

DIGITAL FM STEREO TRANSMITTER

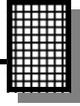


Ramsey Electronics Model No. FM35

A new and improved version of our popular stereo transmitters, the FM35 is an ideal upgrade for improved performance and ease of use! With a low-noise design and a metal case, the FM35 suffers from much less interference for a better S/N ratio. The FM35 also has full digital front panel control of output power, volume, balance, stereo/mono, and frequency!

- **Synthesized 87.9MHz to 108.1MHz for no frequency drift! Direct digital input of frequency, no jumpers or DIP switches!**
- **Designed for extruded, rugged metal case, all lines have RF chokes, and fully regulated for the cleanest sounding low noise performance yet!**
- **BNC style RF output for easy, reliable connections.**
- **Fully digitally controlled transmit power for custom coverage capabilities!**
- **Digital volume and balance controls for easy audio level adjustments.**
- **Runs from 13.8-16VDC, includes 15V DC adapter.**
- **Quality of signal indicator lets you know when you have a good signal or over-modulated signal. Lets you know when to turn it up, or down!**
- **Great for schools, health clubs, yard casting, drive-in movie theaters, haunted rides, amusement parks, churches, etc!**





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- FM100B, FM35 Professional FM Stereo Transmitters
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- CW7 CW Keyer
- QRP Power Amplifiers

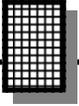
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FM35 Digital FM Stereo Transmitter
Ramsey Electronics publication No. FM35 Rev. 1.9c
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INSTRUCTION MANUAL FOR

DIGITAL FM STEREO TRANSMITTER

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INTRODUCTION

The Ramsey FM35 is a true SYNTHESIZED STEREO FM broadcast transmitter, which any person may build and use in accordance with the rules of their nation's telecommunications authority. For U.S. residents, that authority is the Federal Communications Commission (FCC). The FM35's low-power broadcasting capability and other practical uses can be fun and interesting for people of all ages, but the FM35 is not a toy. We will refer to the FCC regulations frequently in this manual and provide you with some information necessary to enjoy the FM35's capabilities in accordance with the law.

Typical uses for the FM35 include the following:

- Extension of home stereo system and computer audio - without wires.
- Listening aid for auditoriums, churches.
- Student-operated school radio station.
- College dorm favorite music broadcast service.
- Drive-ins, haunted hayrides, amusement parks, etc.
- Short-range, two-channel experiments and demonstrations.

We think you will be very pleased with the transmitting range, low noise, audio quality, frequency stability and stereo channel separation of this build-it-yourself synthesized FM stereo transmitter. If you use your FM35 in accordance with applicable FCC rules a whole new world of sharing music, news, and views with friends and neighbors awaits you.

Since the sharing of music and information is vital to the culture of our 21st century global community, we realized that our FM35 Digital Synthesized FM Stereo Transmitter was certain to attract worldwide interest among hobbyists, students and "pioneers." While the use of the FM35 may need to be limited to "wireless stereo extensions" in some USA households (to comply with FCC Rules, Part 15), we have seen it serve very well as a serious, though simple, broadcast station for remote villages throughout the world where low cost AM-FM receivers are available to people of all economic levels. While you're using your FM35, sitting back and listening to your own personal radio station, consider this: many other small transmitters like the FM35 are faithfully relaying news and information to listeners in remote areas around the world. The FM35 is most definitely not a toy!

FM35 CIRCUIT DESCRIPTION

We will begin by talking about the new and improved power supply section of the FM35. First off take a look at L1, C8, and C7. These parts form a low-pass filter designed to remove any RF from escaping through the power jack on the FM35, but more importantly to keep RF from entering back in! RF can easily get into power regulators and other components and cause them to “flake out” as we call it. The leads to hum and excessive noise in some cases, and can be very hard to remedy without these filters.

D1 is designed to protect you in the unlikely event that power is connected in reverse polarity. The diode is placed in-line with the power. Since a diode can only conduct in one direction, it prevents a reversed power supply from damaging your new FM35! We figured the addition of a this part was worth the peace of mind. C5 is another part used to reduce RF interference.

C13 is used to “smooth” any ripple there may be on the input to VR1, a 12VDC low dropout regulator. You may ask “what does low dropout mean?” No it doesn’t mean the regulator was made by a bunch of kids from a privileged school, it means that it can regulate lower voltages than it’s non-low dropout versions can. In this case to regulate to 12V, VR1 only needs about 0.8V across it, this means it can regulate 12.8V and up!

C9 is used in conjunction with VR1 for good regulation of the +12V. The +12V is then fed to VR2, a standard 5V regulator. This simply steps the +12V down to +5V for our logic and audio circuits. At this point our voltages are very well regulated for lowest noise! C10 works with VR2 for good regulation.

Now on to the audio input and control circuitry!

Audio is introduced into the FM35 at J8 (left) and J10 (right). For now we will only talk about the left channel, as the right channel is a duplicate of the left. Immediately after J8, you will notice L2 and C28. These parts are to prevent EMI produced from transmitting from getting into your FM35 and ruining the audio quality, similar to what we’ve prevented in the power supply above. After this filter the audio goes into U4:A, a simple rail to rail opamp. R46, U2:A, and R43 set the gain of the opamp.

You may wonder, where is U2:A? I don’t see any pots! Well, U2:A is a digitally controlled pot. Inside the IC are a bunch of transistors switching in and out resistor arrays to make a digitally controlled variable resistance. In turn, this variable resistance controls the gain of U4:A, thus U2:A is the volume and balance control! We just happened to draw the IC like a pot in the schematic software to make more sense.

After this gain stage, the audio moves on to U5:B, another opamp

surrounded by a bunch of resistors and capacitors. This arrangement of parts is a low pass filter. This filter is designed to help reduce high-frequency audio signals from mixing with the stereo pilot signal and producing mixing products of various frequencies. Ok, perhaps that is too much to bite off. In layman's terms, this low pass filter prevents high frequency audio signals like symbols and chimes from getting garbled up during the creation of a stereo signal before transmission, so it increases the audio quality of the final transmitted signal.

This signal is then piped off to U3, the BH1415F stereo modulator IC. We won't get into that quite yet, because we have another circuit of importance before this that you will find to be very helpful to you during day to day use! Take a look at D9, D10, and R39. These are peak detectors that sample both the left and right channels and combine them together, which is presented on pin 3 of U5:A. The levels that these diodes detect are then compared against the constant voltage level seen on pin2 of U5:A. Right now R33 and R38 are not used, but are there in case the threshold needs to be changed in future revisions. Your product uses the 2.5V bias reference because it happened to be the correct value to detect audio peaks. Notice I used the term compare; U5:A is set up to be a comparator since it has no negative feedback.

Once the voltage on pin 3 surpasses that on pin 2 (our reference), the state of the output pin 1 of U5:A goes high (5V). If the voltage on pin 3 goes below that on pin 2, the output goes low (0V). The comparator is set up with these specific diodes and voltage reference so that audio peaks surpassing a very specific level flip the comparator state back and forth. This change of state is then sent to the microcontroller U1, and the program in there counts how many times this happens in an interval of time and then computes a quality of signal value for you. In our case, the comparator is designed to detect peaks over +/-75kHz of deviation, which is the standard bandwidth used by radio stations. If you run the volume up too high on the FM35, the comparator reference level is surpassed often, the micro counts this, and an indicator on the display will show a poor quality of signal indication.

Speaking of the reference voltage, all of the analog circuitry needs to be biased up at 1/2 of the supply voltage so that your audio signal has the greatest possible dynamic range. We would like the analog signals to be able to go all the way from 0V to 5V, and in order to do this with minimal distortion we need 2.5V. This bias voltage is generated with a simple resistor divider and then noise filtered by capacitors. This voltage is then "amplified" by U5 which is set at a gain of 1 and then distributed to the rest of the analog circuitry.

This leads us to the next important part of the circuit, the microcontroller. This section is essentially the "brains" of the show. The microcontroller does several things all of the time; it checks for button presses, it counts the quality

of signal information, it measures RF power, and it updates the display. The microcontroller also does important tasks like converting the frequency value to text on the display that you can read, and signals that the stereo modulator IC needs to go to that frequency. It also sends the proper signals to the level control IC U7 DAC(Digital to Analog Converter) , U2, the digital pot, and DS1, the LCD display. In all there is a lot going on inside of the microcontroller, and be glad you don't have to do things with a bunch of dip switches any more.

Now here comes the fun part, the stereo modulator IC, U3. This IC is a great little part, and contains a lot of circuitry that helps us get on the air with minimal fuss, and great sound. This IC not only contains a stereo multiplexer, but also a phase locked loop (PLL), audio filters, and equalizations.

The audio filter portion of the part adds a little more low-pass filtering to the audio to increase quality more than what our external low pass filter does on its own. The equalization portion enhances the high frequencies for the radio standard of 75uS in the US. 75uS is just a term used for a high-pass filter to enhance the high frequency audio before transmission to help reduce noise upon reception.

The PLL is the portion of the IC which locks your chosen transmission frequency to the crystal reference X1. The PLL portion also contains an oscillator circuit which works in conjunction with the external parts of D5 and the STUB (that weird trace on the back of the board). D5 is called a varactor diode, and is a special variety of diode that is connected backwards. As a reverse DC voltage is applied across the diode, its capacitance varies. The higher the voltage, the less the capacitance. This is due to depletion layers of the diode junction, but we wont get into details here. This variable capacitor in conjunction with the stub, which is actually an inductor (coil) is the basis of our voltage controlled oscillator! As the voltage increases across D5, the frequency of oscillation increases.

The stub is just acting like a coil in this circuit, and because it is part of the circuit board layout, it has a very predictable value. This prevents us from having to tune anything in this section like our old products. Just turn the unit on, and you are good to go! The best part of the stub is it's low sensitivity to microphonics. Microphonics is a term used for mechanical vibrations that are picked up in a VCO circuit by vibrating components changing in value because of mechanical shock. The sub value is very hard to alter from mechanical shock, and therefore quite immune to vibration.

So what actually tunes the VCO you may ask? Good question. A PLL uses a phase comparator to compare the crystal frequency with the oscillator frequency combined with some internal dividers which are programmable. If the frequency is too low, U3's PLL tells pin 7 to turn up the voltage. This signal on pin 7 needs to be filtered and amplified for good control, and that is

provided by Q2 and Q3, along with R18, R17, C34, R20, C38, R21, and C33. All of these parts together act like a low pass filter to slow the tuning time enough for our multiplex signal to still be transmitted, but the tuning signals to not be transmitted. The parts in this section are carefully chosen for best operation in audio performance, but have the drawback of being really slow to tune from one end of the dial to the other. To speed it up would mean to lose some of the low frequency response of our audio signal. In the case of the FM35, we have made the PLL very slow to pass low frequency audio very well for best quality. You will just have to be patient when you turn the unit on before you can begin transmitting. Since most of these transmitters are left running all the time on the same frequency, we knew this wouldn't be a problem for most of you.

Now there are some other tricks going on in the PLL and the VCO circuit which you may wonder about. What is the purpose of U6, a DAC(Digital to Analog Converter)? Because we are tuning a broad range of frequencies in the FM30, the VCO's tuning sensitivity vs. frequency can change quite a lot. Without this part a properly adjusted +/-75kHz FM stereo signal at 108.1MHz may be +/-250kHz by the time you get down to 88.1MHz! This is unacceptable, because it would be very hard to know when you were over-modulating without test equipment. This would also render the quality of clipping detector useless. U6 corrects the tuning sensitivity by acting like a variable pot based on the tuning voltage. As the tuning voltage applied to D5 goes down, the microcontroller, U3, adjusts U6 based on transmitting frequency, so that less of the control signal from U3 pin 5 that is injected into the PLL control loop. It is a great little compensation circuit which keeps our signal within +/-10kHz of error across the band!

Now that we have our locked frequency and our multiplexed signal added to it we want to get the level up to where we can transmit it! The level directly out of U3 on pin 11 is small, just enough to cover a room, so we need to boost it a little. U8 is a high-gain amplifier which will get up the level for us so the FM35 has a little more "oomph". However we don't want too much "oomph" where we don't need it, so before the final amp we have D8, which is another special variety of diode called a pin diode. This diode has a neat way of working like a variable RF resistor. As you put more and more current through it, more and more RF will pass through it too. To vary the current through D8, we have U7 DAC. This will generate from 0-5 volts in 256 steps, and in doing so, will drive D8 with 256 steps of current control, which gives us the ability to control output level quite a bit. L5 and C62 prevent RF from getting back into the gain control of U7 and messing it up.

The higher level RF out of U8 is then sent through a low pass RF filter to reduce harmonics, and finally to the output jack where you would connect an antenna. L6 is simply to provide a DC path to ground in case of any static electricity or low frequency interference.

Whew, a lot to absorb here! Surprising how much great info can be gleaned from a simple transmitter, isn't it? We covered a lot of aspects of electronics here in one simple project, digital, power, RF, and analog. If you want more information on these subjects, there are a lot of great electronics books and websites out there, and here are some keywords to search for: COMPARATOR, VARACTOR DIODE, PIN DIODE, LOW PASS FILTER, DIGITAL POT, DAC (Digital to Analog Converter), MULTIPLEX.

Have fun and happy broadcasting!

-Ramsey Staff.

FM35 SETUP:

It's time to set up and test your FM35, then get on the air. You'll need an antenna and a line level audio source such as a CD player or computer sound card. Here we go!

FM35 operation is about as simple as it gets. The [SETUP] button cycles through the various screens, and the [UP]/[DOWN] button adjusts the value on the particular screen.

First of all, adjust the contrast pot, R1, if needed, by turning the orange top to the right (clockwise as you're looking at it) until it's about halfway to its stopping point.

Connect the included power supply. Also connect your antenna. You shouldn't operate the FM35 without some kind of antenna; a transmitter should always transmit into a load of some kind and not into an open, especially with a 1 watt RF power output.

Turn the transmitter on. You should hear a beep and see "FM-35, Rev 1.7" on the display, then in a few seconds the screen will change to a default display. The default display shows the current set power, frequency, clipping detector status, and the VCO voltage while still attempting to lock. Readjust your contrast now if you need to.

Pressing the [SETUP] button once brings us to the frequency display. Here, using the UP/DOWN buttons, we can select our frequency of operation. Note the voltage display which indicates the current VCO voltage. This helps us diagnose any problems if something goes wrong. If the voltage stays low (<0.5V) or high (>9.9V) no matter what frequency we choose, then the FM35 may not be locked.

Set your desired test frequency now. You should choose an open or "dead" spot on the FM dial as a starting point if you're not yet sure what frequency you can transmit on without interfering with anyone. Check the FCC information section of this manual for more details on legal part 15 broadcasting. Use the UP/DOWN buttons to select your frequency.

Pressing the SETUP again gets us to the mode display. Here you can toggle Stereo and Mono modes.

Another press of the SETUP button brings us to the volume display. Connect your line level source to the FM35. Your source can be a CD player line out, a computer sound card line output, or any other audio source you desire as long as it is line level. Anything other than line level audio will sound distorted and cost you time troubleshooting a non-existent problem. NEVER connect the

FM35 audio inputs to speaker outputs of a high power stereo system; such a connection will destroy the IC chip. Trust us when we say that a true line level audio source will give you the best results with your FM35.

The default volume setting is roughly $\frac{1}{2}$ of full, which is a gain of 1. This means that 500mV peak audio coming into the FM35 is 100% modulation, typically, depending on frequency. The volume display also includes the clipping detector status and you should adjust the volume until the indicator toggles from '–' to 'g' occasionally, roughly a 50/50 timing between the two, with an occasional 'c' mixed in. If the character is always at '–', the modulation is too low, and if 'C' ever shows up (capitol) it means you are overmodulating. It's best to set your level up or down until you see the lower case 'c', which means that you're on the edge of clipping. If you see the lowercase 'c' it means that you're distorting a bit so if you want to avoid that completely, make sure you set the level so that you only see the 'g'. Of course you can simply adjust the volume until it sounds right to you.

The order of characters is approximately on average:

'–' \leq +/-60kHz

'g' $>$ +/-60kHz and $<$ +/-75kHz

'c' $>$ +/-75kHz and $<$ +/-90kHz

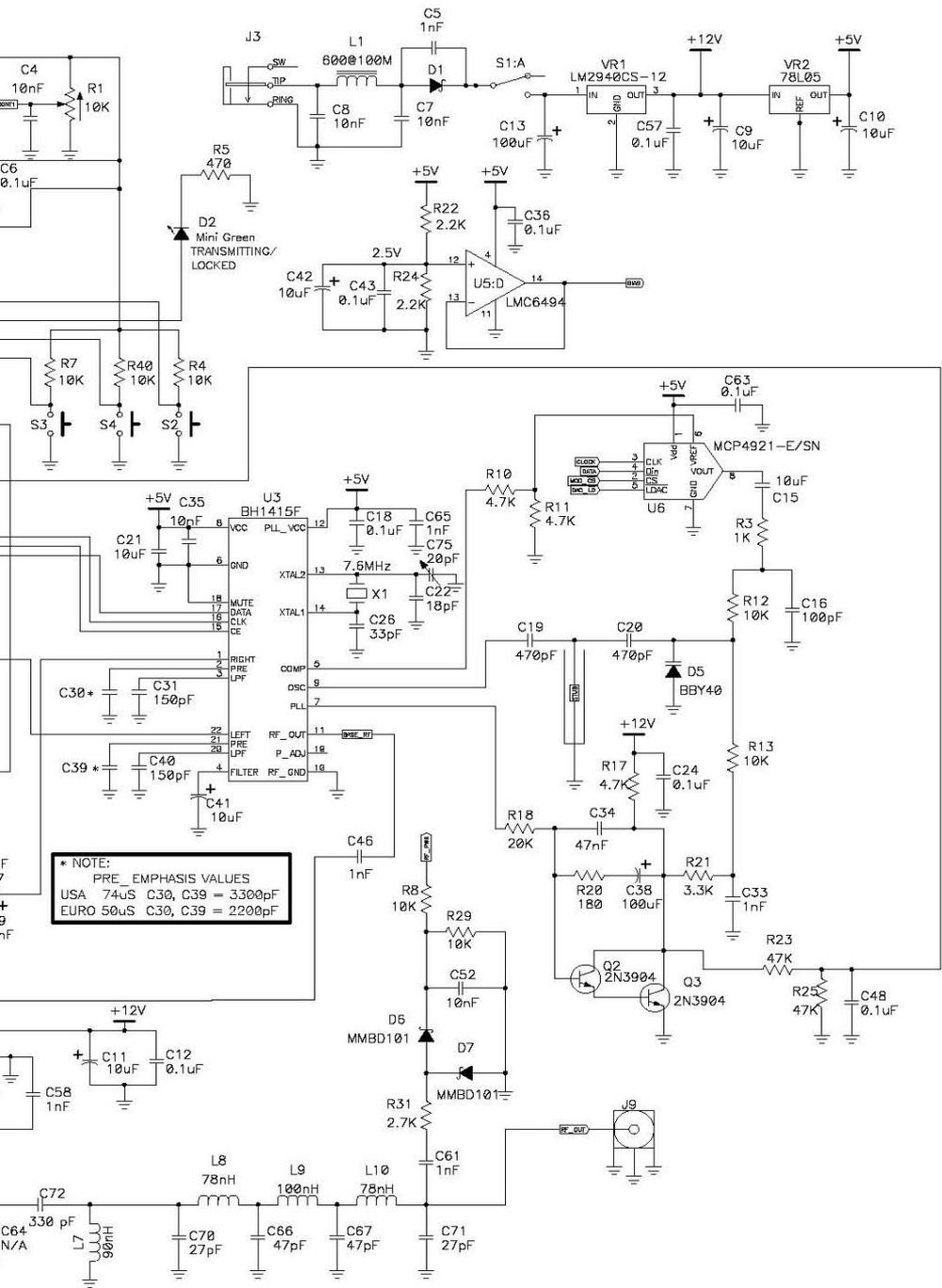
'C' $>$ +/-90kHz

Remember from the circuit description that the indicator doesn't specify the exact level, but the frequency with which the audio signal surpasses approximately 60kHz of deviation. The indicator is based on music signals, not test tones.

Again pressing the setup button will get us to the balance setting. The balance simply attenuates one side or the other depending on the adjustment. Set in the center there is no attenuation. Use the [UP]/[DOWN] buttons to swing the balance to the left or the right.

Press setup again to access the power adjustment. The best way to adjust this is to listen on a receiver into the transmitter input. (front living room, garage, deck) and have someone else turn up the power until you receive the signal clearly. Stop adjustment right at this point; this is as far as you will need to go! You may be surprised by how little power you really need. If you have to run it at full power you may need to play with the antenna a bit because that may indicate that you don't have a good match.

The last setup screen allows you to save all of your changes. Pressing the [UP] button will save them to the internal FLASH memory; [DOWN] will continue to use the current settings, but will not save them to FLASH in case you need to make some more changes. Cycling through all of the displays again will get you back to this screen to save all of your changes.



USING THE FM35 WITHIN THE HOME

Typical use for the FM35 would be to connect it to a personal computer within a large home so that whatever MP3 or other audio files are playing can also be tuned-in on portable FM radios in other rooms, the garage or out in the yard. Use the RF adjustment control to fine tune the RF output level to just reach the area you intend to cover.

The audio connection consists of using shielded audio cables to connect the line or speaker level output to the audio inputs of the FM35. Consult the literature that came with your stereo equipment.

Even if you intend use of the FM35 for your own home and family, it is still your responsibility, in accordance with Part 15 of the FCC Rules, to ensure that this operation does not cause interference to your neighbors.

EXPERIMENTAL "BROADCASTING" PROJECTS

To use the FM35 successfully as a "broadcasting" service for interested listeners in a school or immediate neighborhood, most of your effort will be concentrated on smoothly "managing" or mixing the audio signals fed into the transmitter input. Operation of the transmitter itself consists simply of the following:

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

The more home-built your complete setup, the more it is in conformity with the spirit of FCC Part 15 regulations.

You can greatly add to the versatility and professionalism of your transmitting station by adding an audio mixer and/or processor. Mixers allow you to smoothly 'blend' from one audio source to another just like the commercial stations do.

ANTENNA IDEAS

A simple, yet very effective, antenna for the FM35 consists of a "dipole", set up either horizontally or vertically, and connected to the transmitter output jack

through a few feet of coaxial cable (either RG-58, RG-59 or miniature RG-174, available at Radio Shack and other sources). Correct dipole lengths for major sections of the 88-108 MHz band are:

88 MHz, each side: 2.7 feet; 5.4 feet total
98 MHz, each side: 2.4 feet; 4.8 feet total
108 MHz, each side: 2.2 feet; 4.4 feet total

You can see that there's not a great difference in antenna length from 88 to 107 MHz. Some antenna designers have the view that an "approximate" dipole such as 2.5 ft. on a side will do fine, while others believe it is worth the effort to calculate the length for your exact frequency, using the simple formula of Length (of one side, in feet) = $234/\text{Frequency in MHz}$.

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

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

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

Ham radio books and magazines are filled with antenna principles and ideas which can be adapted to your application. Our TM100 Tru-match FM antenna is an ideal mate to your transmitter. It features proper impedance matching for optimum power transfer and range. See our catalog for details.

ANTENNA ALTERNATIVES

If your situation involves a single large building or multi-level home where reception from the FM35 antenna may tend to be uneven because of walls and other VHF path obstacles, you might set up the FM35's output in a "carrier-current" configuration. If you know how, then do so - safely. If not, you can show your FM35 and this book to a licensed radio engineer and negotiate with that person for a safe installation which will feed your signal through interior wiring of your home or building. Do not attempt such an installation unless you know exactly what to do and not to do. Also, because such an installation is beyond the original purpose of this product and the safety standards intended for all Ramsey kits, and because we have not tested the FM35 in such an installation, we cannot provide further details.

APPENDIX A: FCC RULES AND INFORMATION

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

An interim explanation of applicable FCC regulations supplied as a personal assistance to FM35 builders, by Dan F. Onley (K4ZRA)

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

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

To order your copy of FCC rules part 15, call the US Government, Superintendent of Documents, at 202-512-1800, or fax at 202-512-2250. To order the correct document, ask for "CFR Title 17: Parts 1 to 199." The cost is \$24.00. Master Card and Visa are accepted.

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

Licensed FM broadcast stations and their listeners have ALL the rights! Your use of a device such as the FM35 kit MAY have some limited privileges in locally-unused band space, but your non-licensed use of the FM35 has absolutely NO rights at all over the rights of licensed broadcast operators and the rights of their listeners to interference-free reception. If your operation of a device such as the FM35 interferes with ANYBODY'S use or enjoyment of an FCC licensed transmission of any kind, your only choice is to IMMEDIATELY terminate or change the operation of your low-power transmitting device so as to cause no more interference. That's it! No discussion, no exceptions.

Unlicensed operation of small transmitting devices is discussed in "Part 15" of the FCC Rules. These Rules are published in 100 "Parts," covering everything imaginable concerning the topic of "Telecommunications." The six books containing the FCC Rules are section 47 of the complete Code of Federal Regulations, which you are likely to find in the Reference section of your Public Library. If you have questions about the legal operation of your FM35 or any other kit or home-built device which emits RF energy, it is your responsibility to study the FCC regulations. It is best if YOU read (and consult with a lawyer if you are in doubt) the rules and do not bother the understaffed and busy FCC

employees with questions that are clearly answered in the rules.

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

1. In the past, no "two-way communications" use of the 88-108 MHz FM broadcast band was permitted. This prohibition does not appear in the current edition of Part 15. Previous editions of Part 15 discussed "wireless microphones" (such as Ramsey FM-1, FM-4, etc.), while the June 23, 1989, revision eliminates this discussion in favor of more detail regarding computer and TV peripherals and other modern electronic conveniences. However, it is not immediately clear that the 1989 revision of the FCC Rules Part 15 necessarily "cancels" previous regulations. Laws and rules tend to remain in force unless they are specifically repealed. Also, FCC Rule 15.37 discusses "Transitional Provisions for Compliance with the Rules," and states in item (c): "There are no restrictions on the operation or marketing of equipment complying with the regulations in effect prior to June 23, 1989."
2. It is the sole responsibility of the builder-user of any FM broadcast-band device to research and fully avoid any and all interference to licensed FM broadcast transmission and reception. This instruction manual gives you practical advice on how to do a good job of finding a clear frequency, if one is available.
3. For some frequency bands, the FCC sets 100 milliwatts (0.1 watt) as the maximum permitted power output for unlicensed, home-built transmitting devices, and that the combined length of your antenna and feedline (coaxial cable or other) must not exceed 10 feet. The technical standards for 88-108 MHz are very different, primarily concerned with band width and RF field strength.
4. FCC Rules do not differ for "stereo" or "monaural" transmissions.
5. Broadcasting on the grounds of a school (AM emissions only) is specifically permitted and encouraged between 525 and 1705 KHz under Part 15.221. Use our AM-1 AM radio broadcast kit for this use.
6. FCC Rule No. 15.239 specifically addresses operation in the 88-108 MHz FM broadcast band for which your FM35 transmitter kit is designed. However, this Rule does not, by itself, tell you everything you need to know about using a device of this kind. Therefore, we are noting a series of Part 15 regulations which should be observed:
 - a. The "bandwidth" of your transmission is limited to 200 KHz, centered on the actual operating frequency. Since 200 KHz is enough spectrum

space for several different FM stations, this is a "generous" limitation designed to accommodate cruder FM devices. Properly built and adjusted, the FM35 kit operates well within this limit. In fact, its signal should sound no "wider" than any other FM station when listening on an ordinary FM radio.

- b. FCC Rule 15.215(a) says: "Unless otherwise stated, there are no restrictions as to the types of operations permitted under these sections." This general provision appears to leave you free to use your FM stereo transmitter in a manner similar to operations of an FM broadcasting station, or to use it for any other non-interfering, practical application.
- c. FCC Rule 15.5: General conditions of operation: "(b) Operation...is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical equipment, or by an incidental radiator. (c) The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference."
- d. The most specific FCC regulation of 88-108 MHz FM Broadcast band unlicensed operation is that the "field strength" of the signal must not exceed 250 microvolts/meter at a distance of 3 meters from the transmitter (FCC rule 15.239). If you have any concern about this emission limit, have your device checked by a technician with accurate measuring equipment. Remember that the "field strength" of a signal is determined as much by the antenna as by the RF output of the transmitter itself.

APPENDIX B: UNDERSTANDING LEGAL "FIELD STRENGTH"

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

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

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

| DISTANCE FROM TRANSMITTER ANTENNA | | | |
|--|-------------|----------------------------|-----------------------------|
| METERS | FEET | FIELD STRENGTH (μV) | TOTAL RECEPTION AREA |
| 3 | 10 | 250 | 314 FT |
| 6 | 20 | 125 | 1256 FT |
| 12 | 39 | 63 | 4800 FT |
| 24 | 78 | 31 | 19113 FT |
| 48 | 157 | 15 | 1.8 ACRES |
| 96 | 315 | 7.5 | 7.2 ACRES |
| 192 | 630 | 3.8 | 28.6 ACRES |
| 384 | 1260 | 1.9 | 114 ACRES |
| 768 | 2520 | .95 | 458 ACRES |
| 1536 | 5036 | .5 | 1830 ACRES |

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

For other kinds of radio services, the FCC restricts such factors as transmitter power or antenna height, which cannot really limit the possible "range" of a transmission under good conditions. By restricting the maximum field strength

at a specific distance from your antenna, the FCC clearly plans for your signal to "die out" at a specific distance from your antenna, no matter what kind of transmitter power or extra-gain antenna you are using. On the other hand, the FCC standards do make it legal and possible for you to broadcast on a school campus, campground or local neighborhood, as long as you do not cause interference to broadcast reception.

"Why talk about acres"?

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

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

In fact, the most significant distance in the above chart is the 1.9 μV signal strength permissible at 1260 feet (about 1/4 mile), covering a circular area of about 114 acres. A quick glance at stereo FM receiver specifications shows typical sensitivity of 1.7 μV before considering high-gain antennas or preamplifiers. Your non-licensed signal can provide serious competition to a public broadcast station fifty miles away, a station which someone in your neighborhood may have set up a special antenna to enjoy.

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

SUMMARY

The present edition of Part 15 of the FCC rules does not provide detailed guidance on ALL aspects of using a low-power transmitter such as the FM35. The main point is that you may not cause any interference whatsoever to licensed broadcast services and that you must be willing to put up with any interference that you may experience.

In addition to operations not requiring authorization, you also have the option of writing a clear and polite letter to the FCC Engineer-in-Charge of your local

district, describing your intended operation. Mention the operating frequency and planned hours of operation. This could be a good step to take if your project is in behalf of a school, Scout or community group.

If you become further fascinated with the service rendered by low-power broadcasting, other FCC regulations explain how to apply for a license or other authorization which may permit you to upgrade your FM35 or other equipment to accomplish any objective which the FCC sees to be in the public interest and not interfering with other authorized uses of the radio spectrum.

Lawful use suggestions

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

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

NOTICE:

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

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

Final comment

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

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

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

CONCLUSION

We sincerely hope that you will enjoy the use of this Ramsey product. As always, we have tried to compose our manual in the easiest, most "user friendly" format possible. As our customers, we value your opinions, comments, and additions that you would like to see in future publications. Please submit comments or ideas to: techsupport@ramseyelectronics.com

And once again, thanks from the folks at Ramsey!

THE RAMSEY KIT WARRANTY

1. GENERAL:

Notice that this is not a "fine print" warranty. We want you to understand your rights and ours too! All Ramsey kits will work if assembled properly. The very fact that your kit includes this new manual is your assurance that prior to release of this kit, a varied group of knowledgeable people have assembled this kit from scratch using this manual. During this process, changes and additions are noted by each assembler and integrated into the final version of the manual...which you have! If you need help, please read through your manual carefully, all information required to properly build and test your kit is contained within the pages! However, customer satisfaction is our goal, so in the event that you do have a problem, please note the following:

2. DEFECTIVE PARTS:

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

3. MISSING PARTS:

Before assuming a part value is missing, check the parts listing carefully to see if it is a critical value such as a specific coil or IC, or whether a RANGE of values is suitable for the component (such as a "100 to 500 uF capacitor"). Often times, common sense will solve a mysterious missing part problem. If you're missing five 10K ohm resistors and received five extra 1K resistors, you can pretty much be assured that the "1K ohm" resistors are actually the "missing" 10 K parts ("Hum-m-m, I guess the orange band really does look red!") Ramsey Electronics project kits are packed with pride in the USA by our own staff personnel. While separate QC checks are made on all product kits, we too are human, and once in a great while there is a chance something can get through those checks! If you believe we packed an incorrect part or omitted a part clearly indicated in your assembly manual for your Ramsey kit, please contact us with information on the part you need. Contact our Repair Department via telephone, email or writing. Please have your invoice number and date of purchase handy.

4. REFUNDS:

All Ramsey products, kit or factory assembled units have an unconditional 10 day (from the date of purchase) return policy to examine our products. If you are not satisfied for any reason, you may return your unassembled kit with all the parts and instructions, or your factory assembled and tested product, together with your proof of purchase to the factory for a full refund less shipping. The return package should be packed securely. Insurance and tracking is highly recommended. A reminder, this applies to unassembled kits. They must be in the same new condition as received, not partially assembled! Assembled kits cannot be returned for credit. No RMA's are required; simply return to Ramsey Electronics LLC, Attn: Product Returns, 590 Fishers Station Drive, Victor, NY, 14564. If you have any questions, please contact us at 585-924-4560.

5. FACTORY REPAIR OF ASSEMBLED KITS:

Most of us at Ramsey are technically oriented and we do realize that things happen! Even following the best practices, with all of the best intentions, there is that chance that your kit doesn't work when you have completed it. Each manual goes into detailed troubleshooting based on the specific kit to help you troubleshoot the problem. We have found that 95% of returned kits involved wrongly installed components (wrong part or backwards polarity). This section of the warranty assumes you have gone through all those steps, and have now reached the point that you need to send it back.

To qualify for factory repair of customer assembled kits, the following conditions apply:

1. Kits must not be assembled with acid solder flux
2. Kit boards or circuits must not be modified in any manner from the version received
3. Kits must be fully assembled, not partially assembled. Our warranty does not include "finishing" your kit!
4. Must include a full description of the problem encountered including the troubleshooting steps you have already done.
5. Must not include non-standard, non-Ramsey accessories, cases, enclosures, knobs, etc. or any batteries.
6. Must include the minimum repair fee of \$25 USD in the form of check, money order or credit card authorization.
7. Ramsey Electronics, LLC reserves the right to refuse any repair due to excessive errors in construction methods.
8. If, due to customer construction methods, the repair is estimated to exceed the minimum flat rate, Ramsey Electronics, LLC will contact the customer to discuss the repairs needed and to receive authorization and payment for repair prior to repair.
9. In the unlikely case that a defective part is found to be the cause of the problem, the repairs will be made at no-charge to the customer, and any payments received for repair will be returned or credited back to the customer.
10. Properly pack your kit, insure the package, and use a carrier that can be tracked. Ramsey Electronics, LLC is not responsible for any loss or damage in shipment. Send the package together with your repair fee to the return address below. No RMA is required.

6. FACTORY REPAIR FEES:

Please understand that our Tech Support Group personnel are not volunteers! They are a dedicated group of highly trained technicians each configured with a very properly equipped test bench. Upon receipt of a repair, the setup, testing, diagnosis, repair, paperwork, and repacking of your kit requires nearly an hour of their time regardless of the size or complexity of the kit! The minimum repair fee represents ½ hour Tech Support time at \$50/hour USD. We try to keep all kit repairs within the realm of the \$25 flat rate whenever possible...and trust us; we exceed that time spent on most kits received more often than not!

7. CONTACT INFORMATION AND RETURN ADDRESS:

Technical Questions

RAMSEY ELECTRONICS, LLC
Attn: Tech Support
590 Fishers Station Drive
Victor, NY 14564
585-924-4560; 585-924-4886 Fax
techsupport@ramseyelectronics.com

Product Repair & Returns

RAMSEY ELECTRONICS, LLC
Attn: Repairs
590 Fishers Station Drive
Victor, NY 14564
585-924-4560; 585-924-4886 Fax
repairs@ramseyelectronics.com

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