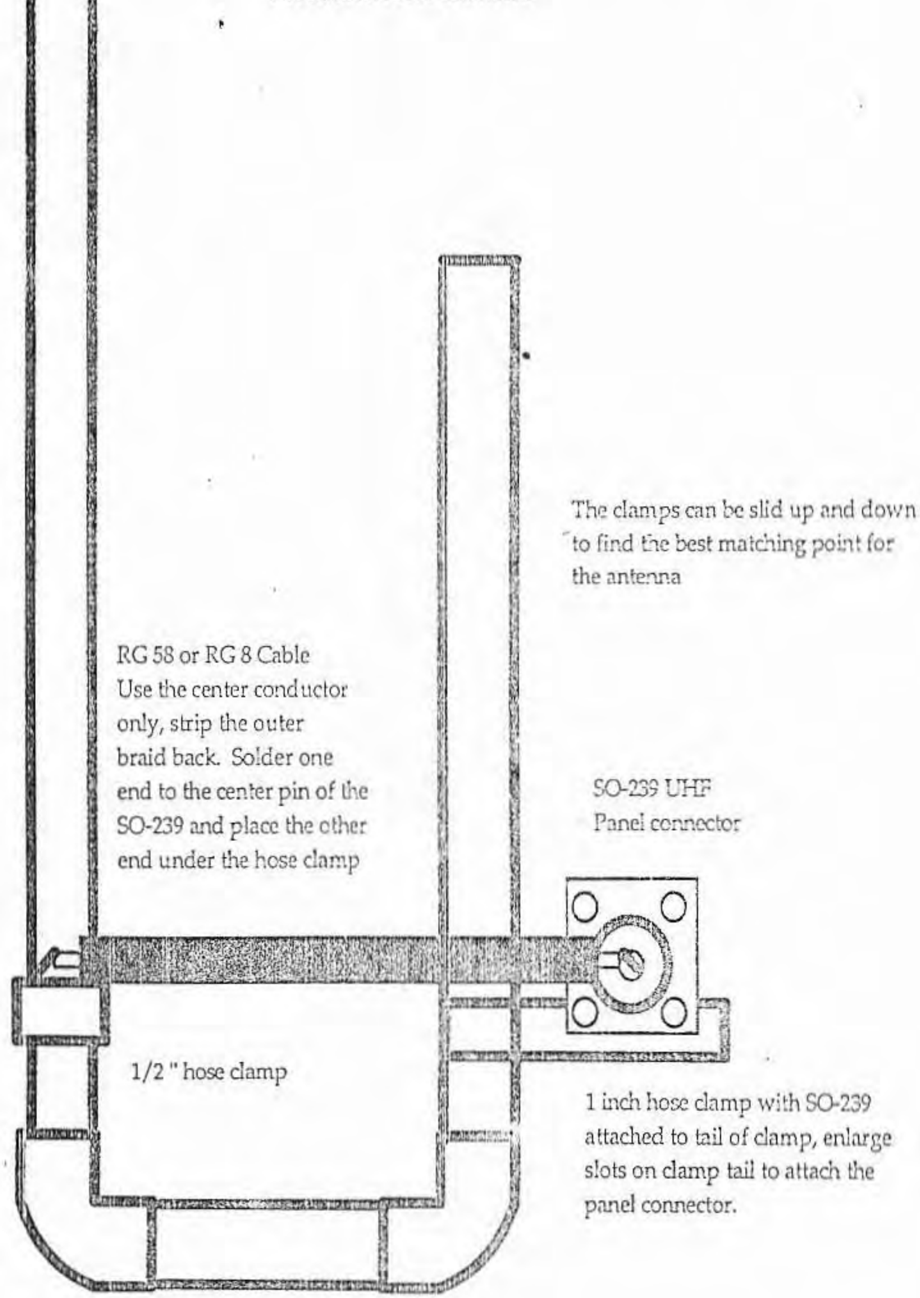
$D = B$

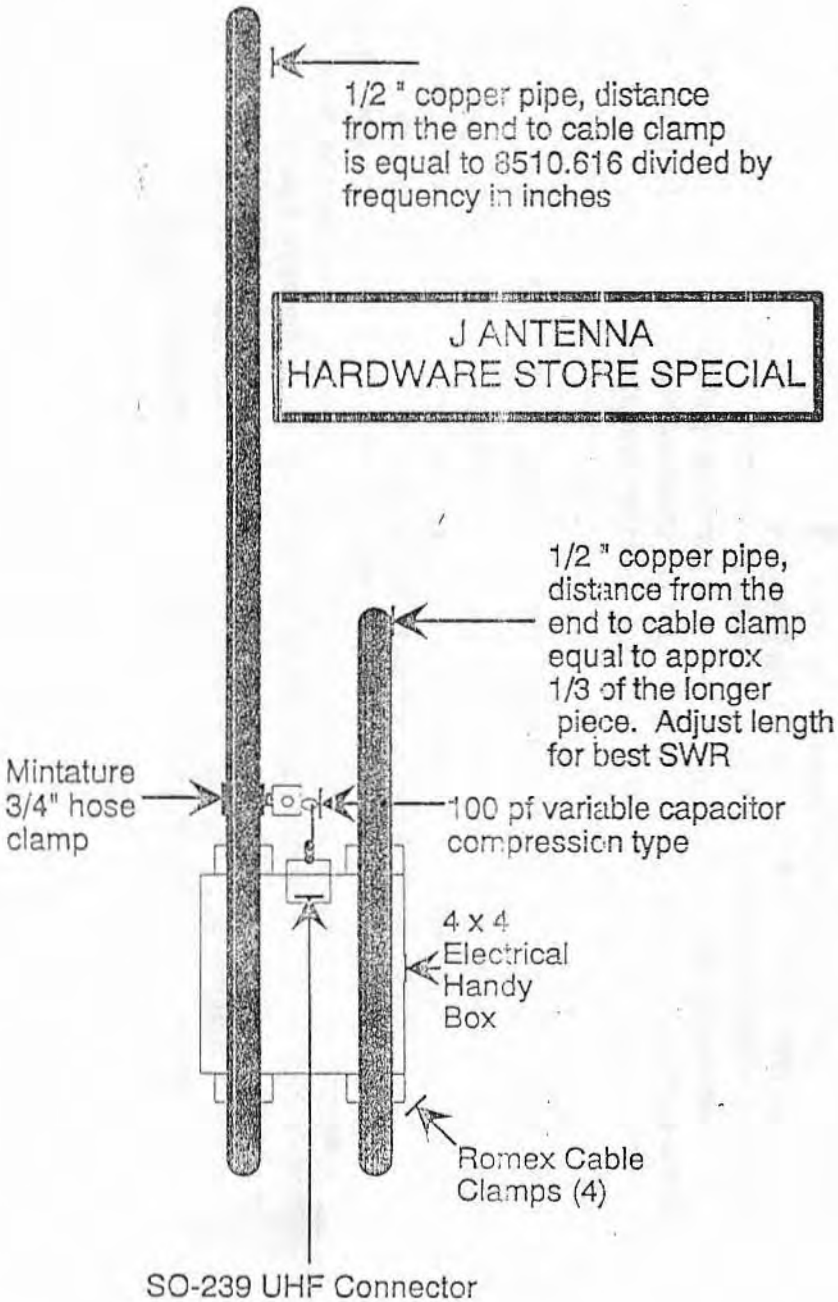
$E = (5610/f) -- B$

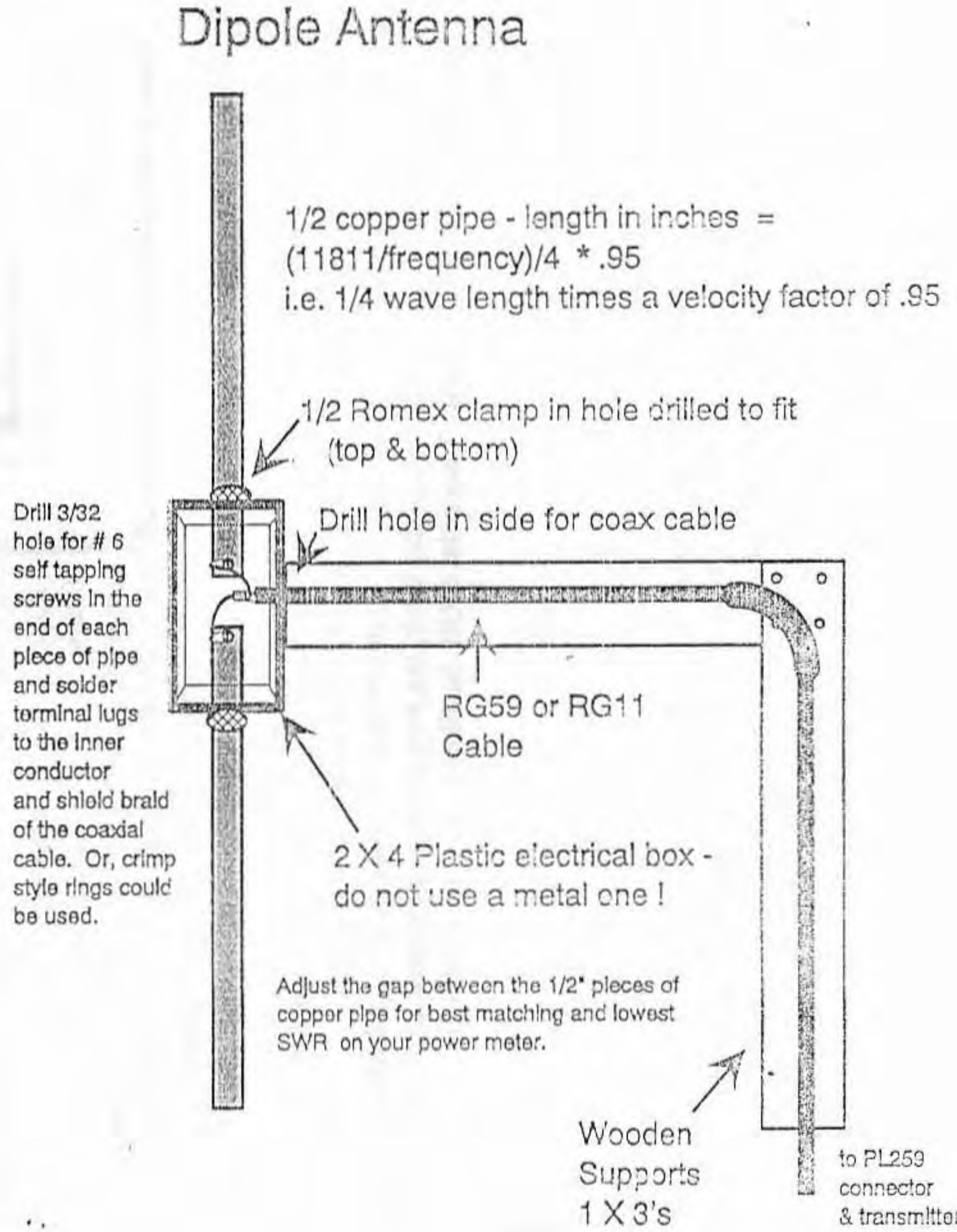
Results are in inches,
f = the desired operating frequency in megahertz
i.e. 88.1

SLIM JIM ANTENNA

Attachment details




1/2 " copper pipe, distance from the end to cable clamp is equal to 8510.616 divided by frequency in inches
J ANTENNA
HARDWARE STORE SPECIAL
1/2 " copper pipe, distance from the end to cable clamp equal to approx 1/3 of the longer piece. Adjust length for best SWR
Mintature 3/4" hose clamp
100 pf variable capacitor compression type
4 x 4 Electrical Handy Box
Romex Cable Clamps (4)
SO-239 UHF Connector


Dipole Antenna
1/2 copper pipe - length in inches = (11811/frequency)/4 * .95
i.e. 1/4 wave length times a velocity factor of .95
1/2 Romex clamp in hole drilled to fit (top & bottom)
Drill 3/32 hole for # 6 self tapping screws in the end of each piece of pipe and solder terminal lugs to the inner conductor and shield braid of the coaxial cable. Or, crimp style rings could be used.
Drill hole in side for coax cable
RG59 or RG11 Cable
2 X 4 Plastic electrical box - do not use a metal one !
Adjust the gap between the 1/2" pieces of copper pipe for best matching and lowest SWR on your power meter.
Wooden Supports 1 X 3's
to PL259 connector & transmitter

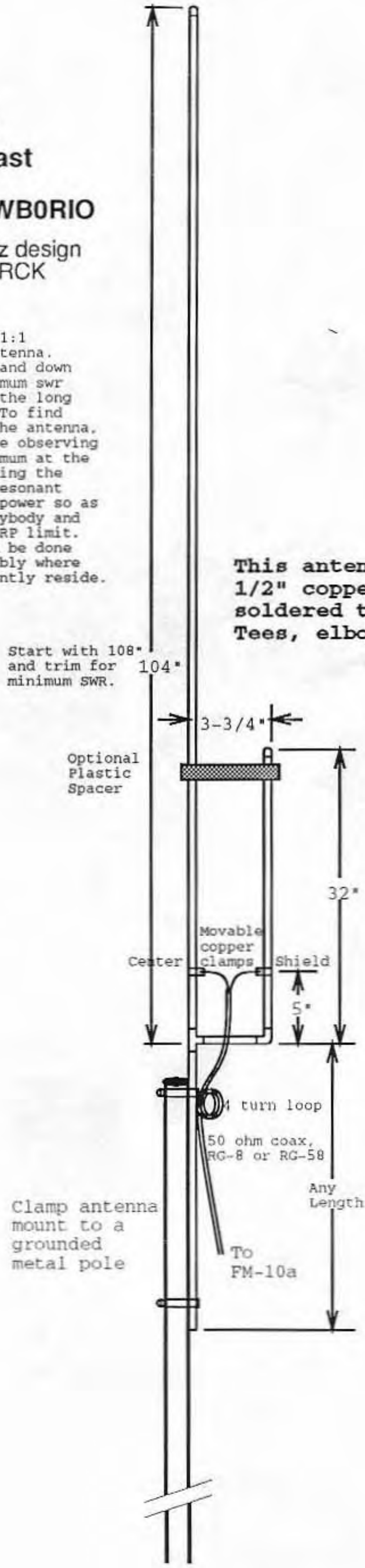
J–Pole Antenna tuned for 89 Mhz in the FM broadcast band

G. Forrest Cook WB0RIO

Based on the 146 Mhz design by Ed Humphries, N5RCK

It is possible to get a 1:1 SWR reading with this antenna. Move the coax clamps up and down in parallel for the minimum swr then trim the length of the long element for resonance. To find the resonance point of the antenna, sweep the FM10a VFO while observing the SWR, it will be minimum at the resonant point. Shortening the antenna will raise the resonant frequency. Use minimal power so as not to interfere with anybody and never exceed the legal ERP limit. All antenna tests should be done in a clear area, preferably where the antenna will permanently reside.

This antenna is made from 1/2" copper tubing and it is soldered together with plumbing Tees, elbows, and nipples.

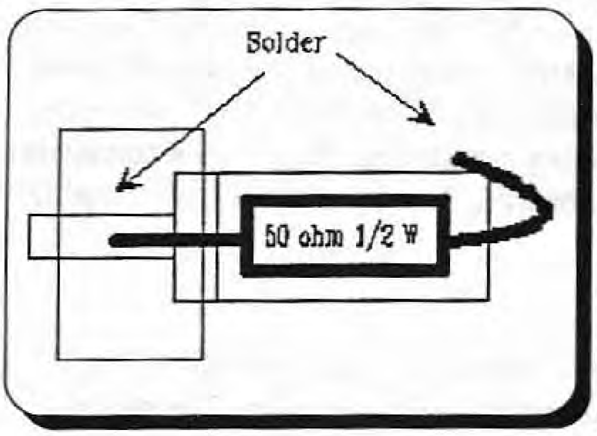


Tools & Equipment

Obviously you will need the basics, solder and a soldering iron. Solder should be rosin core, not acid core. Radio Shack and other electronics stores carry large quantities of suitable solder. A small 25 to 35 watt soldering iron (do not try to use a big soldering gun.) I prefer a battery iron or a soldering station that is safe for delicate components. If you are using a cheap soldering iron and are going to solder IC's, un-plug it right before use, this will protect the component from voltage spikes and RF radiation from the AC power line.

A voltage/ohm meter is next on the list. This device will measure voltage, resistance, current, and usually a few other things. If you have money to burn, I would shop around and get one with a 20mhz frequency counter built in. One important quality you may want to look for is the volt mesuring is of the high impeadance type, 20,000 ohms per volt or better. Currently I have seen them go for around $60 bucks, with the basic units costing between $15-$20.

If you are going to build an antenna and/or an amplifier a SWR/Power meter is almost essential (see FIG. 10.) Cheap ones can be had for about $20 at Radio Shack. These cheap models will register SWR fairly accurately in the FM Broadcast band, and will give you a rough estimate of power output, enough for tuning up power amplifiers. More expensive ones are available, even ones that were designed to operate on the FM Broadcast band, but these get quite pricey.



Next on the shopping list is A 50 ohm non-inductive load, or dummy load. This can be purchased at Radio Shack, or made quite simply by taking a 50 ohm resistor and placing it in a UHF or BNC male connector. An Eithernet terminator could even be used for testing transmitter power output of up to 500mw. If you make a homemade one and it burns up, then make a bigger one next time (that's what I always say.) The CB loads advertised to handle 5 watts usually contain a 2 watt 50 ohm resistor. Shown at left is a simple design. Very important, use carbon resistors only, wire wound resistors won't work.

Later on we will cover a simple dummyload/power meter that you can build for around $5 that will measure power very accuratly with your hi-impedance volt meter.

There are many other pieces of test equipment that would be quite useful when doing the modifications and projects described in this book, but they are very expensive, and their operation is out of the scope of this book. Check the ARRL handbook if you need more info on RF test equipment.

Assembling Your Station

There are a few basic things you must have to set up a radio station, a transmitter, an antenna and an audio source. An audio source could be a tape player, microphone, CD player, or a mixing console that incorporates all of these items. A transmitter converts the audio source to radio waves at the desired frequency you wish to broadcast. You could say that a transmitter converts AF (audio frequencies) to RF (radio frequencies). Finally, you must have an antenna to efficiently radiate the RF to your target audience.

Other things that you might like to add are RF amplifiers, RF filters, and RF measurement devices. A RF amplifier will boost the signal level coming out of the transmitter (this may or may not be needed depending on the design of the transmitter, and the coverage desired.) RF filters make sure that unwanted harmonics or radio waves generated by the transmitter or RF amplifiers are not radiated. Harmonics could cause unwanted interference with a number of different radio services including airplane guidance systems and public safety vehicles. A sure way to draw attention to yourself! A number of RF measurements devices from SWR/Power Meters to frequency counters to spectrum analyzers can be used to make sure that you are radiating an effective clean signal (though some is out of reach to the average clandestine radio operator.)

Figure 9 shows a possible radio station setup using some of the items discussed in this book. We have a mixing console with two tape decks, two CD players and two microphones feeding a Ramsey FM-10. The FM-10's output signal is being boosted to around 800mw using the 800mw amp. plans. The 800mw of power is then fed into a modified Ramsey PA-1 power amplifier which boosts the signal again to about 12 watts. The harmonics are then filtered down with a low pass filter and the cleaned signal is routed, through a length of coax, to our 1/4 wave groundplane antenna where it radiates to the world. A setup like this could have a range between 5 and 30 miles depending on the height of the antenna and the surrounding environment.

Figure 11 shows some useful items to connect everything together. A) converts an RCA connector to a UHF connector, this us useful to convert the RCA RF output to a UHF connector for use with CB/Amatuer Patch cables. B) is a UHF to BNC connector, some people (like me) use BNC connectors instead of UHF connectors. C) is a coax patch cord with UHF connectors. This is useful for connecting stages together. I have, during prototyping, forgone the connectors and have soldered the cable right to my amp/transmitter boards. This is reflected in my amplifier designs under the board layout section.

The BA1404 and Transmitter Design

The BA1404 is a monolithic FM stereo transmitter on a chip. It contains left and right channel AF amplifiers, a stereo modulator, a FM RF exciter, and a RF amplifier. The stereo modulator creates a stereo composite signal from a 38Khz quartz controlled frequency source (xtal.) The FM modulator oscillates a carrier in the FM broadcast band (76 to 108 Mhz) and modulates it with the composite signal. The RF amplifier creates energy to emit the modulated FM signal. It also functions as a buffer for the FM modulator. All this in a small 18 pin package with few external parts!

Before the advent of the BA1404, generating a stereo signal was a much more complex task and is beyond the scope of this book (see sources for information on these methods.) Although it is possible to generate a higher quality stereo signal using these methods, with more control over the stereo modulation and levels. The BA1404 is much easier to produce low cost, easy to assemble, high performance, designs.

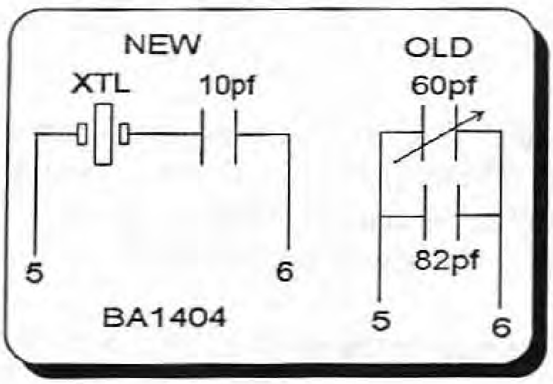
The most frustrating thing about the new kits based around the BA1404 is the fact that they all use inductor/capacitor tanks to determine there operation frequency. This leads to frequency drift and no way to determine exactly what frequency you are operating on without constant retuning with a frequency counter. The solution is to use the BA1404 only for the composite stereo generation, and to digitally frequency synthesize the carrier with a phase lock loop. This is actually not as hard to do as it may sound. (See PLL design)

The Ramsey FM-10

The Ramsey FM-10 is one of the more popular BA-1404 stereo transmitters on the market. What makes it so popular is that it has a small output amplifier. The BA1404's RF output is very small, around a tenth of a milliwatt. The FM-10's output amplifier boosts this up to about 8 mw, so the range is much greater than kits that don't provide an output amplifier. With a good antenna you could get up to 1/4 mile range with a stock FM-10. The following list of modifications assumes you have an FM-10.

Stereo Pilot Modification

(Ramsey has just released a fix that does basically what this mod does, also the newer kits will contain this mod. Call Ramsey to get a free mod for your FM-10 today!) One of the most frustrating things about the FM-10 is the stereo pilot. Ramsey really skimped on this one. Where many of the other kits include a 38Khz crystal for a rock solid stereo pilot, Ramsey decided to use a couple of capacitors. This has created nothing but problems for the kit builder. If you are having problems with stereo separation, you can solve this by lowering the value of C7 to 60pf (this usually works.) But messing with this mess you almost need a frequency counter so you can 'see' 19Khz at the test point.



The best thing to do is do it the way it should of been done in the first place. Purchase a 38Khz crystal (see sources) and insert it in place of C7 and C8. See diagram at left for details. Once mod is done, the stereo signal should be rock solid, with no adjustments necessary.

Anti-Drift Modification

Another big problem with all BA1404 Transmitters that use an inductor-capacitor to generate the frequency that they broadcast on is that they drift, meaning that the frequency changes over time. This can be a problem when you are using a digital PLL receiver to listen to your transmitter. The receiver expects the signal to stay in one place, and if it drifts the receiver could lose the signal.

There is not much we can do to prevent the FM-10 from drifting, it is the nature of the beast. But we can make a modification that will minimize the drift. The FM-10 was designed to be a low cost kit so cost saving measures with components are inevitable. Silver Mica, tantalum and negative temperature compensated disc capacitors are more expensive than regular disc capacitors, but they are much more stable. Replacing C16 with the same value of one of the above mentioned capacitors will minimize the drift.

Treble Boost Mod

The FM-10 appears to have been designed by someone outside the United States since its treble boost (pre-emphasis) is designed for the European audio standard of 50 microseconds. Receivers in the US are set up for 75 microsecond de-emphasis. R3 and R6 determine the time constant for the pre-emphasis curve. Replacing them with 75K ohm resistors (standard value 68K ohm resistors are close enough) will result in improved audio response.

A much better pre-emphasis/input circuit is shown in the July 1992 issue of Radio Electronics. Not only do they use 75K ohm resistors in there pre-emphasis, but they filter stray RF signals by inserting a .001 cap between pin 1 (of the BA1404) and ground, and pin 18 and ground.

This mod is not that critical, and it might even sound worse on cheap receivers, since they are mass produced for the world market. They were designed for the European audio standard, which Japan and other Asian countries use.

RF Amplifiers

Aye, mate. I know this is what you have been waiting for. Like most humans you're probably obsessed with power. This is not the first place I would go to increase range (an antenna is), but if you have a good antenna already this is the place to look.

Since most of the decent quality FM transmitter kits have feeble output, an amplifier is almost a necessity. Presented here are several designs that can help you reach out to your audience.

Ramsey PA-1 Modification

The Ramsey PA-1 is a 2-meter amateur radio amplifier kit sold by Ramsey Electronics. With a simple modification it can be converted for 3-meter (FM Broadcast band) use. It is ideal in that it can handle up to 40 watts of output power (subject to the amount of input power), which is plenty for most clandestine radio operations. The modifications are as follows :

L1 - Should be replaced with a 1-turn 1/4" diameter coil, identical to the stock L2 shown in the PA-1 manual.

L2 - Should be replaced with a 2 turn 1/4" diameter coil, one more turn than the above coil. (see the PA-1 manual for info on how to wind these coils.)

Tune up should be the same as in the PA-1 manual. Note that the FM-10 kit cannot be used to drive a PA-1 kit alone. The FM-10 kit doesn't put out enough power to turn on the PA-1 kit running class-c. You have two options. One, you can do the "biased on" (newer kits may call this class-b) modification shown in the PA-1 manual. Doing this you can drive the PA-1 with a stock FM-10, yielding about 250mw of output power. Or two, you can drive the PA-1 with the output of the 350mw or 800mw power amplifier, with the end result about 4 watts and 12 watts respectively.

It should be noted here that running the PA-1 "biased on" (or class-b) produces a much cleaner output signal than running the PA-1 class-c. Class-c amplifier outputs are known to be rich in harmonics and must be filtered out. I would still filter the class-b output though.

350 mw amplifier

Section not finished (see included design). Note : all parts mounted on etched side, do not drill holes.

800 mw amplifier

Section not finished (see included design). Note : all parts mounted on etched side, do not drill holes.

Other amplifiers
Section not finished (see included design).

Harmonic Filters

Harmonic filters or low pass filters are used to filter out unwanted signals generated in the oscillation or power amplification stages. If 100MHz signal is generated or amplified there is a very good chance that you would get signals at 200MHz, 300MHz and just about every other multiple of 100MHz. If you designed a low pass filter for 100MHz it would let any signal 100MHz or below pass the filter with very little attenuation. Higher frequencies would be attenuated at a much higher rate.

For any transmitter that puts out over 25mw it is recommended that you do some filtering. For higher outputs the better the filtering you will probably need. It is recommended that you keep the harmonics at least 40db below the main (fundamental) frequency. This is hard to measure without an expensive piece of equipment called a spectrum analyzer but in practice you can be relatively sure that your harmonics are suppressed enough by selecting the appropriate filter for your power level.
(section not finished, see diagrams)

Power Supply

There are a number of different options when it comes to power supplies. You could use a car battery, CB radio power supply, or build your own. You need to use a regulated power supply or a battery. This is very important. An unregulated power supply will cause a nasty 60-hz tone to be introduced in your transmitted signal. This sounds real bad, and no one will listen to you.

Figure 12 shows a simple regulated power supply you can build from easily obtainable parts. It will deliver about 1.5 amps at 12 volts. This is enough power to run a transmitter of up to 1.5 to 2 watts output. It is ideal for using in a design that incorporates the FM-10 and the 800mw or 350mw amplifier in one case.

Be very careful when messing with AC Line power, it can kill! Cover all AC soldered connections with heat shrink tubing. A 1 amp 250 volt fuse is also advised to be run in line with the switch.

B1 is a full wave bridge rectifier. This converts AC to DC. C1, C2 and C3 are filter capacitors. They smooth out the saw blade DC output of B1. The 7812 chops the voltage down to 12 volts and regulates it there. C4 filters out any 60-hz component that may still be present. The output will be smooth DC perfect for supplying a transmitter.

If you need a power supply that will supply more current, or has different specifications than the one shown here, consult the ARRL handbook for detailed information on power supplies.

Studio Setup

- mixing equipment
- live -vs- tape
- call in/mixer to phone line project/phone loop pairs

Possible Setup

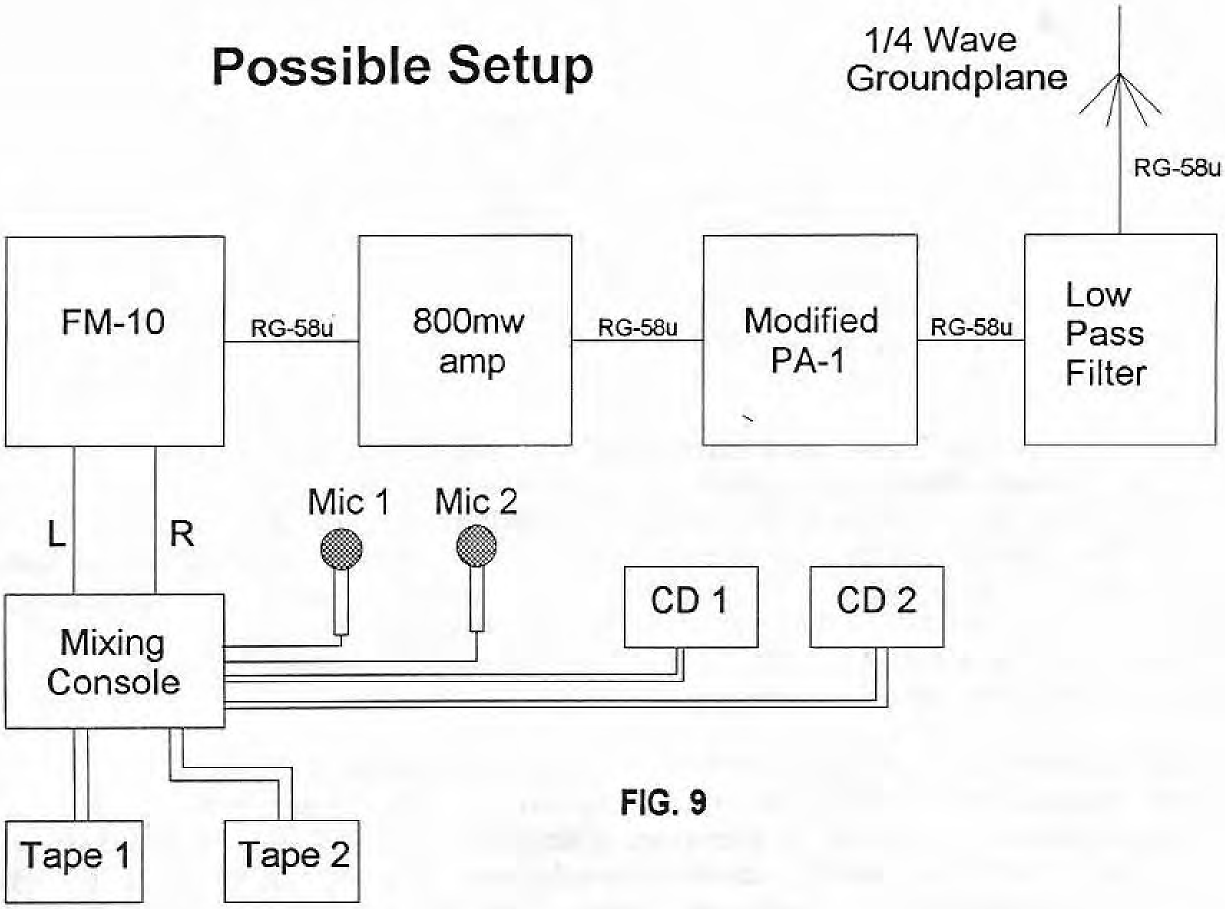


FIG. 9

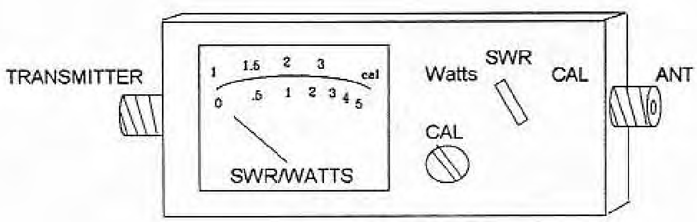


FIG. 10

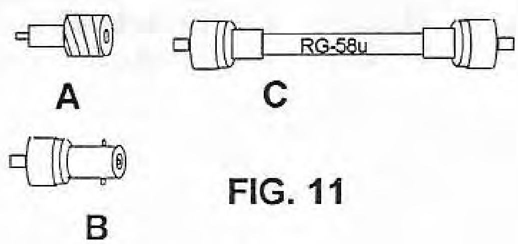


FIG. 11

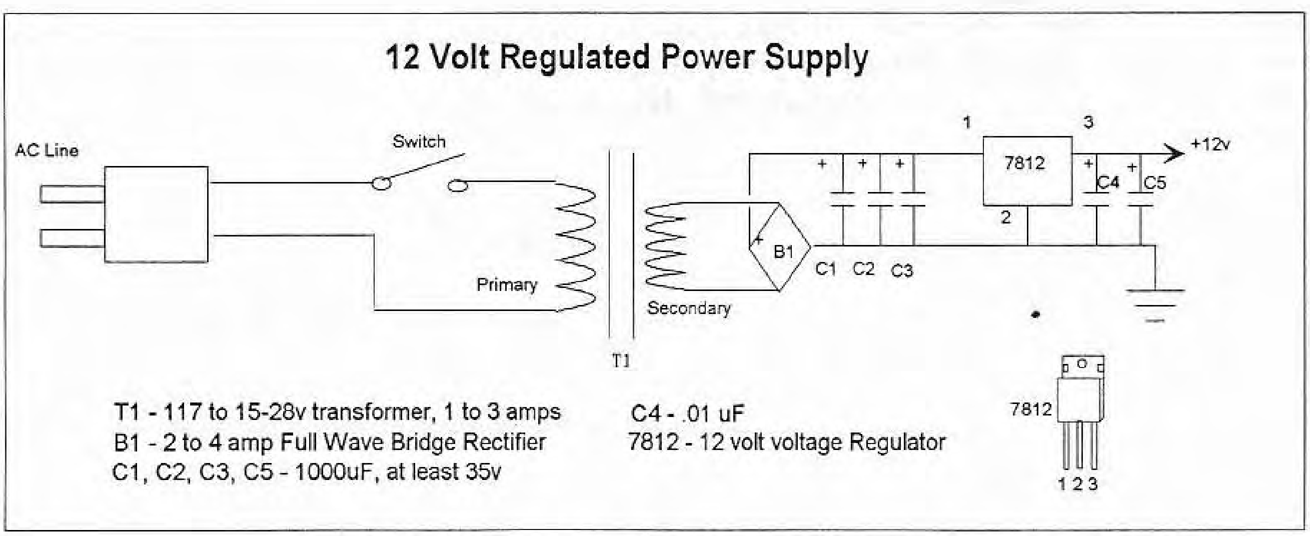


FIG. 12

Harmonic Filters

RF amplifiers, no matter how well made, will distort their inputs. Some amplifiers are designed to distort the signal in order to increase efficiency. Class A amplifiers, like the 30 mw booster are biased on and conduct over the entire input wave form. This type of amplifier introduces a small amount of distortion. Class C amplifiers, like the PA-1 and 800mw, are not biased on and only conduct when the input signal is positive. These type of amplifiers act some what like an amplified half wave rectifier and therefore introduce a considerable amount of distortion.

Tuned circuits at the input and output of RF amplifiers act as filters to "clean up" distortion. These simple filters do a good job of converting distorted sine waves into clean sine waves but they do not block RF energy located at integer multiples of the original (fundamental) frequency. These unwanted bands of RF energy are knows as harmonics. An amplifier designed to boost a 100 MHz signal will produce unwanted RF energy at 200 MHz (2nd harmonic), 300 MHz (3rd harmonic), 400 MHz, etc. The amount of energy in the individual harmonics is a function of the type of distortion. In general, most of the energy will be in the 2nd, 3rd and 4th harmonics.

If these harmonics are not filtered they will interfere with TV and radio transmissions. An unfiltered transmitter operating at 95.9 MHz will produce a second harmonic at 191.8 MHz - the same frequency used to transmit sound for TV channel 9. Operating such a transmitter will almost certainly invite complaints and investigations by the FCC. Therefore, any transmitter that puts out more than 25mw should have some type of filtering. FCC rules require that VHF equipment reduce the second, third, and fourth harmonics by -25dB, -27dB, -30dB respectively and that no harmonic have a level of more than .7mw. The 7 element Chebyshev filter described below has been found to reduce the harmonics associated with a typical 1-watt signal to less than .1mw

Just for your information, the FM-10 puts out about 8-9mw and the second harmonic is -25dB off. The FM-4 kit by Ramsey puts out 130mw and the second harmonic is only -12dB off. This means that the second harmonic of the FM-4 is about as powerful as the FM-10!

Filter Design

Modern network theory and digital computers have made the design of filters fairly straightforward. Simple low pass filters can be designed by transforming normalized filters to frequency specific filters. This transformation is accomplished by multiplying the component values of the normalized design by the following frequency specific constants:

$C(ref) = 1/2\pi F(ref) R(ref)$
$L(ref) = R(ref) / 2\pi F(ref)$
$Ri = ri * R(ref)$
$Li = li * L(ref)$
$Ci = ci * C(ref)$

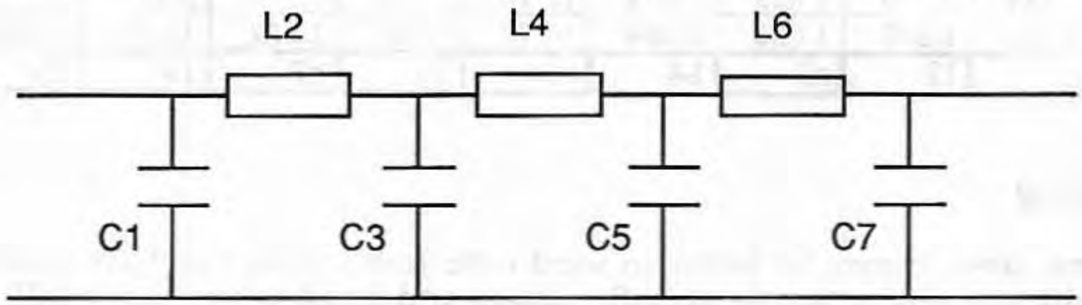
$F(ref)$ = Transmitter frequency
$R(ref)$ = Input Impedance

ri, li, and ci are taken from the "Chebyshev Low Pass Coefficient Table".

Example: Design a 7th order Chebyshev filter tuned for 85.8 MHz and an input/output impedance of 50 ohms.

R(ref) = 50 Ω
F(ref) = 85.8E6 Hz
L(ref) = 50/2 * 3.14159 * 85.8E6 = 9.275E-8 H
C(ref) = 1/2 * 3.14159 * 85.8E6 * 50 = 3.710E-11 F

C1, C7 = .6301*3.710E-11 = 23.4 pF
C3, C5 = 1.579*3.710E-11 = 58.6 pF
L2, L6 = 1.282*9.275E-8 = .119 μH
L4 = 1.575*9.275E-8 = .146 μH

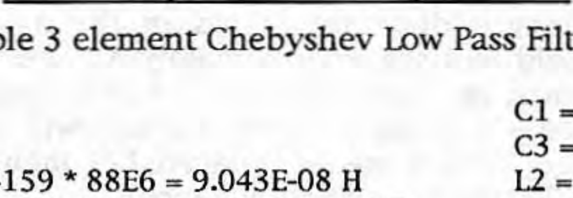


A 7 element Chebyshev Low Pass Filter

These values agree with experimental results published by Mycal Johnson in the 4th addition of the FM-10 FAQ. These experiments showed that values of .12 μH for L2 and L6, .15 μH for L4, and variable caps for C1-C7 yielded a decrease of -45dB on the second harmonic, -55dB on the third harmonic, and -65dB on the fourth harmonic.

In another experiment by a (poor) anonymous contributor, a filtered 3 watt transmitter (FM-10 to 30 mw booster to 800 mw amp to PA-1) was tuned to 104.5 MHz. The distance the second harmonic could be heard on a portable scanner decreased substationally. All coils were made from #14 wire, .4" in diameter, .5" long. L2 and L6 were each 4 turns. L4 was 4.5 turns. Variable capacitors were used for C1-C7. Alignment was accomplished by tuning C1-C7 for maximum output to the antenna and minimum VSWR between the filter and transmitter.

This procedure can also be used to design a simple 3rd order filter. It should be noted that this design corrects errors in the design published in previous issues of the FAQ. This example assumes the transmitter is tuned to 88 MHz.



Simple 3 element Chebyshev Low Pass Filter

R(ref) =50 Ω
F(ref) =88E6 Hz
L(reff) =50/2 * 3.14159 * 88E6 = 9.043E-08 H
C(reff) =1/2 * 3.14159 * 88E6 * 50 = 3.617E-11 F

C1 = .4520*3.617E-11 = 16 pF
C3 = .4520*3.617E-11 = 16 pF
L2 = .7838*9.043E-8 = .071 μH
R1 = 1.000*50 = 50 Ω

Chebyshev Low Pass Coefficient Table

N	c1	l2	c3	l4	c5	l6	c7	l8	c9	r1
2	.2858	.2746								.9608
3	.4520	.7838	.4520							1.000
4	.5379	1.041	1.084	.5168						.9608
5	.5849	1.169	1.369	1.169	.5849					1.000
6	.6126	1.240	1.505	1.446	1.290	.5885				.9608
7	.6301	1.282	1.579	1.575	1.579	1.282	.6301			1.000
8	.6419	1.309	1.623	1.643	1.710	1.560	1.363	.6167		.9608
9	.6501	1.328	1.652	1.684	1.779	1.684	1.652	1.328	.6501	1.000
N	c1	l2	c3	l4	c5	l6	c7	l8	c9	r1

Coil Winding

In some cases, it may be better to wind coils rather than purchase molded inductors. Molded inductors only come in specific values and hand wound coils will often have a better Q. The following tips will be useful in designing inductors.

L = (rN)**2/(9r + 10l) where

L = Inductance in μH
r = Coil radius (center of coil to center of conductor).
N = number of turns
l = Coil length (N times the distance between centers of adjacent turns)

Example. The 3rd order filter above requires a .071 μH coil. Assume we want a coil with r = .25 and L = .5 (a length/diameter or form factor of 1) then

.071μH = (.25*N)**2/(9*.25 + 10*.5)
= .0625N**2/(2.25+5)
= .0625N**2/7.25
N**2 =.071*7.25/.0625

N = sqrt(.071*7.25/.0625) = 2.87 turns
Rounding up to 3 turns will yield a coil with an inductance of .078μH

To first order, the size of the wire is not important. However, the size of the wire and the length/diameter ratio of the coil will determine the coil's Q. Larger conductors and large length/diameter ratios will give better Qs. However, increasing the length/diameter ratio to values greater than 4 provides little improvement in Q.

Keep in mind that placing the coil in a shielded box will change the effective inductance of the coil. The amount of change depends on how far away from the shield the coil is placed. Coils with length/diameter ratios in the 1-3 range placed 5*(winding diameter) away from the shield will see approximately a 1-2% decrease in inductance. For example, a coil that is 1/4 inch in diameter and 1/4 inch long (length/diameter ratio or form factor of 1) placed 5*1/4 = 1.25 inches from a shield will have an effective inductance of .99*(unshielded inductance). The same coil placed 1/2 inch from a shield will have an effective inductance of about .85*(unshielded inductance).

3-Meter Hacking Sources

All Electronics Corp.
P.O. Box 567
Van Nuys, CA 91408
Lots of parts, + molded chokes and ferrite beads. FB101-43's, 5 for a buck.

D.C. Electronics
Phone: 1-800-467-7736 & 1-800-423--0070
They sell BA1404's for $2 a piece, seems to be the best deal going. They also sell there own BA-1404 transmitter kit, with a 38khz xtal. They will also sell you 38Khz crystal (this is the reccomended one to use). Great catalog. Lots more RF stuff.

Digi-Key
1-800-DIGI-KEY.. They have lots and lots of items. Most notably, 38Khz crystals by Epson America, Digi-Key part #SE3314.

DVS Communications
PO BOX 452, Wellsville, NY 14895 - alternative programs of "pirate" and clandestine stations.

Federal Communications Commission (FCC)
1919 M Street N.W. Washington, DC 20554 - info on permitted forms of low power broadcast operation.

Free Radio Berkeley
1442-A Walnut St, #406, Berkeley, CA 94709. - (510)464-3041 - frbspd@crl.com
Lots of kits and info for micro power radio.

JM Electronics
(407)767-8196 - audio accessories and transmitters.

JT Communications
(904)236-0744 - Spec-approved FCC broadcast-type FM exciter, tunable 88-108 Mhz (PLL)

Panaxis Productions
PO Box 130, Paradise, CA 95967-0130.. (916)534-0417
Tons of very high quality FM, AM, and TV transmitters and amps. Catalogs are $2, well worth it. A must have item. There stereo transmitters are more expensive than a FM-10, but much higher performance.

Ramsey Electronics
793 Canning Parkway, Victor, New York 14564...(716)924-4560
They make the FM-10 and sell it for $29. They also have a number of other kits, including the PA-1 2 meter amp. (also for $29) and the TV-6 television transmitter ($19).

RF Parts
1-800-RF-PARTS - Sells all kinds of RF Transistors.

Tapto Corp.
1-800-758-2786 - FM oscillator kit, and other stuff.

Tentronic
(208)664-2312 - Another maker of BA1404 kits. Plus other stuff.

ZBS Foundation
RR#1 Box 1201, Fort Edward, NY 12828 - 1-800-395-2549
non-profit org for the arts, adventure, sci-fi tapes and CDs

Books, Articles, and Magizines of Interest.

Video, Stereo and Optoelectronics, Rudolf F. Graf and William Sheets. TAB Books. Ta 'kill UHF TV broadcaster (2 watts). A FM stereo transmitter project (not based on the BA-1404) that includes SCA subcarriers. Some stuff on frequency synthesis. FM receivers with SCA. Carrier current stuff. Neat!

Interface Databook, National Semiconductor, 1990. Great section on frequency synthesis.

The ARRL Handbook, American Radio Relay League, The bible, must have, has the basics on everything. Plus more.

Electronics Now, "Build this FM STEREO BROADCASTER", July 1992 issue

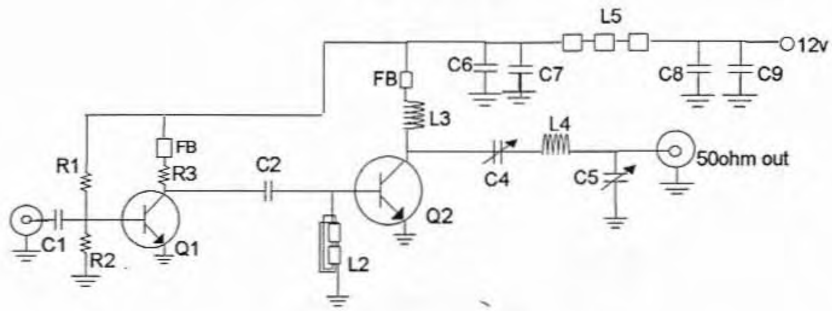
Mondo 2000, "Pirate Media", #11 1993 issue

Radio-Electronics, "Hardware Hacker" Don Lancaster, June 1992 issue. Great schematic on the Pioneer CD-FM-1, a xtal controlled FM transmitter using the BA1404. Worth a look!

Radio Resistor's Bulletin - PO Box 3038 Bellingham, WA 98227-3038
Send $1 for sample -or- mail haulgren@well.sf.ca.us

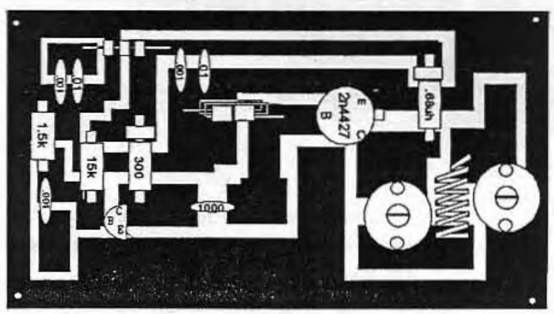
Also of interest although not about FM transmitters but about Clandestine Radio is:
the Association of Clandestine radio Enthusiasts -or- ACE
PO Box 11201
Shawnee Mission, KS 66207-0201
yearly subscription 12 issues.
US $18, Canada/Mexico $19, Rest of the world $25
They had a short (but slightly flawed) article on the FM-10 in there May 1991 issue.

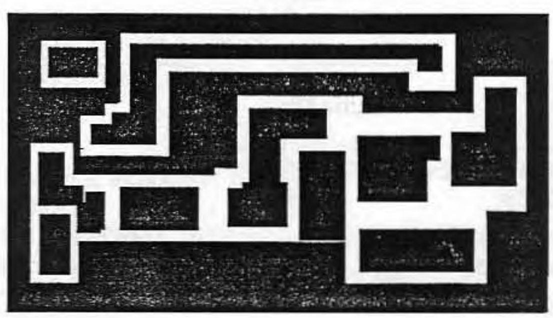
Improved 800mw Output Amplifier for the FM-10



R1 - 20K	Q1 - mps918 -or- mps901
R2 - 1.5K	Q2 - 2n4427 -or- 2n3866
R3 - 300 ohm with ferrite bead	L2 - 2 turns #26 enamel through 2 FB101-43's
C1, C2, C6, C8 - 1000pf	L3 - .68uh moulded choke w/FB101-43
C7, C9 - .01	L4 - 6 1/2 turns of #18 3/8" diam 1/2" long
C4, C5 - 4-65pf	L5 - 3 FB101-43's on 1" wire
Slip on heat sink for Q2	

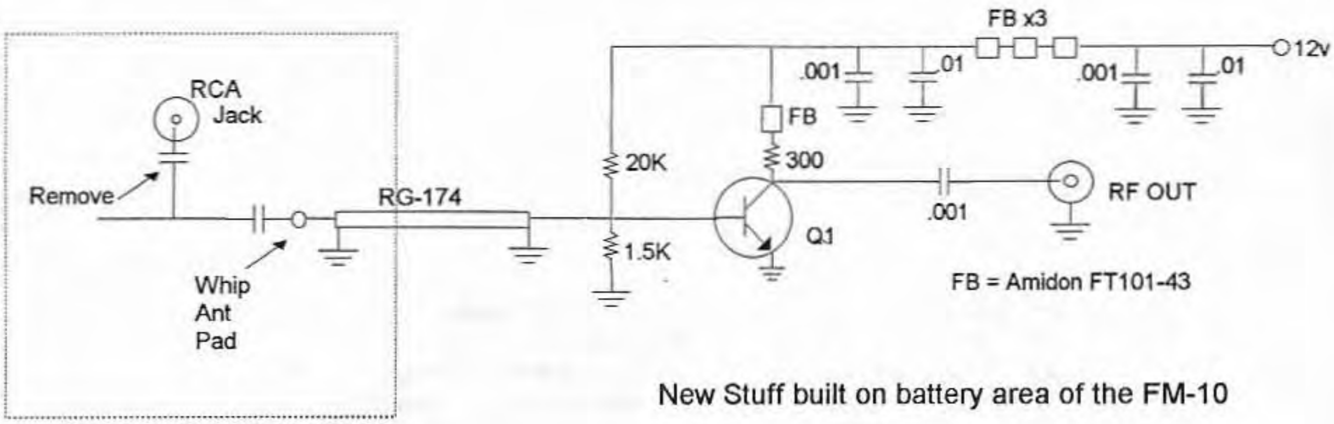
Will put out 1.4 watts with mps901/2n4427 combo
600mw with mps918/2n3866
In between for other combinations





800mw Output Amplifier for the FM-10

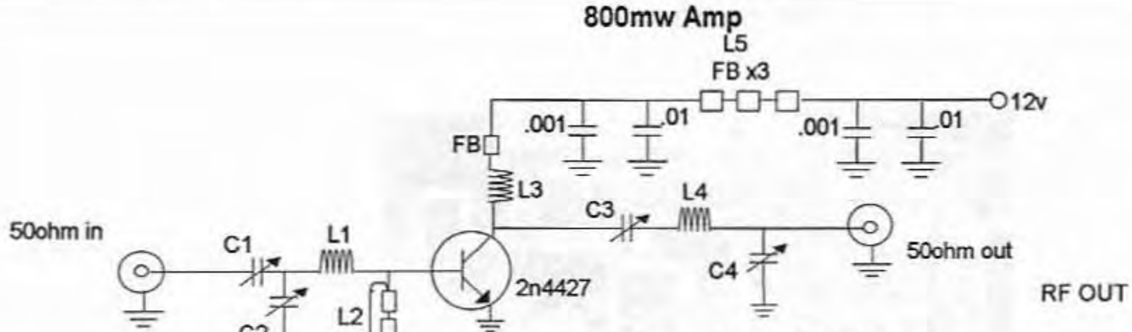
On-Board FM-10 Booster
Pout = 30mw



Existing FM-10 Stuff

Q1 = SK-3444
A MPS2222a or 2n4401 could be used instead.

800mw Amp

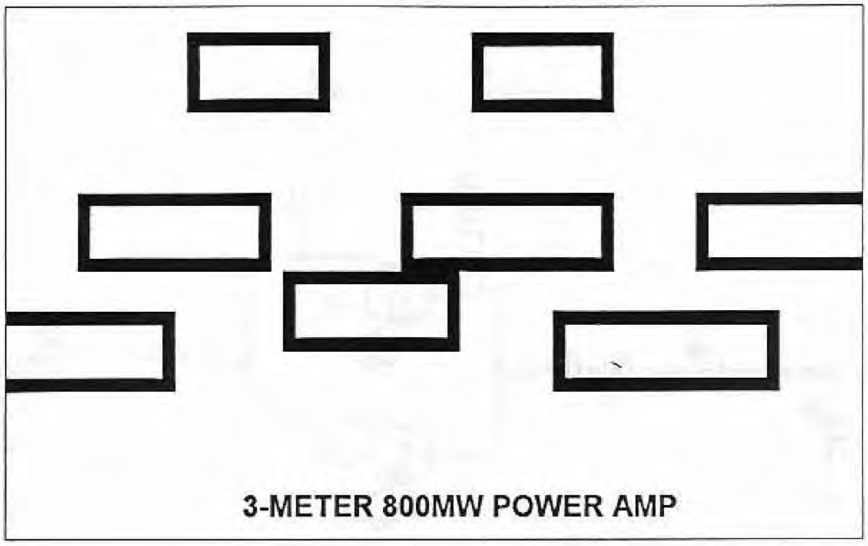


L1 4 1/2 Turns of #18 3/8" Dia 1/4" Long
L2 2 Turns of #26 enamel thru 2 FB101-43's
L3 .68uh moulded choke w/FB101-43
L4 6 1/2 Turns of #18 3/8" Dia 1/2" Long
L5 3 FB1010-43's on 1" wire
C1, C2, C3, C4 : 4-65pf
Slip on heat sink for 2n4427

Tune Up

- o Connect a good 50ohm non-rerective load to the output with RG-58.
- o Apply 12v. It is very useful to be able to monitor the current (250ma or so.)
- o Apply 20-30mw of drive to the input with RG-58 or RG-174 (output of theFM-10 + 30mw booster amp ok.)
- o Tune C1 and C2 for max input current.. (Use an insulated alignment tool!)
- o Tune C3 and C4 for maximum output. C3 and C4 will be quite touchy.
- o This circut is capable of ouput in excess of 1.4 watts, but without a mondo heat sink on the 2n4427 it is better to limit output to 800mw. A slip on heat sink is used. Do not reduce output by detuning. Reduce drive to adjust output (you can raise the 300 ohm resistor in the booster to lower output.) Heatsinking the 2n4427 will allow higher power operation, but may require shielding to to prevent oscillation due to coupling back to L1.

800mw PCB Layout



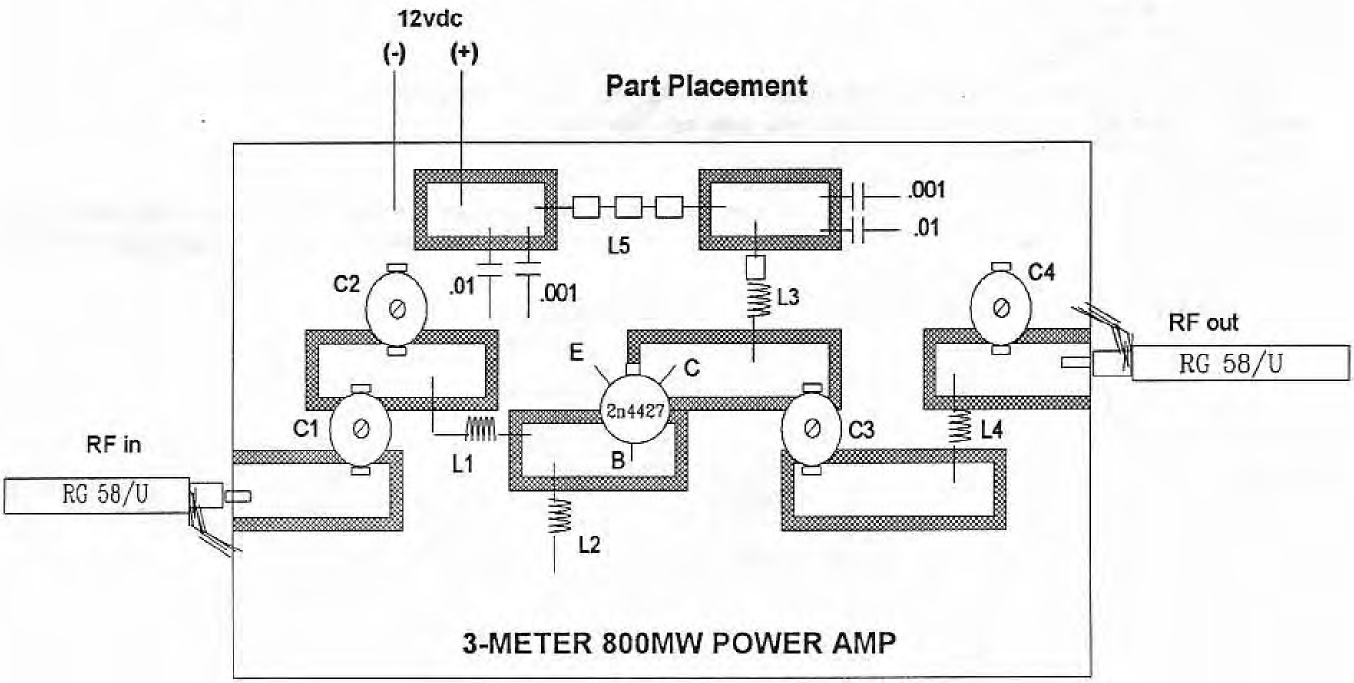
Component side
(Bottom side is solid copper.)

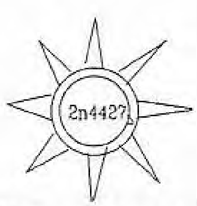
= etched area
white area = copper

Double sided G-10 Glass epoxy pc board 2 1/2" x 4"
(No connection between top and bottom of PCB.)

Note : this layout is not especially critical
Single sided PCB can be used.

Part Placement



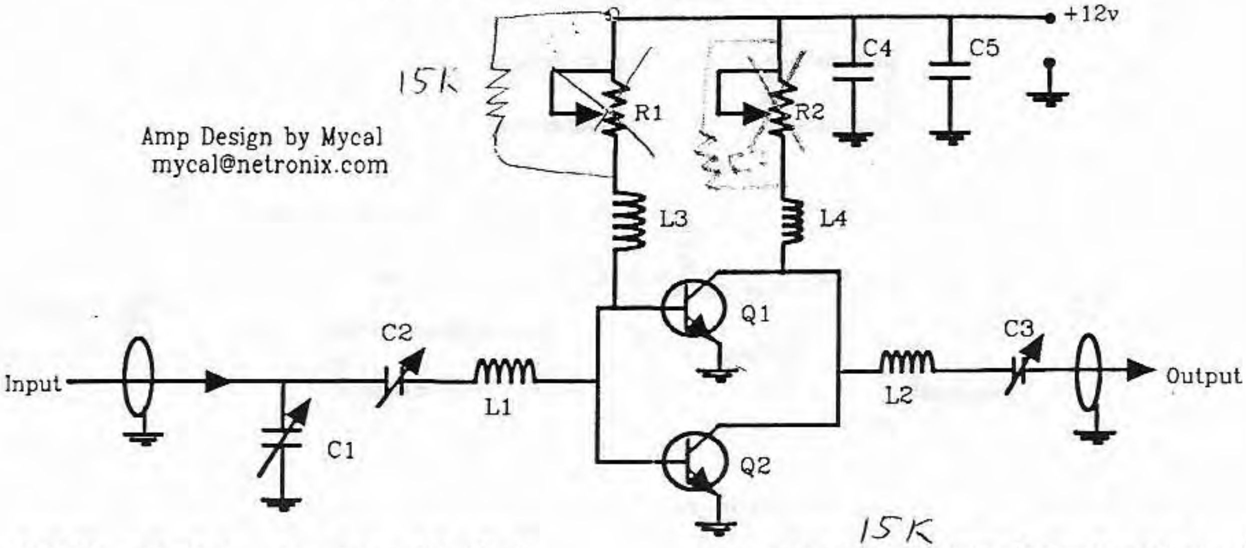


Shown with heatsink on

350mw Amp

Can be driven directly by ramsey FM-10

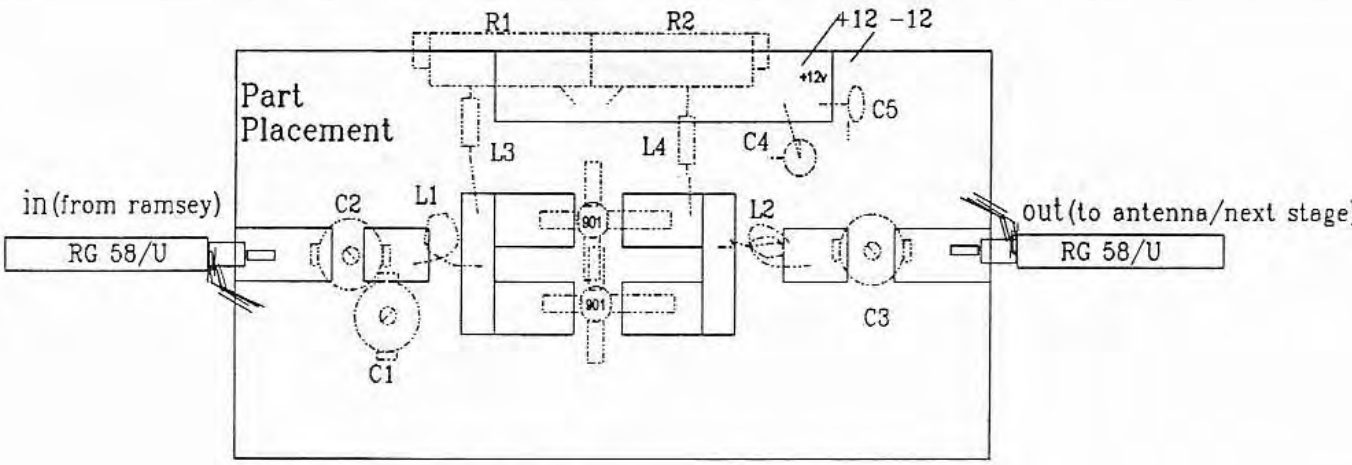
Amp Design by Mycal
mycal@netronix.com



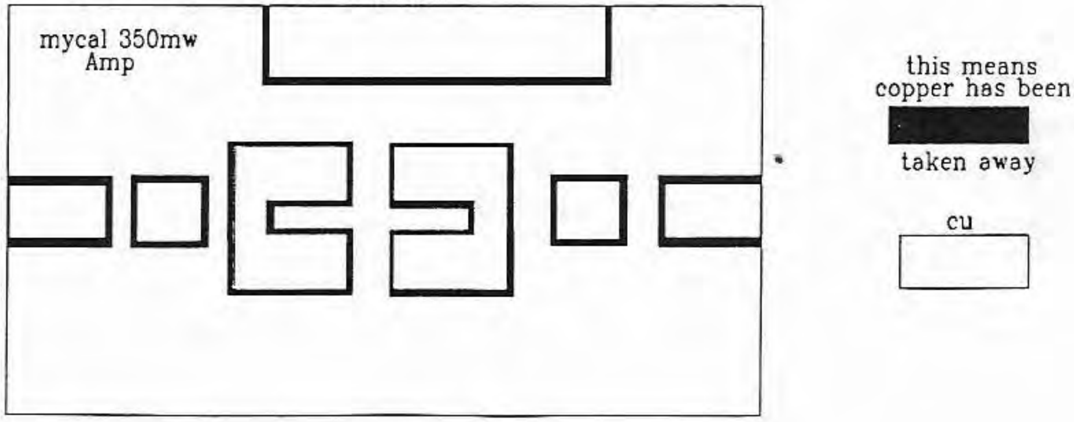
15K

C1,C2,C3 – 15-60pf	L1 – 1 turn #18 1/2" I.D.	R1 – ~~20K Ohm Adjustible (Radio Shack20-turn)~~
C4 – 0.1uf	L2 – 3 turn #18 1/2" I.D. 1/2" Long	R2 – ~~500 Ohm Adjustible (Radio Shack 20-turn)~~ 10 ohm
C5 – 1000pf	L3, L4 – 1uh Molded Choke	Q1, Q2 – MRF-901

Alignment and setup –
-- Adjust R1 to 15k Ohms/
-- Adjust R2 to 100 Ohms
-- Connect 50 Ohm Dummy Load to the output with RG-58, can be run through meter first
-- apply 12v and drive to input (5-15mw, you can use the FM-10)
-- Adjust C1, C2, C3, ~~and R1~~ for max out.
-- R2 can now be adjusted to 0 for max output
-- If you are using this stage as a driver, Do not run R2 at 0 ohms, and watch current carfully, do not let to current flow into Q1 and Q2 on the collector side or the 901's will lose there smoke. I wouldn't go over 75ma.

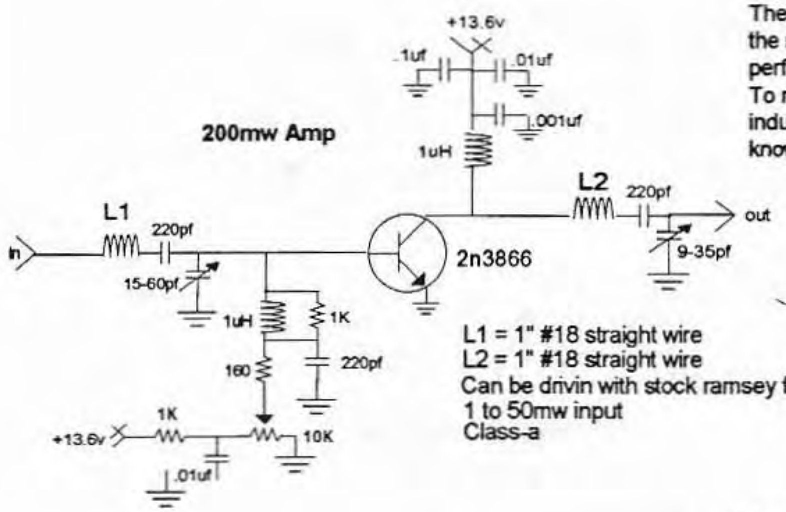


PCB Layout – Actual Size

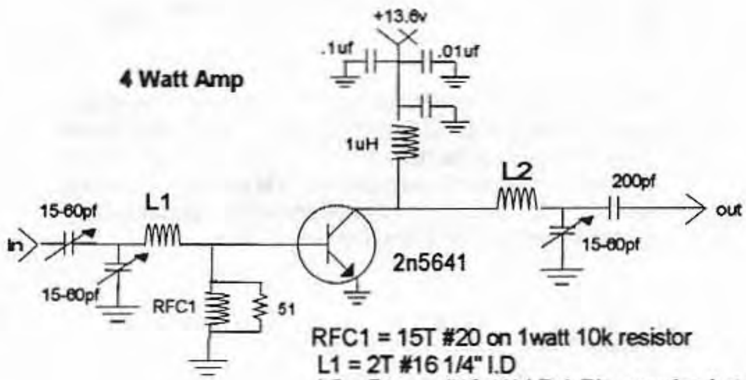


200mw and 4 watt amps

These two amp designes have been floating around the net for a while. I have some doubts about there performance at 3-meters. But they are worth a look at. To me they look more like 2-meter amps. But the inductors could be increased for 3-meters. let me know how they do if you experiment with these.



L1 = 1" #18 straight wire
L2 = 1" #18 straight wire
Can be drivin with stock ramsey for about 125mw out
1 to 50mw input
Class-a



RFC1 = 15T #20 on 1watt 10k resistor
L1 = 2T #16 1/4" I.D
L2 = 5 turns #16 1/4 I.D 1 Dia. spacing between wires
Can be driven by above amp. times 10 power gain to 4 watts out
50 to 400mw input
Class-C

Ramsey PA-1 Modification For 3-Meter Use

Only L1 and L2 need to be changed.

L1 Should be replaced witha 1 turn 1/4" diameter coil, identical to L2 shown in the 2-meter stock design.

L2 Should be replaced with a 2-turn 1/4" diameter coil.

Tune up should be the same as in the PA-1 manual.

You can use the PA-1 with the a stock ramsey if you do the "biased on" (pg 13, PA-1 Manual) modification. This turns on the transistor so that even low powersources will be amplified. This is not neccary if you run another stage in between the FM-10 and the PA-1 that is capable of delivering 30mw or more.

Ramsey PA-1 2-meter to 3-meter conversion mod (updated)

The Ramsey 2-meter amp (PA-1) can be converted for use on the FM broadcast band. The following changes need to be made:

```
  L1 - should be replaced with a 1-turn 1/4" diamater coil, identical
       to the stock L2 shown in the PA-1 manual.

  L2 - no change required

  C1 - no change required

  C2 - should be replaced with a larger trimmer capacitor.  Use a
trimmer
       that will go up to at least 125pF.

  C3 - no change required (*)

  C4 - should be replaced with a larger trimmer capacitor.  Use a
trimmer
       that will go up to at least 125pF.

  * - at higher power levels (>15 watts), this capacitor should be
      replaced with a trimmer at goes up to at least 200pF.
```

Tuning:

Tuning the amp for proper operation on 3-meters can be tricky. I suggest the following setup:

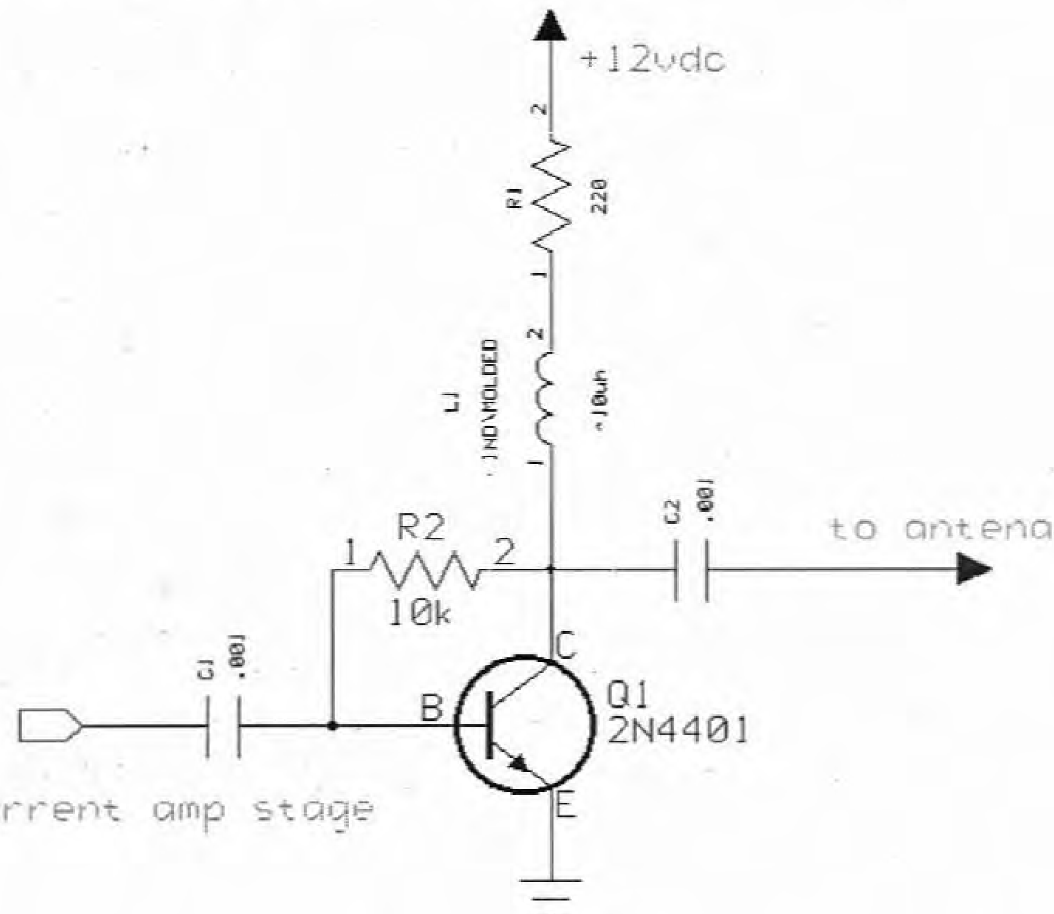
- FM xmitter --- SWR Meter --- PA-1 --- Power Meter --- 50 ohm dummy load

Starting with C1 and C3 about 1/2 turn from closed, tune C2 and then C4 for maximum power output. If the SWR is much over 2:1, you will need to adjust C1, C2, and C4 to reduce it to an acceptable level. Watch the output power while you do this. Sometimes, tuning the trimmers for minimum SWR will peak the power output, whereas other times the power output will drop markedly. Avoid trimming the capacitors that have a large negative effect on the power output. After several iterations of adjustment, you should have decent power gain and low input SWR.

Note: Watch for sudden jumps in power output that you can't linearly tune through. If you encounter this happening, chances are your SWR between the transmitter and amplifier will go way up, too. This is a sign that your amplifier is oscillating and you will need to tune it out of this region for proper operation.

Ramsey FM-10 70mw output amplifier

Provides almost 9db gain to bring the output power of the Ramsey FM-10 Stereo transmitter from 8mw to 70mw. Not the best design, but all parts can be found at Radio Shack! Much better designs are available at the archive site.

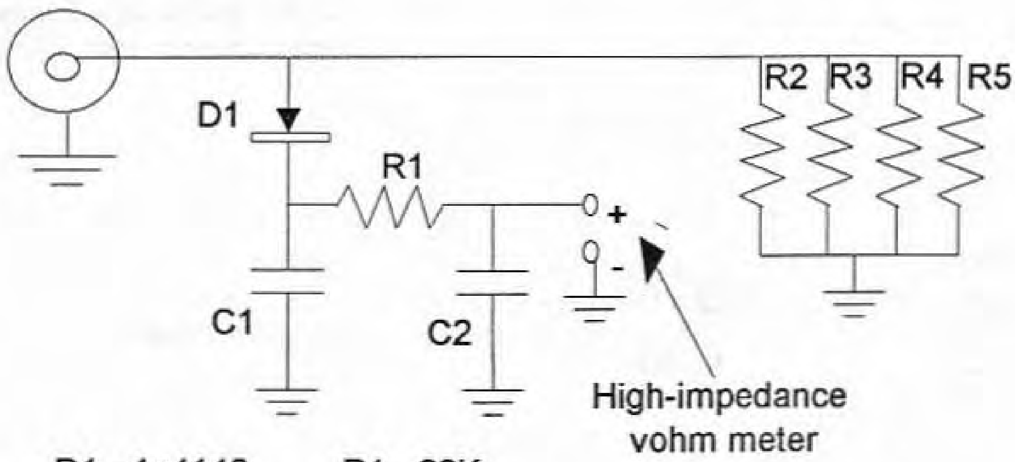


I built this thing right on the underside of the FM-10 kit, C1 is the cap that currently goes to the RCA ant jack, the 9k and the 220 ohm resistor have to be bought, note that if you cannot find 220 ohms you can make one by using 2 440 ohm resistors in parallel, and that a 10k will work in place of the 9k but yields poorer performance (-5%).

The 2N4401 can be found at Radio Shack too. Using the MPS918 instead of the 2N4401 can produce up to 150mw. C2 is of the same value of C1, I took the one that goes to the on board antenna pad.

Important! The value for R1 that seems to be optimal is 220 ohms, but it is very close to the sat point, If the amp. Seems noisy (interferes with the TV etc.) back this value off to 240 ohms. If you lower this value below 205 ohms the power meter may read higher power but this will not be true, the transistor will be spewing all kinds of junk and the power meter will mistake this for higher output (in reality the signal we want will drop considerably.) Well that's it; effective range with a good antenna should be almost triple.

Power Meter/Dummy Load



D1 - 1n4148
C1 - 47pf
C2 - .1uf

R1 - 22K
R2, R3, R4, R5 - 200 ohm 1/2 watt

Note : R2, R3, R4 and R5 could be 1/4 watt for a maximum power handling of about 1 watt, as shown it can hadle 2 watt. The resistors could be replaced with 1 watt or 2 watt carbons for even more power handling ability. Do not use wirewound resistors! You can use the device shown for up to 6 watts of short term testing, just watch the temp!

To calculate power output use the formula :

$$\text{Power Output} = E^2 / 50$$

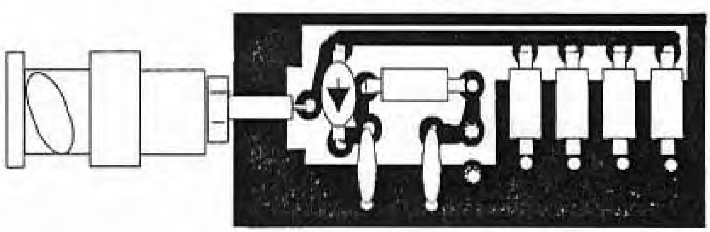
Example if you mesue 2 volts on your VOM :

$$\text{Power Output} = 2^2 / 50$$
$$= 4 / 50$$
$$= .08 \text{ watts}$$
$$= 80 \text{ mw}$$

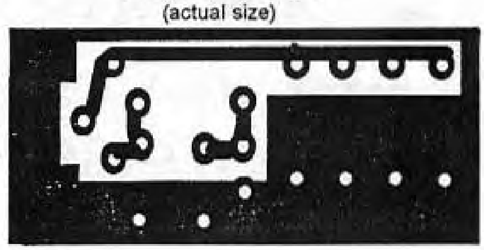
Set VOM to dc volts

volts	power
2v	80mw
3v	180mw
4v	320mw
5v	500mw
6v	720mw
7v	980mw

PART PLACEMENT

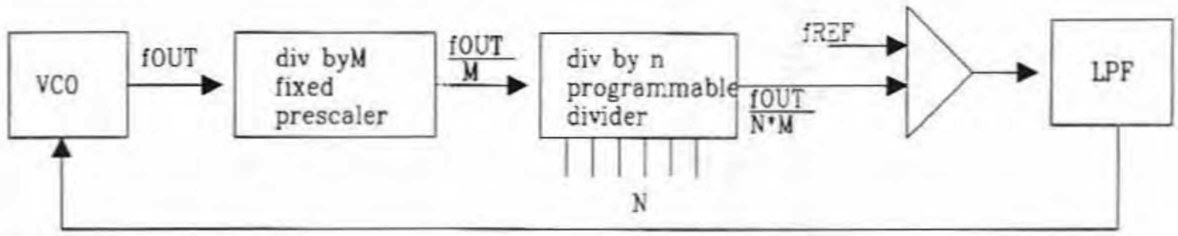


PCB BOARD
(actual size)



PLL Design

This is a preliminary design for a digitally synthesized fm stereo transmitter using the BA1404. MC145151-1(pll synthesizer) and the MC12019(div by 10/11 prescailer).



$fIN = fREF$

$fIN = \frac{fOUT}{N*M}$

$fOUT = (N*M)fREF$

$fOUT = N(M*fREF) \rightarrow fSTEP = M * fREF$

We Want:

fSTEP = 100khz

fOUT = 87.5 -108.1mhz

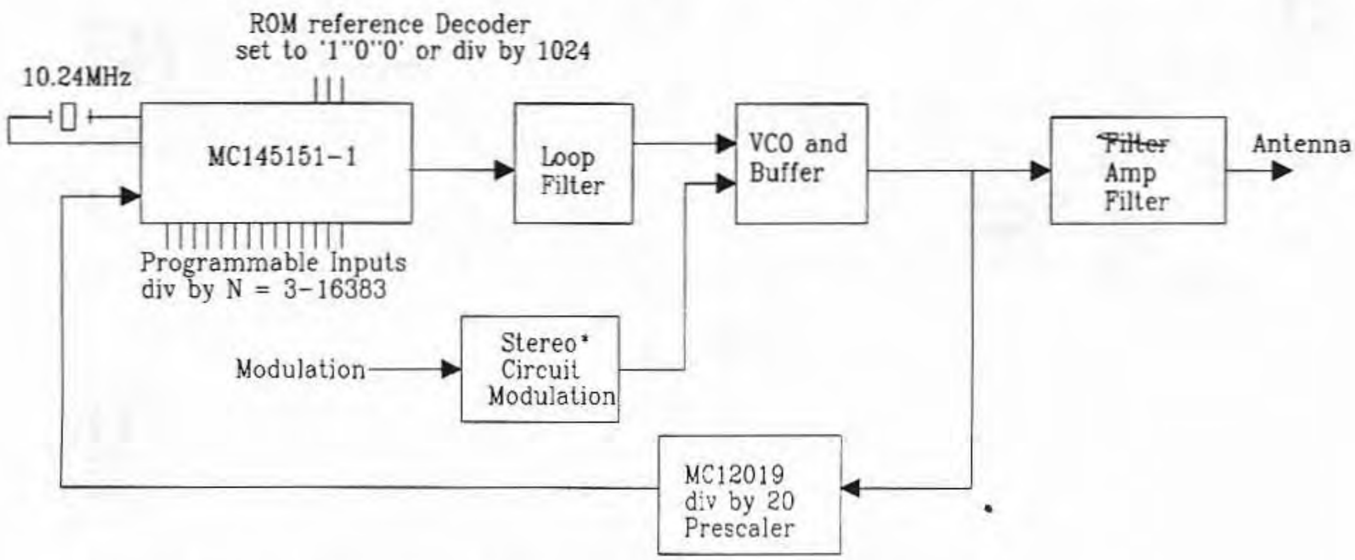
M = 20 --> MC12019

N = 3 - 16383 --->MC145151-1

$fREF = \frac{fSTEP}{M} = 5khz$

(5khz * 1024)*2 = 10.24 mhz Ref Osc. for MC145151-1 using 100 for the reference address divide value

$N = \frac{fOUT(mhz)}{.1}$ ⟶ so 87.5mhz ---> n=875. 108.1mhz ---> n=1081... totally cool



* Stereo Modulation Circut - See notes under car CD player

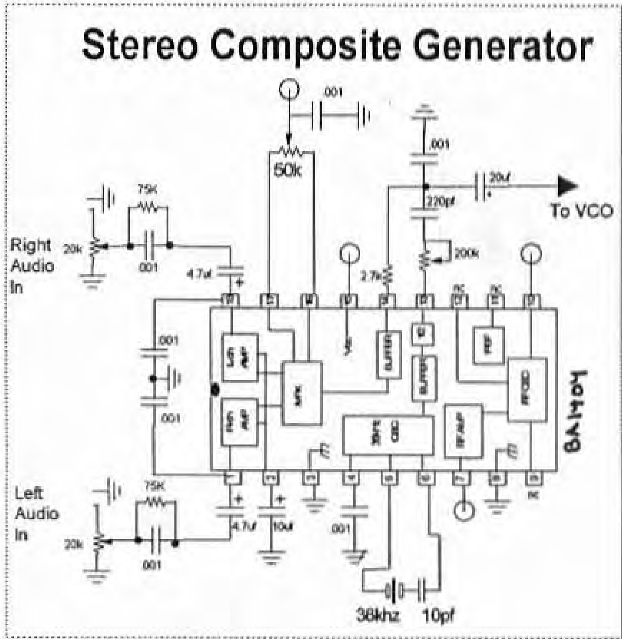
o We are only interested in N=877 to 1081 we can limit the inputs to this range or be carful not to go out of these bounds.

o I am having trouble finding examples on how to modulate the VCO. most PLL books have this block diagram but give no circut examples.

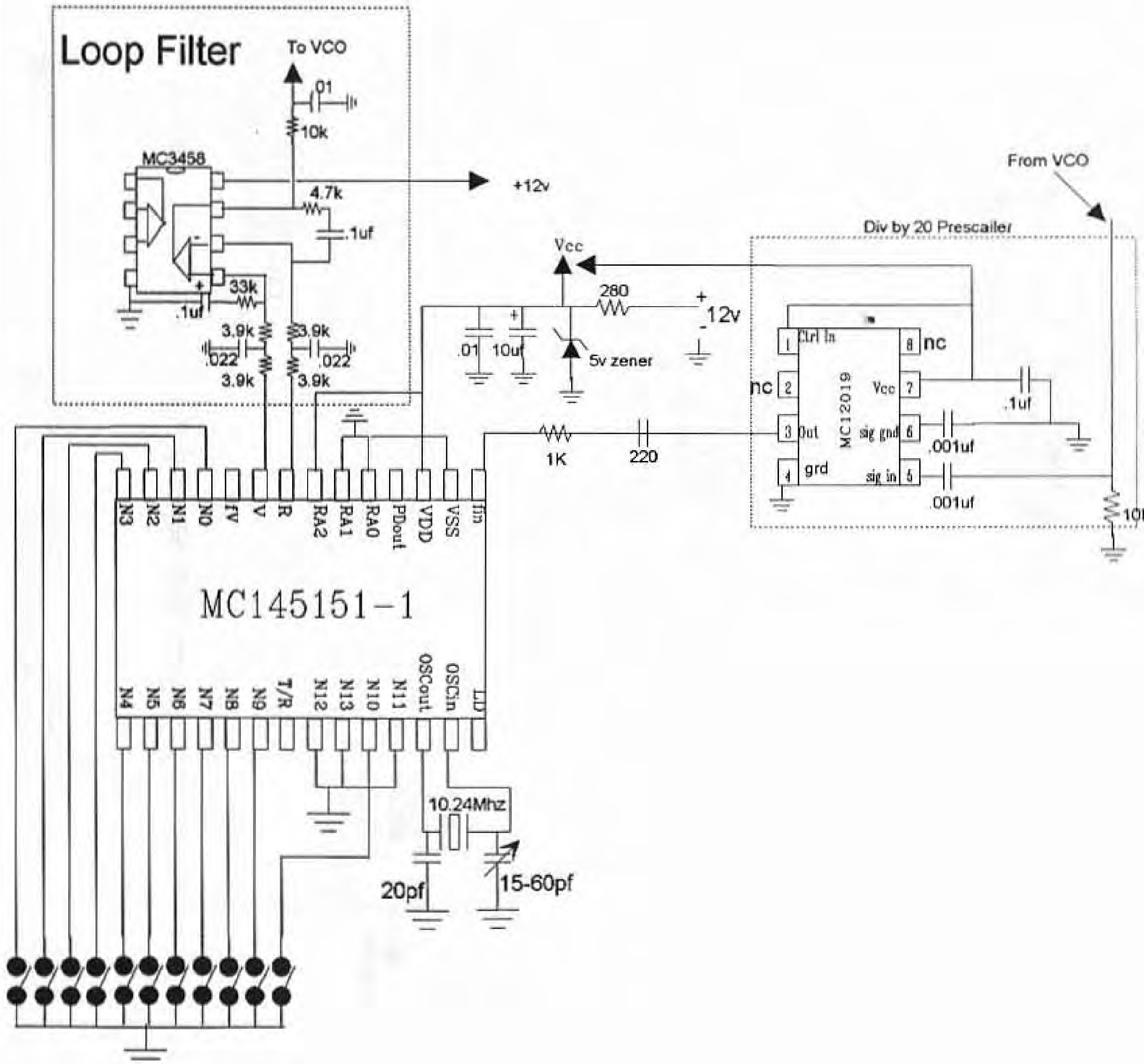
o The filter-amp-filter section will be close to simple 3 element filter from the FM-10 FAQ. an amp close to the dual 901 amp. and another 3 element filter. I am hoping for between 100mw-500mw. depending on the output from the VCO.

o Please see National Semiconductor "Interface Databook" 1990 for further info on PLL design. including schematics for VCO.

o Contact me for further info/spec sheets etc if you ars project or have any ideas or examples for the above.

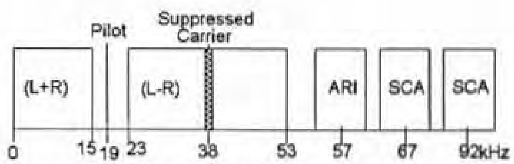


Loop filter must be powered by at least +9v but prefibly +12v
This give a larger voltage output range so we can tune the whole
FM band. Powering with +5v probibly won't cut it.
Voltage need not be regulated for loop filter.



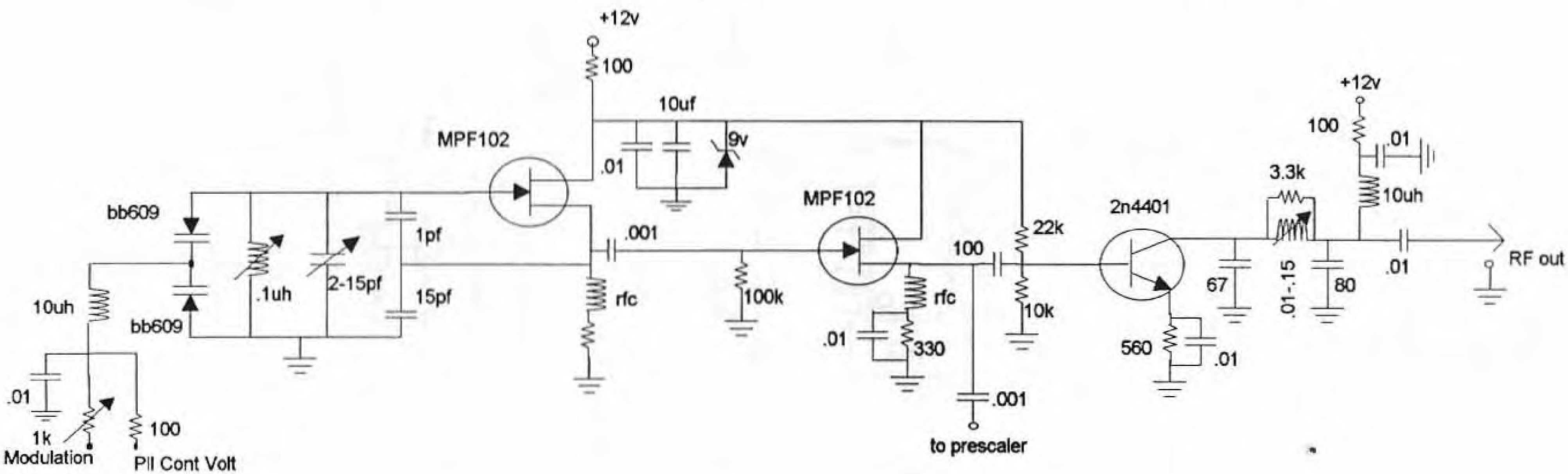
Frequency Synthesized Stereo Transmitter

By mycal@netacsys.com

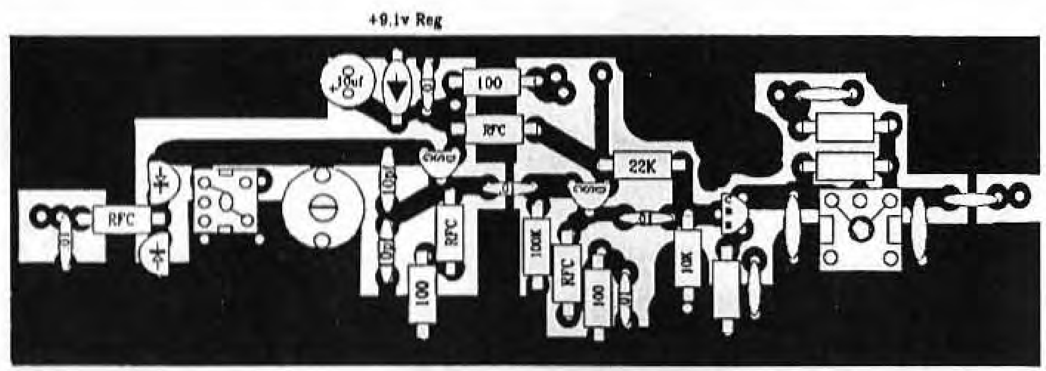


Composite modulating signal

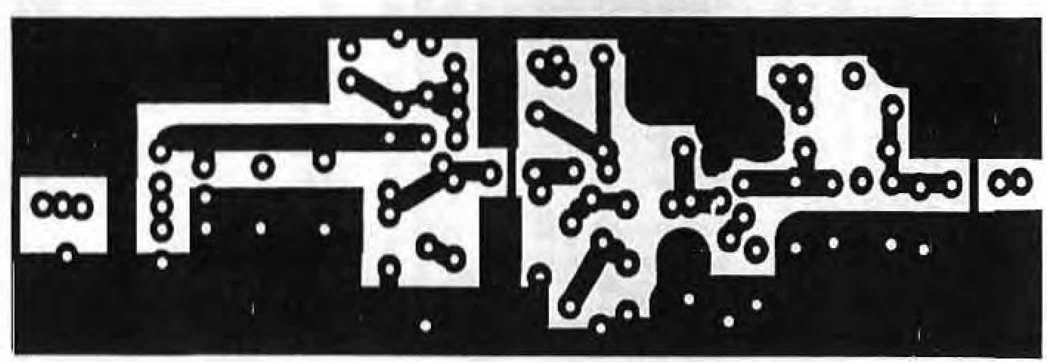
VCO

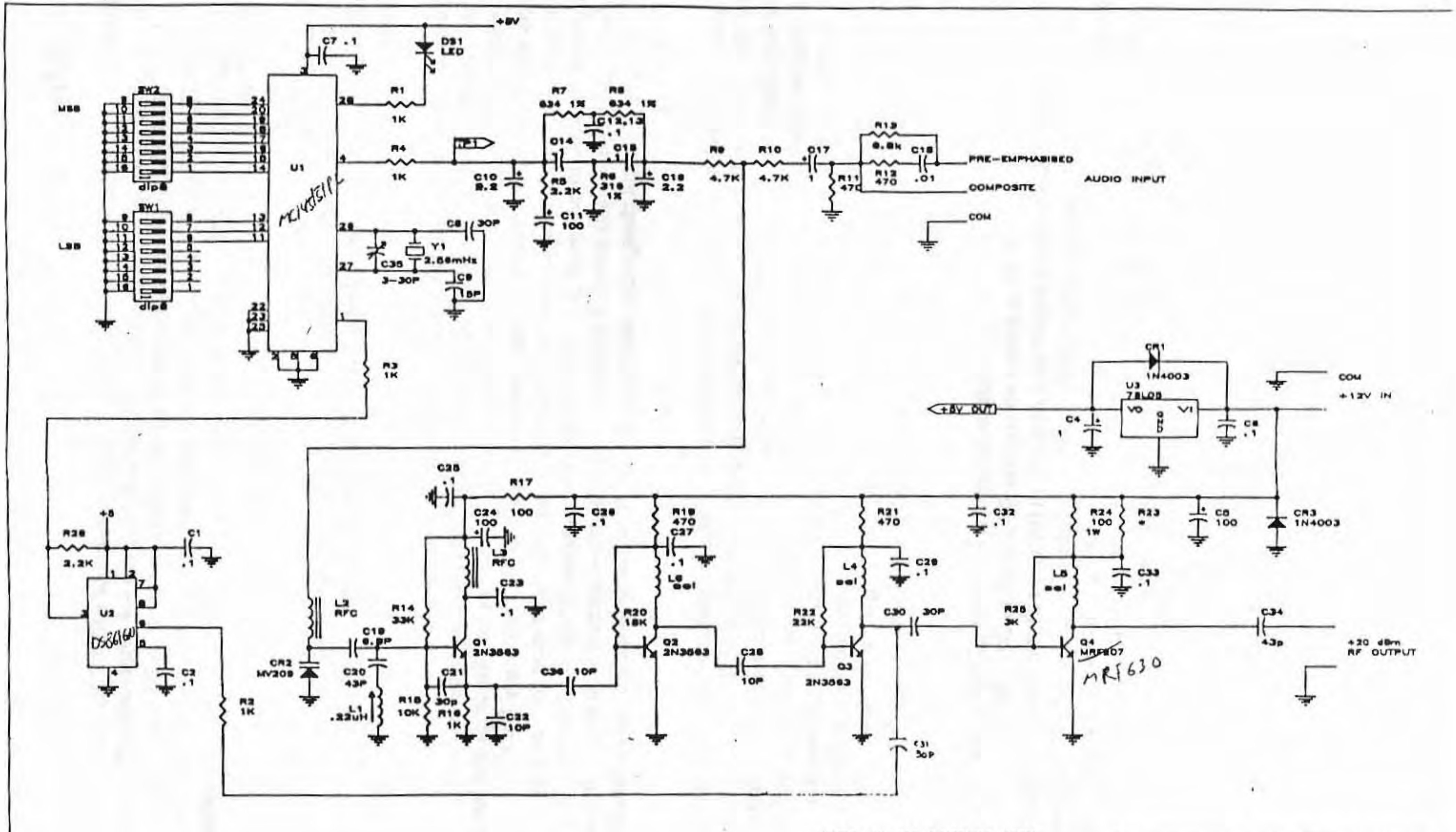


+12v
100
10uf
.01
9v
MPF102
bb609
1pf
.001
MPF102
2n4401
22k
100
3.3k
.01
10uh
+12v
100
.1uh
2-15pf
15pf
10uh
bb609
rfc
100k
rfc
10k
67
.01-.15
80
.01
RF out
.01
330
560
.01
.01
1k
Modulation
100
Pll Cont Volt
.001
to prescaler



+9.1v Reg
100
RFC
22K
RFC
100
100K
RFC
100
10K





NOTES: UNLESS OTHERWISE NOTED,

1) All resistors are in ohms, all capacitors are in microfarads (uF).

2) All caps in pf or P are NPO type.

JT COMMUNICATIONS OCALA, FLORIDA	
Title SCHEMATIC- PLFM-100 SIGNAL GENERATOR	
Size B	Document Number PLFM-100SCH
Date: September 18, 1990	Sheet 1 of

FRB 5 Watt Transmitter

The FRB 5 watt transmitter is a economical, easy to build transmitter suitable for micro power radio. It is capable from operating from 50 to 150 MHz putting out 4-6 Watts into a 50-75 Ohm antenna load. The frequency stability is approximately 10 kHz. It has an audio frequency response of 20 Hz to 20 kHz in mono. A stereo generator can be easily attached to the input circuitry. Audio input impedance can be set to 600 or 10 K ohms. And harmonic suppression is better than 20 dB.

Theory of Operation
Resistor R1 is selected to match the output impedance of you audio source. This is usually 600 Ohms for Broadcast Audio standard equipment or 10K Ohms for most consumer electronics such as cassette and disk players.

FM Broadcast band transmissions use *pre-emphsis* at the transmitter and *de-emphasis* at the receiver. This provides a boost of the higher audio frequencies during transmission, and a corresponding cut during reception. This helps reduce background noise. Since all FM band receivers have a de-emphasis network built into them, music would sound very flat if pre-emphasis is not used in the transmitter. If the transmitter was to be used for voice only, the pre-emphasis network looses most of its importance. Components R2 and C1 form the standard 75 microsecond pre-emphasis network required for faithful music transmission in the United States. Europeans should change the value of R2 to 10K to conform to the European standard of 50 Microseconds.

The audio input level required for 100% modulation with the pre-emphasis network installed is about 0 dBm (or 1 volt peak to peak into selected impedance of 600 or 10 K ohms). If the circuit is to be used for voice only then R2 and C1 can be left out with the input being feed directly to the modulation control (R5). The audio input level for 100% modulation without R2 and C1 is about -20 dBm. It should be noted here that if a stereo generator was to be used with this transmitter, that you would feed the stereo composite signal directly to the modulation control of (R5). You would not want to run the stereo composite signal through pre-emphsis. The stereo composite generator would have its own pre-empasis, and it would take place before the composite signal was generated.

The oscillator and tuning supply voltage is held at a constant by means of Zener diode D2 and capacitor C6. Variable resistor R4 applies a voltage via R7 and R5 to D1. D1 is a variable-capacitance diode whose capacitance depends on the value of the voltage applied to it. The movement of R4 varies the amount of that voltage and therefor can be used for adjusting the operating frequency slightly. Tuning range of this resistor has been measured at about 1 MHz. R3's value could be lowered slightly to extend this range another .5 Mhz or so. But I wouldn't allow the voltage at the output of R4 to be able to be adjusted less than 2 Volts since D4 has a very non-linear response under 2 volts and could create a bad sounding signal.

The audio signal level is determined by R5 is fed through C2 and R5 to D1. This signal appears to D1 as a voltage which is changing along with the audio feed in. This causes capacity changes in D1 which in turn change the frequency of the oscillator. The oscillator is said to be *modulated* and this results in a change of frequency it is *frequency* modulated.

The oscillator consists of Q1, C4, R8, L1 and C5. Oscillation begins with a slight flow of current from the ground up through the bottom of L1. That current flows out the coil's tap, through Q1 via its *source* and *drain* leads and R9 to the regulated +10 volts produced by D2. This current induces a voltage across L1 which is seen, through C4, by the *gate* of Q1. Amplification by Q1 of this minute voltage increases the current through L1. This continues until a current limit is reached at which time the process reverses itself. Current decreases through the coil producing a revers voltage at the gate of Q1 which further decreases the current.

L1 and C5 form a *tank circuit*. This is an electrical circuit which behaves much like a mechanical device such as a guitar string. Pluck the guitar string and it vibrates at a fixed frequency. Put a pulse of current into a tank circuit and it electrically vibrates at a fixed frequency. If you change the length of the guitar string you also change its frequency. If you change the inductance of capacitance of a tank circuit you change its frequency. The frequency of this oscillator and the pulses it produces are therefor determined by the inductance of L1 and the capacity of C5.

The capacity of D1 is in series with C3 and that combination is parallel with C5. C5 is the main tuning component. The change in DC voltage to D1 form R4 is used for *fine tuning*. The audio signal applied to D1 probides the changing voltage required for *modulation*.

The radio frequency signal present at the source of Q1 is fed through C8 to the base of Q2. The operating bias for Q2 are established by R10 and R11. The amplified signal appears at the collector and across L2. C9 and L2 form another *tank circuit* which is tuned to the same frequency as the oscillator. A low impedance point is tapped-off from L2 and the signal is fed through a series-tuned circuit of C10 and L3. This signal arrives at the base of Q3 the power output transistor.

Q3 is operated without forward bias (class-c). Its base resistor, R13, is simply connected to ground. This *zero bias*, as used in power output stages, allows the transistor to pass high-current pulses with a *resting state* between pulses. These current pulses develop a corresponding voltage across L4. L5, C11, and C12 form another tank circuit. Almost all of the power output produced by Q3 id developed in this final tank circuit. The proper adjustment of C11 and C12 couple this power to the antenna.

5 Watt Transmitter Construction Checklist

Insert and solder the following resistors/jumpers/inductors :

- O Insert R1 680 ohms (blue grey brown), (R1 could also be 10K, see circut iscription)
- O Insert R2 15 K ohms (brown green orange)
- O Insert R3 10 K ohms (brown black orange)
- O Insert R6 68 K ohms (blue grey orange)
- O Insert R7 68 K ohms (blue grey orange)
- O Insert R8 68 K ohms (blue grey orange)
- O Insert R9 150 ohms (brown green brown)
- O Insert R10 22 K ohms (red red orange)
- O Insert R11 1 K ohms (brown black red)
- O Insert R12 110 ohms 1 Watt (brown brown brown)
- O Insert R13 56 ohms (green blue black)
- O Insert the inductor L6 (molded choke)
- O Insert the jumper as shown.

Insert and solder the following capacitors :

- O Insert C1 marked .005 or 502
- O Insert C2 marked 1uf, note correct polarity
- O Insert C3 12 pf, marked 12
- O Insert C4 12 pf, marked 12
- O Insert C8 12 pf, marked 12
- O Insert C7 .1uf disc, marked .1
- O Insert C13 .1uf disk, marked .1
- O Insert C14 1000pf disk, marked .001 or 102
- O Insert C15 1000pf disk, marked .001 or 102
- O Insert C6 marked 22 or 47 uf, note correct polarity
- O Insert C16 marked 22 or 47 uf, note correct polarity

Insert and solder the following variable capacitors :

- O Insert C5 3-30pf trimmer capacitor
- O Insert C9 9-50pf trimmer capacitor
- O Insert C10 9-50pf trimmer capacitor
- O Insert C11 16-100pf trimmer capacitor
- O Insert C12 16-100pf trimmer capacitor

Insert and solder the following variable resistors:

- O Insert R5 500 ohm variable resistor
- O Insert R4 100 K ohm variable resistor

Insert and solder the following semiconductors :

- O Insert and solder D1, 9.2v Zener diode. Band pointing at the center of the board.
- O Insert and solder D2, MV2113 varicap tuning diode. Flat side pointing away from the center of the board.

- O Insert Q1, marked 2n4416, note correct orientation on board.
- O Insert Q2, marked 2n3866 or 2n4427, note correct orientation on board.

Insert and solder the following coils :

- O Insert L1, 6 Turns #18 .25" diameter, connect a tap wire at 2.5 turns from the ground end.
- O Insert L2, 6 Turns #18 .25" diameter, connect a tap wire at center of coil.
- O Insert L3, 4 Turns #18 .25" diameter.
- O Insert L4, 2.5 Turns #18, .25" diameter.
- O Insert L5, 4 Turns #18, .25" diameter.

Install the last transistor and heatsinks :

- O Insert Q3, note correct orientation on board. Mount from the bottom with the writing of the transistor facing up. See Layout sheet for more detail.
- O Install heatsink on Q3.
- O Install heatsink on Q2.

Install the feed wires :

- O Install the power cables, use red and black wires if possible, connecting the red wire to the +12volts area as shown on the layout diagram. Connect the black wire to the curcut ground as shown on the layout diagram.
- O Install the audio input cable, shielded audio cable works best. Connect the center strand of the cable to the place marked Audio Input and connect the surrounding braided strand to the place marked Audio Ground.
- O Lastly, install a piece of 50 ohm coaxial cable to the RF output. Connect the center strand to the place markded RF out, and the braided shell to the place marked RF ground.

Ok, now your transmitter should be assembled. Go back and check all your work. Make sure that all the solder connections are shiney and don't bridge over traces. Once this is done you should prepair to tune the transmitter up. You may want to wait until after you have done some testing before mounting you transmitter in a case.

Tune Up

(1) Connect the piece of 50 ohm coaxial cable to a power meter with a *dummy load* on its output jack. You can use a "CB" watt-meter, or a more accurate VHF watt-meter. The power meter/dummy load shown in this book can also be used.

(2) Set R4 and R5 at mid-range.

(3)Apply 12volts DC to the transmitter.

(4) Feel around to see if anything gets too hot to the touch or smokes. If it does stop right here, switch off the power supply immediatly and check for wireing errors. Otherwise continue.

(5) With the aid of a frequency meter, frequency counter, or a radio which tunes the required frequencies nearby, adjust C5 as close as possible to the desired frequency.

(6) While watching the watt-meter slowly adjust C9 and C10 for maximum power.

(7) Next adjust C11 and C12 for maximum output power.

(8) Go back to C9 and C10 and readjust if necessary. You may have to jump back and forth between C11/C12 and C9/C10 several times to obtain maximum output. Proper adjustment not only yields maximum output but reduces harmonic content. You should be able to get between 3.5 and 5.5 watts output.

(9) Fine tune to the desired frequency with R4. Check C9/C10, C11/C12 again.

(10) Apply an audio signal at the level you'll normally be using to modulate the transmitter. Adjust R5 for proper modulation. Without a calibrated modulation monitor you have only one easy way to do this. Compare the loudness of your transmitter with that of another FM signal. Tune-in a local FM station and adjust your transmitter's modulation level so it is almost as loud as the test station. You may want to do this with several different test stations.

Now that you know your transmitter is functioning correctly, it is time to put it in a metal case. Not only will this make it an attractive easy to use device but it will improve the frequency stability. Once this is done, go through the tune up procedures again to make sure nothing has changed. Then enjoy your transmitter.

Helpful Hints

You will notice that these assembly instructions call for L2 to be 6 turns. In my prototype I could adjust the transmitter below the FM broadcast band fine. But when I approached the lower part of the band it would jump to above the FM broadcast band. I found that Q2 and its associated tank circuit wanted to resinate above the FM band, this caused the oscillator Q1 to want to jump and match Q2. Increasing L2 1 turn seemed to bring this back down so I could cover the FM broadcast band. Also I have L5 at 4 turns, this seems to provide a better match, thus transfers more power to the antenna. You could leave L5 at 4.5 turns and spread the coils apart to acheave the same results.

When mounting the transmitter in a case it is vary handy to have R4 accessible on the outside of the case so it is possible to fine tune the frequency during transmitting. A multi turn pot would be ideal and recommended, but a single turn pot would do. The reason is that it can take up to 15 minutes for the oscillator to heat stabilize, this causes a slight drift upwards in frequency. I have seen up to 500kHz of shift before the oscillator stabilize. This can be compensate for by giving the fine tune pot a little twist every couple of minutes at the beginning of the broadcast. Once the temperature has stabilize, drift is minimal. Never the less, I would still monitor the frequency with a frequency counter, or a very accurate digital tuner during any broadcast.

PARTS LIST FOR 5 WATT TRANSMITTER

Resistors (1/4 Watt unless specified)

		Color code
R1	10KOhms -	brown black orange
R2	15K	brown green orange
R3	10k	brown black orange
R4	100K potentiometer	
R5	500 0hm potentiometer	
R6,R7,R8	68K	blue gray orange
R9	150 Ohms	brown green brown
R10	22K	red red orange
R11	1K	brown black red
R12	110 Ohms 1 wattt	brown brown brown
R13	56 Ohms	green blue black

Capacitors (16 or 25 volt min. rating)

C1	.005 or .0047 mfd disc	
C2	1 uf electrolytic	
C3,	33pf - 47 pf ceramic disc (NPO)	
C4, C8	12 pF disc (NPO type)	
C5	3-30 variable trimmer	green plastic
C6, C16	22 or 47 uf electrolytic	
C7, C13	.1 uF disc	
C9, C10	9-50 trimmer	orange or green ceramic
C11,C12	10-100 trimmer	black plastic
C14, C15	1000 or 2000pf (.001mfd or .002 mfd)	

Inductors: (#20 tinned, solid bus wire, 1/4" I.D.)

L1	6 turns tapped at 21/2 tums
L2	5turns tapped at center
L3	4turns
L4	21/2turns
L5	41/2turns

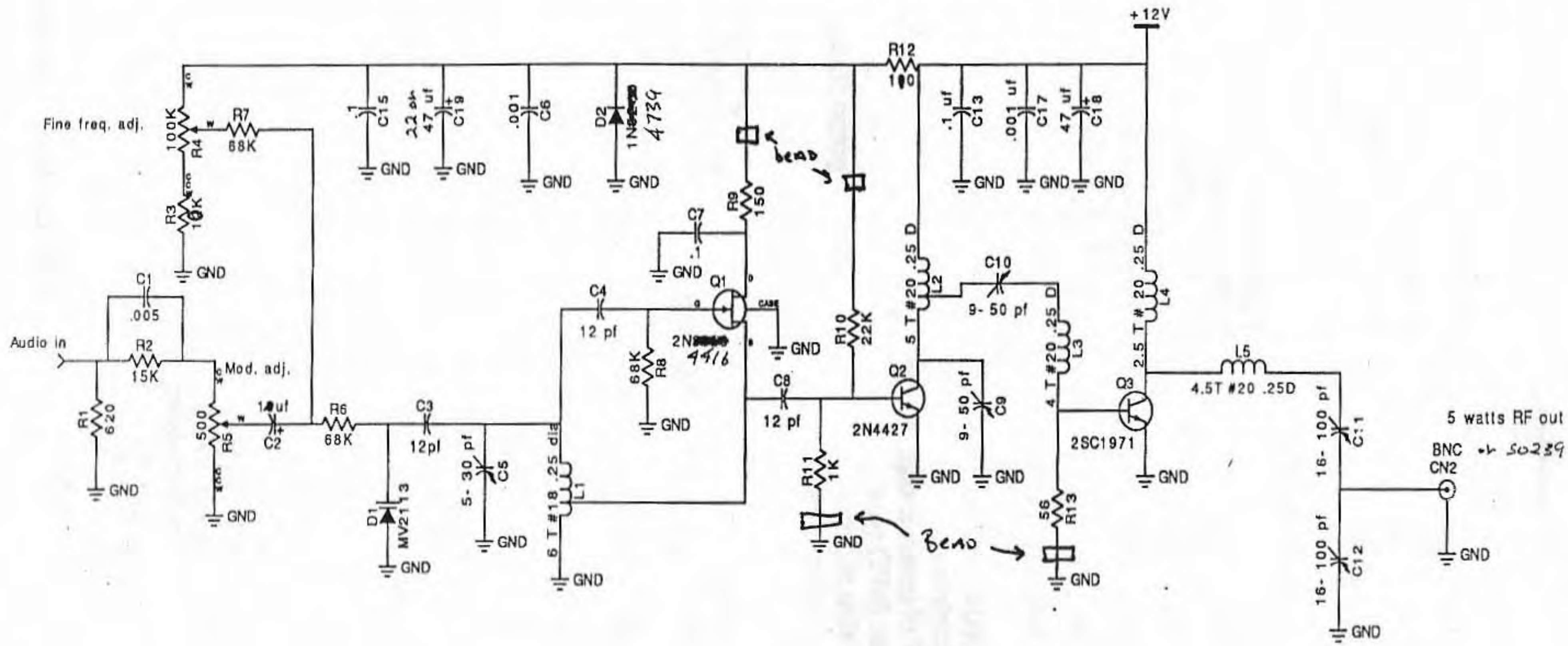
(All turns are spaced one wire diameter apart)

L6	1uh inductor

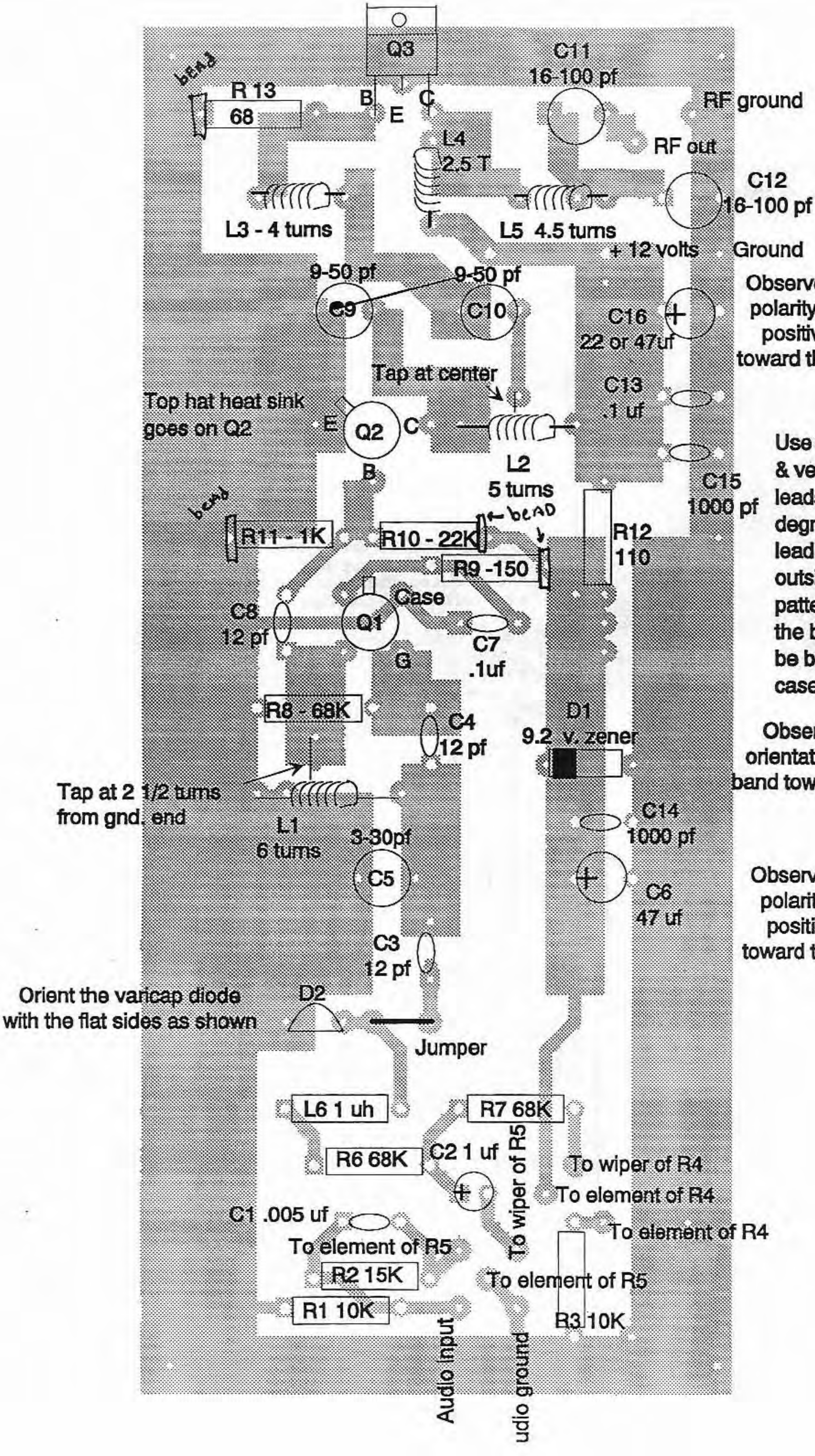
Semiconductors

D1	1N4739 9.1 volt zener diode
D2	MV2113 varicap tuning diode
Q1	2N4416 Field Effect Transistor
Q2	2N3866 or 2N4427 (NPN)
Q3	2SC1971 RFpower (NPN)

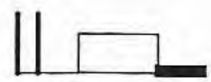
Top Hat Heatsinkfor 2N4427or 2N3866, thermal pad for Q3, SO-239 socket, 1/8 " mini jack & plug, wire & such.



5 Watt Transmitter



Observe correct polarity on C16 positive lead toward the middle



Use needle nose pliers & very carefully bend the leads of Q3 up at a 90 degree angle with the center lead off center from the outside leads to match the hole pattern. It is soldered in from the bottom side so the tab can be bolted to the bottom of the case for heat sinking

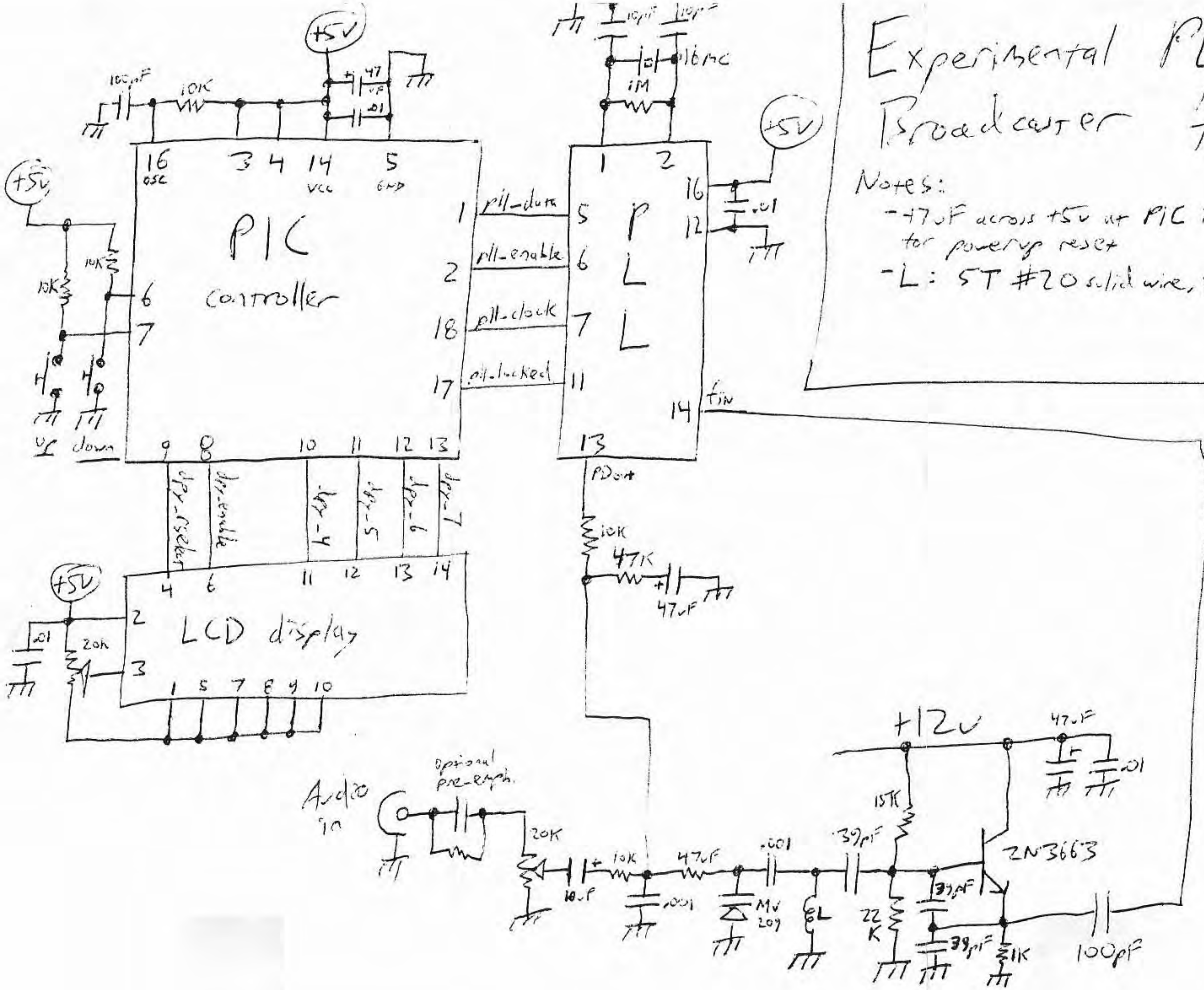
Observer correct orientation of D1with band toward the middle

Observe correct polarity on C6 positive lead toward the middle

Experimental PLL Broadcaster

Paul Thomas

Notes:
- 47uF across +5v at PIC is important for powerup reset
- L: 5T #20 solid wire, 1/8" I.D.



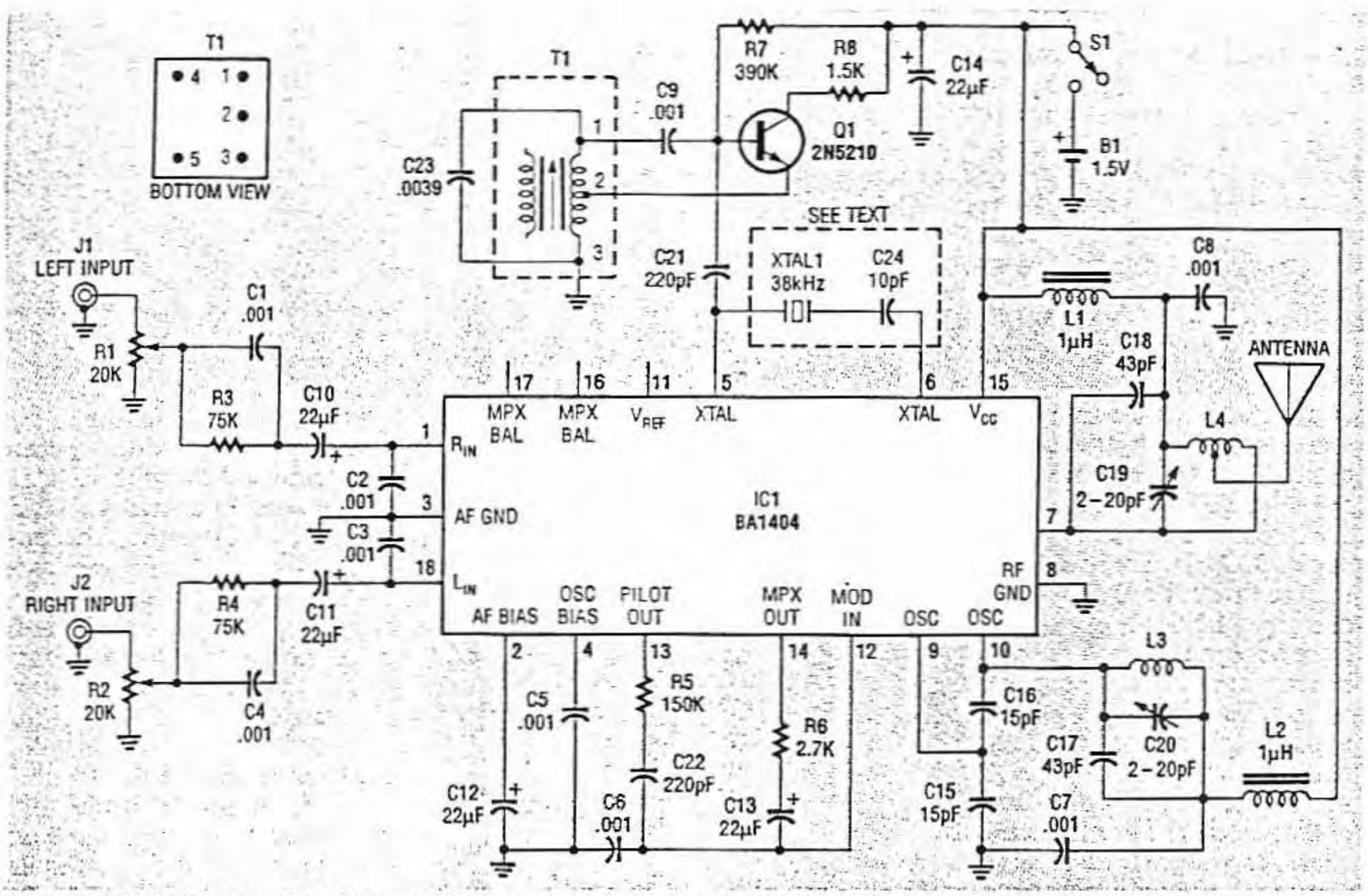
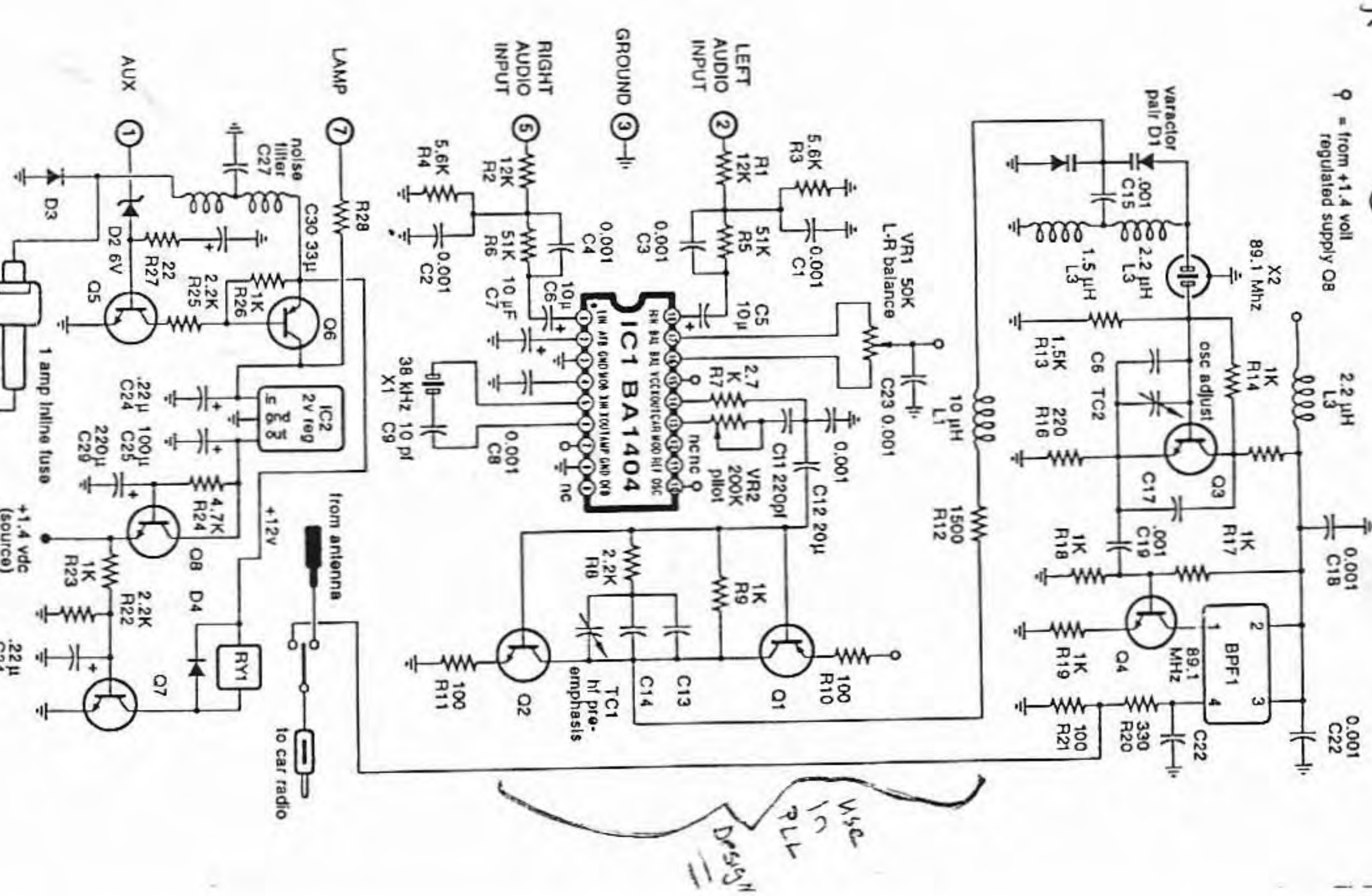
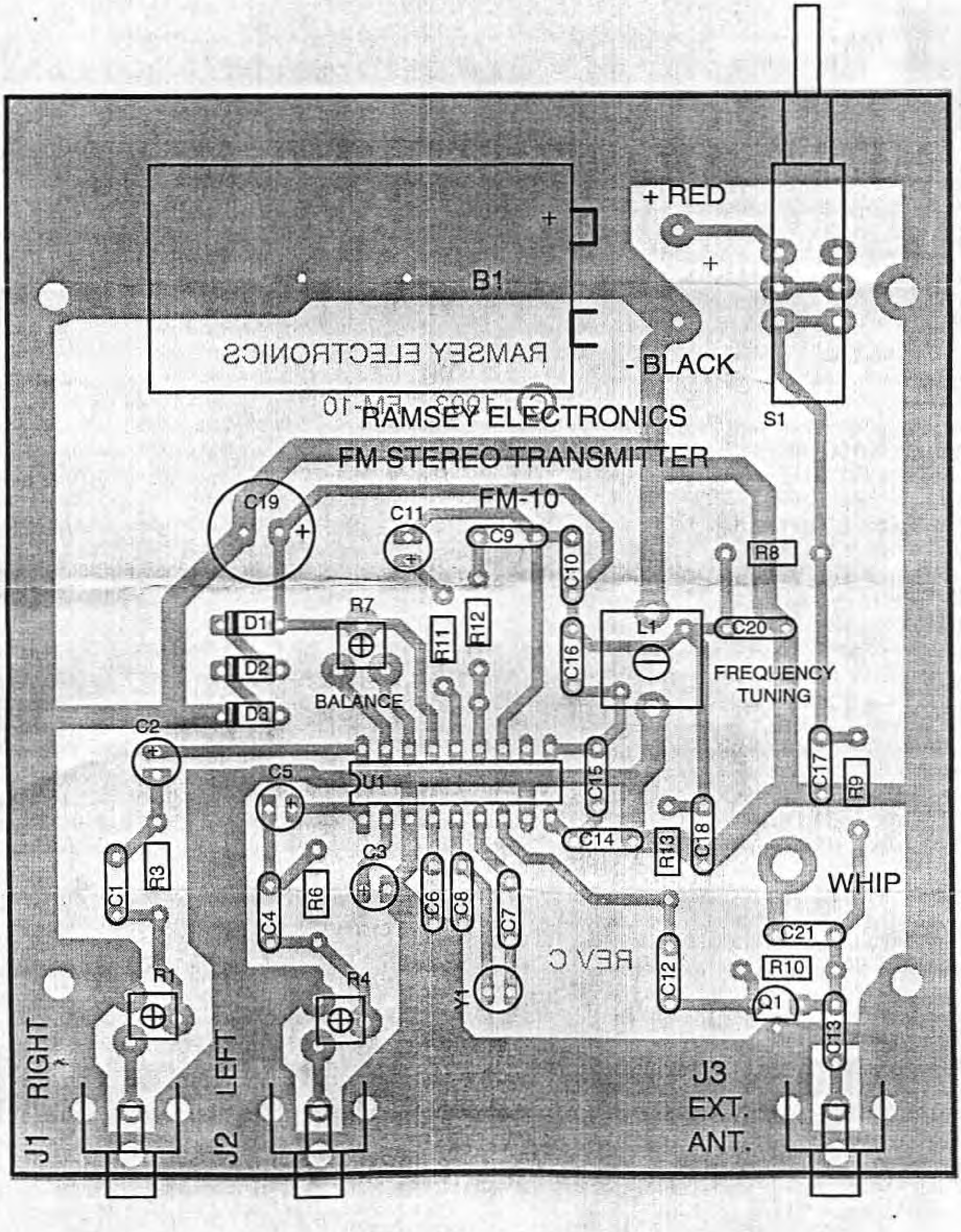


FIG. 2—THE HEART OF THE FM TRANSMITTER is a BA1404 FM stereo transmitter IC. The left input-signal level is adjusted via R1, pre-emphasis is provided by C1 and R3,

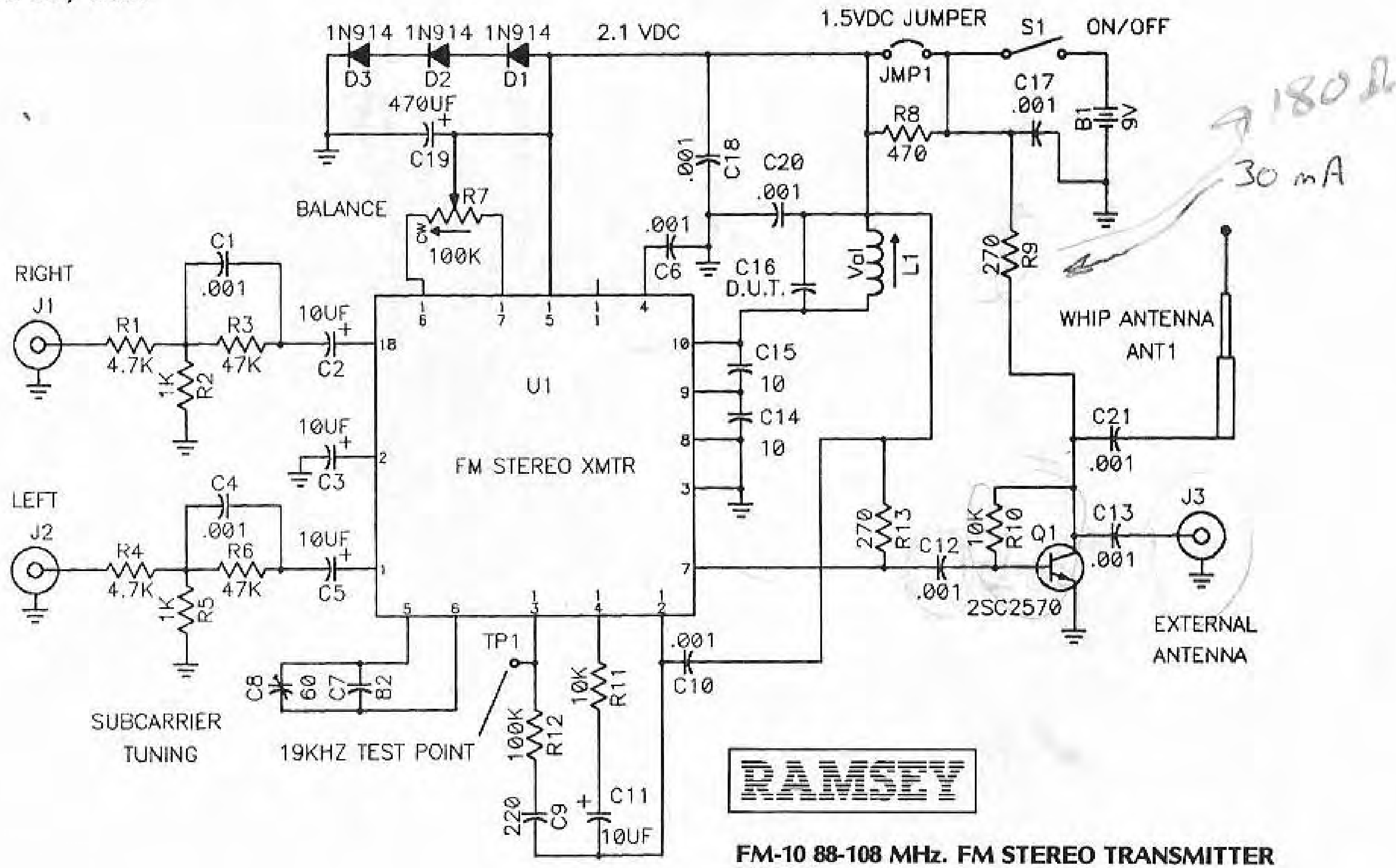


* CAR CD PLAYER

Use in PLL Design


+ RED
B1
- BLACK
RAMSEY ELECTRONICS
FM STEREO TRANSMITTER
FM-10
S1
C19
C11
C9
C10
R8
R7
D1
D2
D3
R11
R12
L1
C20
C16
FREQUENCY
TUNING
BALANCE
C2
U1
C5
C15
C17
R9
C14
R13
C18
C3
R3
C1
R6
C4
C6
C8
C7
WHIP
C21
R10
C12
Q1
Y1
R1
R4
C13
RIGHT
J1
LEFT
J2
J3
EXT.
ANT.

Circuit Revision 3, March 1991
Ramsey Electronics, Inc.

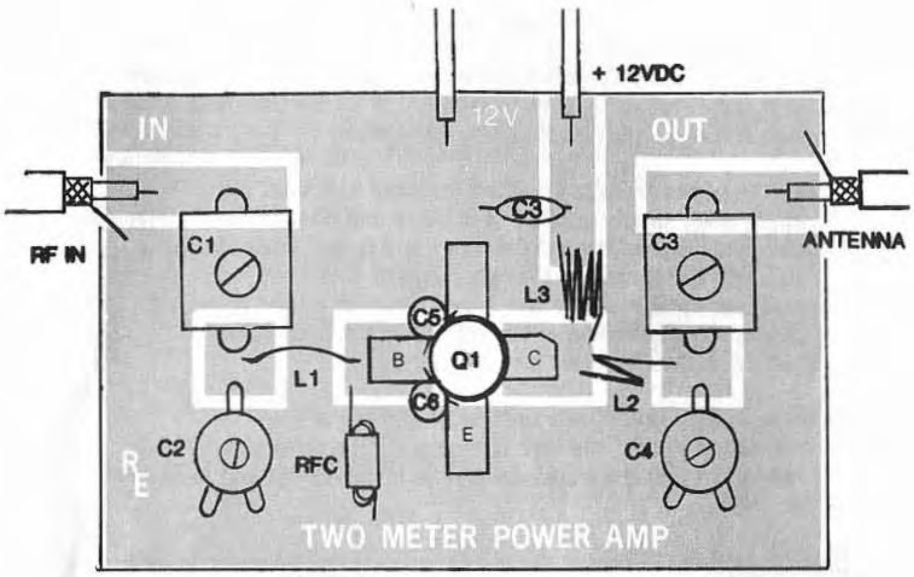


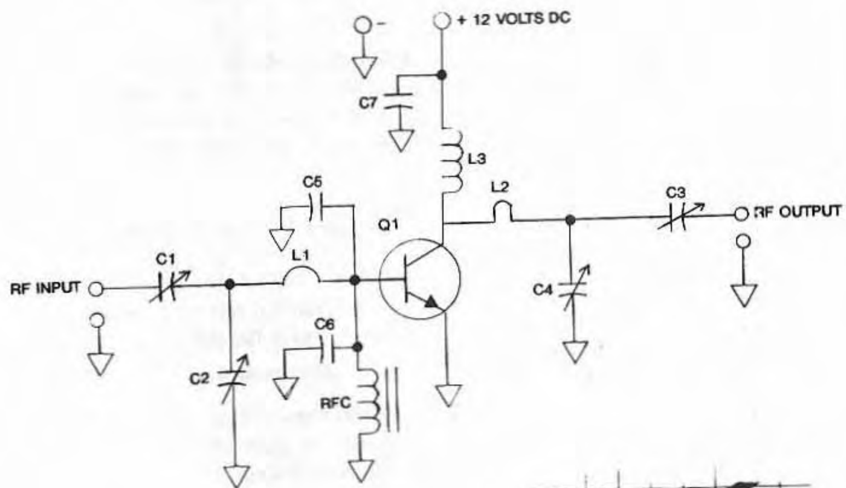
FM-10 88-108 MHz. FM STEREO TRANSMITTER

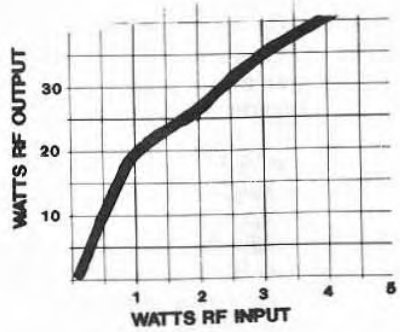
NOTES:

1. C16 (22, 27 or 33 pf.) determines section of band tuned by L1.
2. Jumper in place of R8 permits 1.5-3.0 VDC operation.

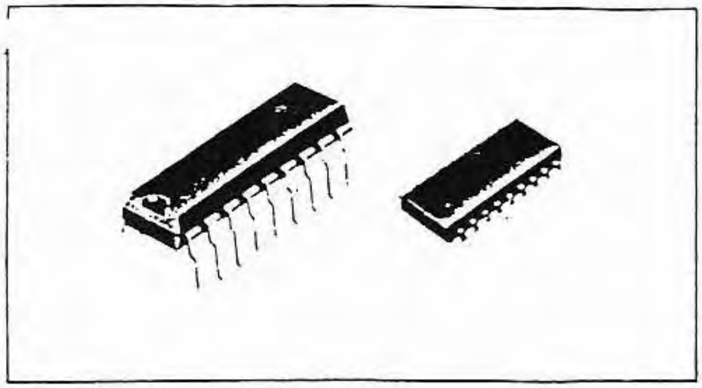
Ramsy PA-1


+ 12VDC
12V
IN
OUT
RF IN
ANTENNA
C1
C3
C3
L3
C5
Q1
B
C
L1
L2
C6
E
C2
RFC
C4
TWO METER POWER AMP


+ 12 VOLTS DC
C7
L3
C5
L2
C3
RF OUTPUT
Q1
C1
L1
RF INPUT
C4
C6
C2
RFC


WATTS RF OUTPUT
30
20
10
1
2
3
4
5
WATTS RF INPUT

BA1404 BA1404F



The BA1404 and BA1404F are monolithic FM stereo transmitters. The devices contain a stereo modulator, an FM modulator, and an RF amplifier.
The stereo modulator creates a stereo composite signal (which consists of a main (L+R), sub (L-R), and pilot signals) from a 38 kHz quartz controlled frequency.
The FM modulator oscillates a carrier in the FM broadcast band (76 to 108 MHz) and modulates it with the composite signal.
The RF amplifier creates energy to emit the modulated FM signal. It also functions as a buffer for the FM modulator.

Features

1. Low-voltage, low-power design.
2. Stereo modulator, FM modulator, and transmitter implemented on a single chip.
3. Few external components required.
4. High separation (45 dB typ.).

Applications

FM stereo transmitters
Wireless microphones

NOTE: VCC 1.5 TO 3 VOLTS
MORE THAN 3.5 V MAY BURN UP THE IC

Dimensions (Unit: mm)

BA1404

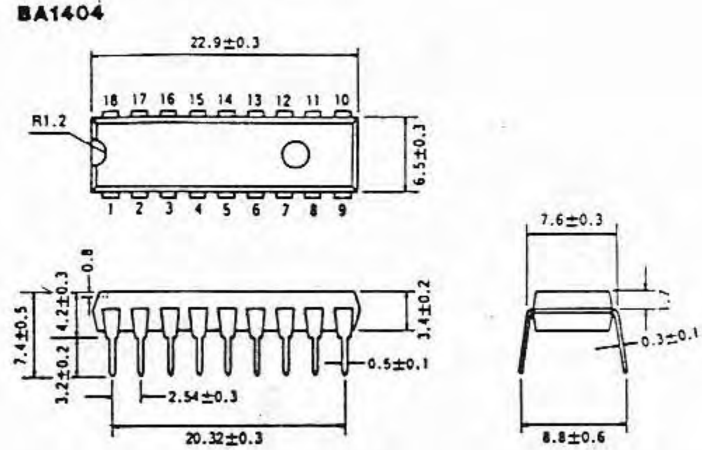


Fig. 1

BA1404F

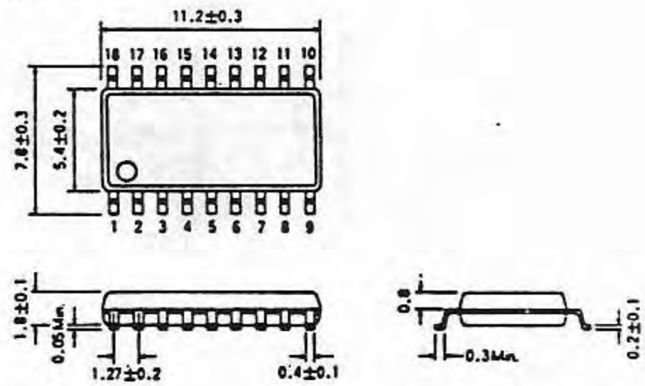


Fig. 2

Block Diagram

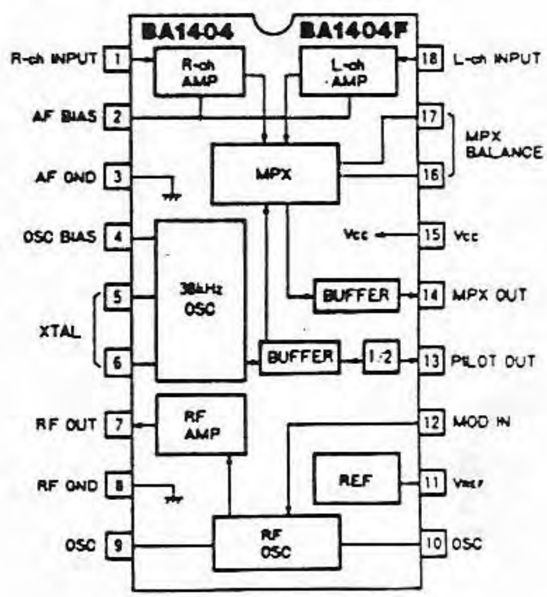


Fig. 3

Absolute Maximum Ratings (Ta = 25°C)

Parameter	Symbol	Limits	Unit
Supply voltage	V_{CC}	3.6	V
Power dissipation	Pd	500*	mW
Operating temperature range	Topr	−25 ~ 75	°C
Storage temperature range	Tstg	−50 ~ 125	°C

*Derating is done at 5mW/°C for operation above Ta = 25°C.

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Supply voltage	V_{CC}	1	1.25	3	V	—

Electrical Characteristics (Ta = 25°C, V_{CC} = 1.25V)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Quiescent current	I_O	0.5	3	5	mA	—
Input impedance	Z_{IN}	360	540	720	Ω	f_{IN} = 1kHz
Input gain	G_V	30	37	—	dB	V_{IN} = 0.5mV
Channel balance	CB	—	—	2	dB	V_{IN} = 0.5mV
MPX maximum output voltage	V_{OM}	200	—	—	mV p-p	THD ≤ 3%
MPX 38kHz leakage	V_{OO}	—	1	—	mV	Quiescent condition
Pilot output voltage	V_{OP}	460	580	—	mV p-p	No-load
Channel separation	Sep	25	45	—	dB	with standard demodulator
Equivalent input noise voltage	V_{NIN}	—	1	—	μV rms	IHF-A at 38kHz stop
RF maximum output voltage	V_{OSC}	350	600	—	mV	—

Test Circuit and Application Example

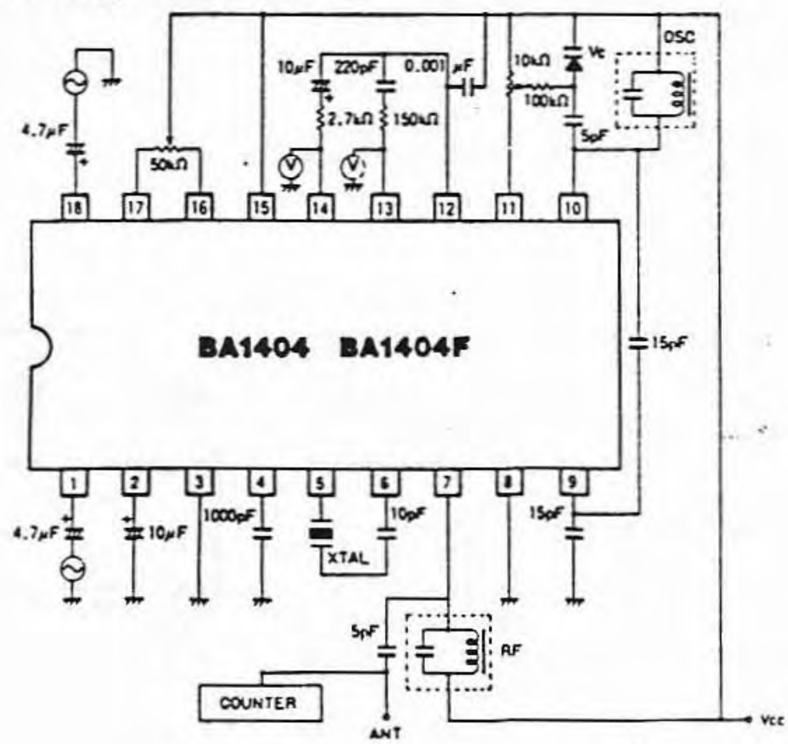


Fig. 4

Coil data (OSC, RF common)

Bobbin	φ5mm with ferrite core
Coil	φ0.5mm enamel wire
Numbers of turns	2.25 turns
Capacity	47pF

Precautions

1. To match the frequency response of the transmitter with the FM broadcast receiver, use a pre-emphasis network with a time constant of 50 μs at the input of the AF amplifier. Use the following circuit and components:

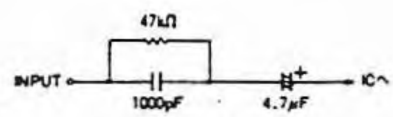


Fig. 5

2. When synthesizing a composite signal from the stereo modulator output with pilot signal, channel separation may deteriorate unless the two signals are in-phase. Note this point if you change the constants of the external components connected to pins 12, 13, and/or 14.

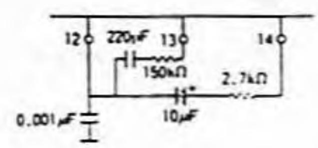


Fig. 6

Precautions

3. The carrier for an FM stereo signal can be modulated with an AF signal of up to 19 kHz. If impulse audio input, such as from an electronic musical instrument, is expected, use a low-pass filter at the input of the device to prevent beat interference or deterioration of separation.
4. While the device ensures good separation even if the balance control pins (16 and 17) are left open, it provides an even better separation if you connect around 50 kΩ across these pins to optimize the dc balance in the multiplex circuit.
5. The output voltage at pin 11 is internally set to (V_{CC} − 0.7) V.

BA1404 BA1404F

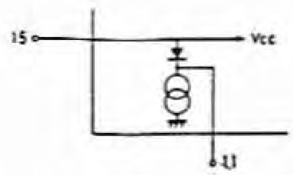


Fig. 7

Electrical Characteristic Curves

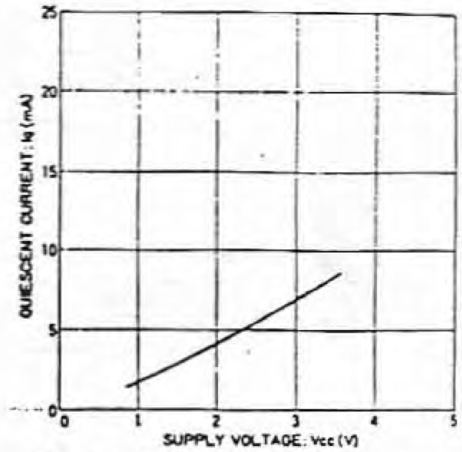


Fig. 8 Quiescent current vs. supply voltage

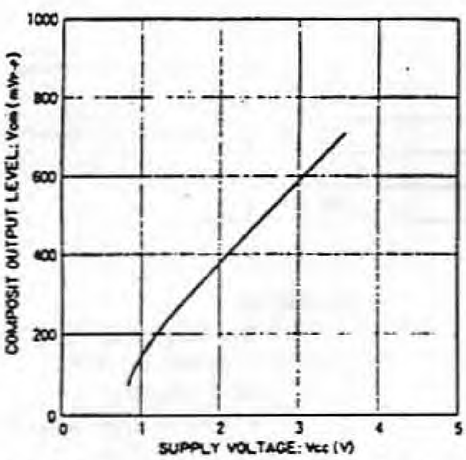


Fig. 9 Composite output level vs. supply voltage

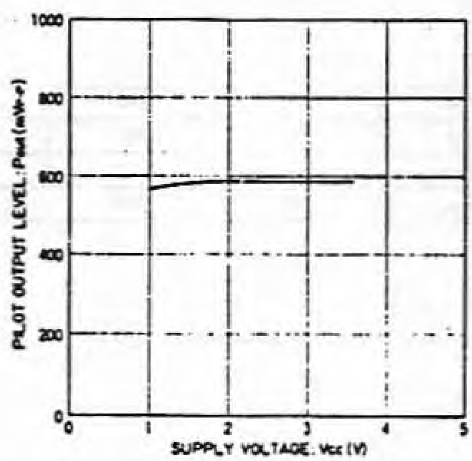


Fig. 10 Pilot output level vs. supply voltage

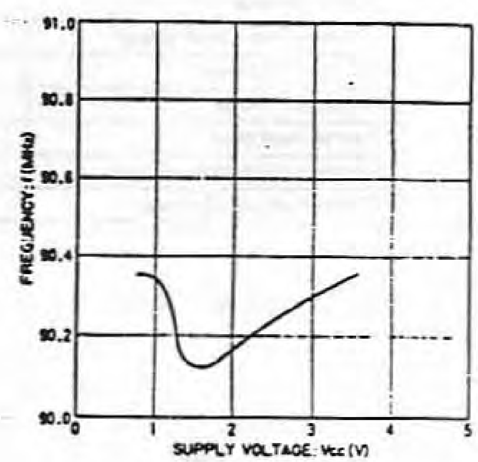


Fig. 11 Frequency vs. supply voltage

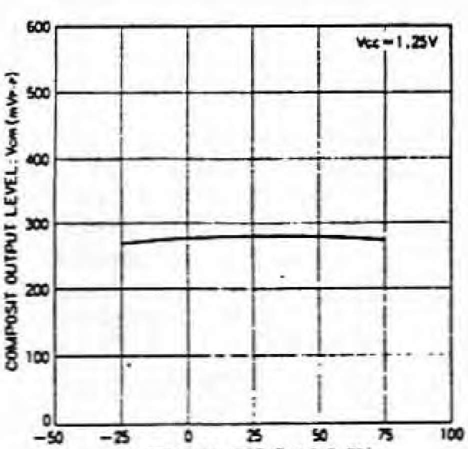


Fig. 12 Composite output level vs. ambient temperature

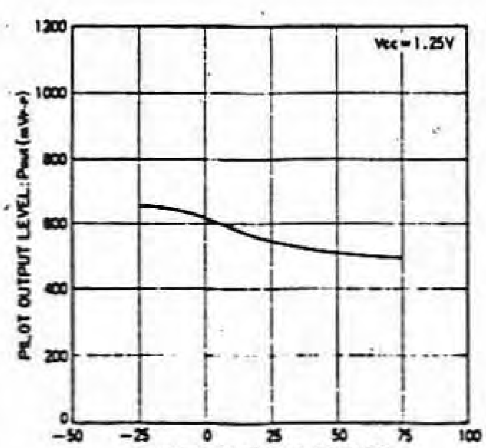


Fig. 13 Pilot output level vs. ambient temperature

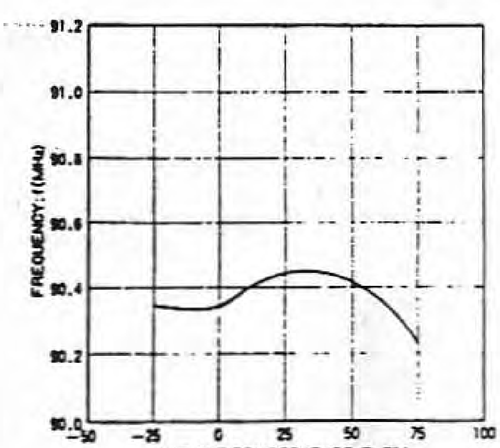


Fig. 14 Frequency vs. ambient temperature