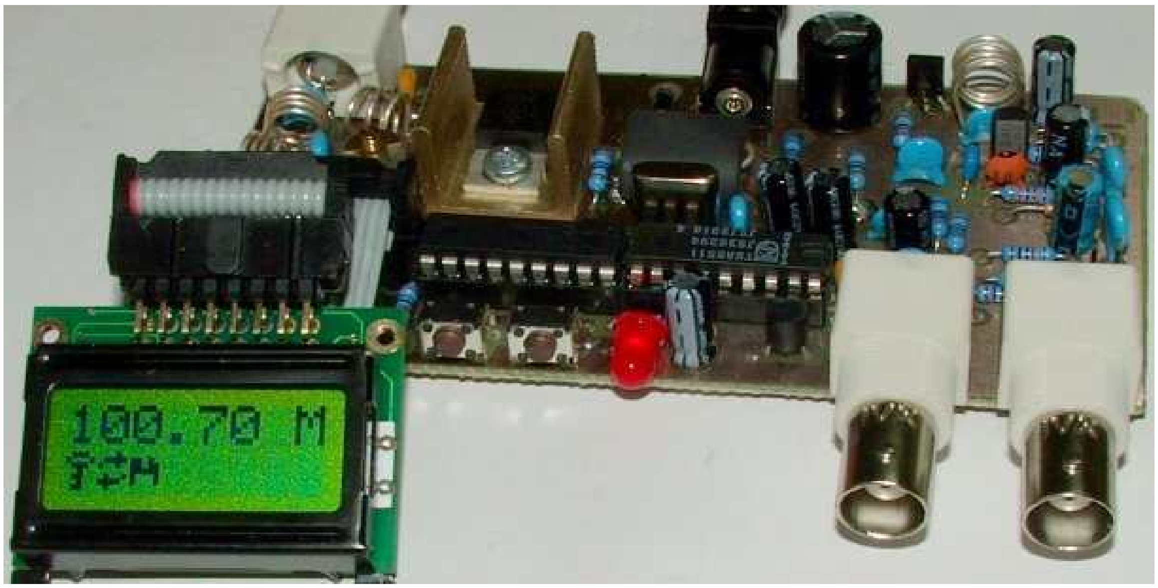
Assembling the modified (lower output) version of the Pira 5W PLL Transmitter

Modifications in these instructions reduce the five-watt transmitter at Pira.cz to only 150–200 mW; some parts have been removed and jumpers are put in their place. These instructions were written by (wvengineer) Tim Yoos at the Do It Yourself Christmas Forums.



This is an easy-to-build, high-quality PLL FM transmitter with a typical output power of 150-200 mW and no-tune design. The transmitter includes RDS/SCA input and Audio/MPX input with optional pre-emphasis. It can be used with or without a stereo encoder. Tuning over the FM band is provided by two buttons. The transmitter works with or without the LCD display.

The original design for this transmitter is not my own and I take no responsibility for this project. The schematic, parts list, and parts layout can be found at http://pira.cz/entx4.htm I merely wanted to go in detail of the building process and provide a step-by-step guide throughout the build.

These are the same fellows that make the RDS encoder many at DIYC use and they also make many other things FM-related; be sure to check out everything at: http://pira.cz

The first part of these instructions will focus on all the surface-mount components on the underside of the PCB. Then we will attack all the other parts on the component side, first with the resistors and jumpers, then move on to all the capacitors, then the IC sockets, buttons, connectors, headers, etc.

Table of contents

Tools you will need

- Soldering iron, preferably with a conical tip.
- Rosin core solder.
- Braided solder wick.
- Needle nose pliers.
- Wire cutters.
- Fine tip tweezers.
- Magnifying glass.
- Quarter-inch, No. 20 bolt, one inch or longer.
- PIC programmer (PICkit2 or similar).
- Windows-based PC to drive PIC programmer.
- Hot glue gun or non-corrosive silicone
- Rubbing alcohol and cotton swabs

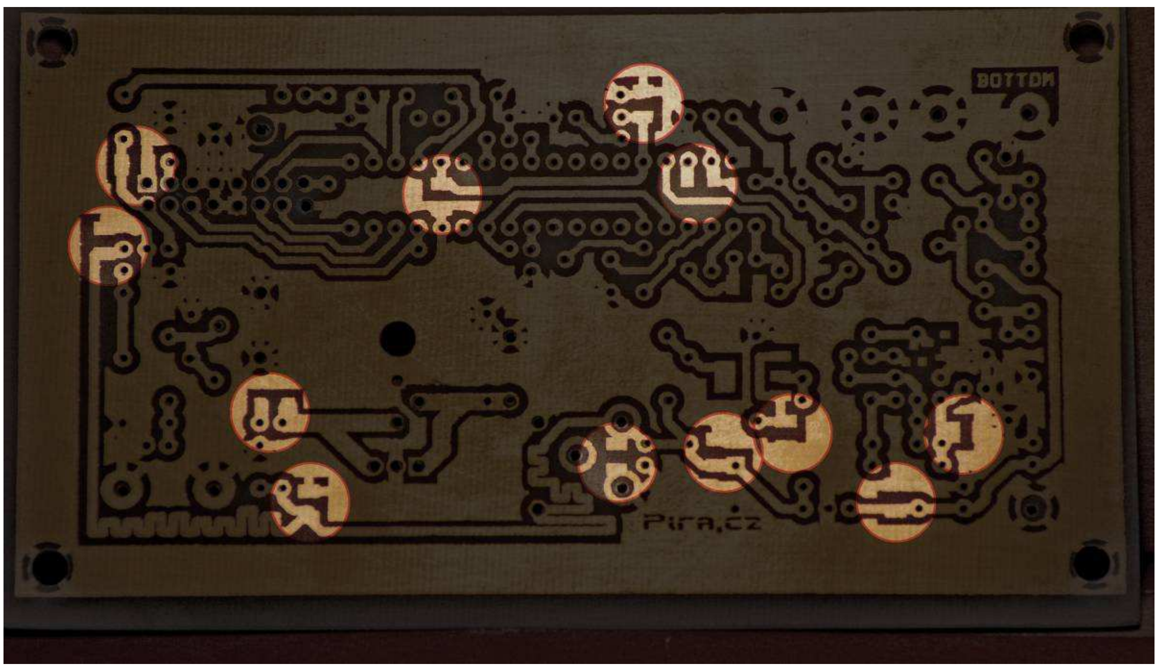
Part 1: Surface-mount components

Section A: .1uf capacitors

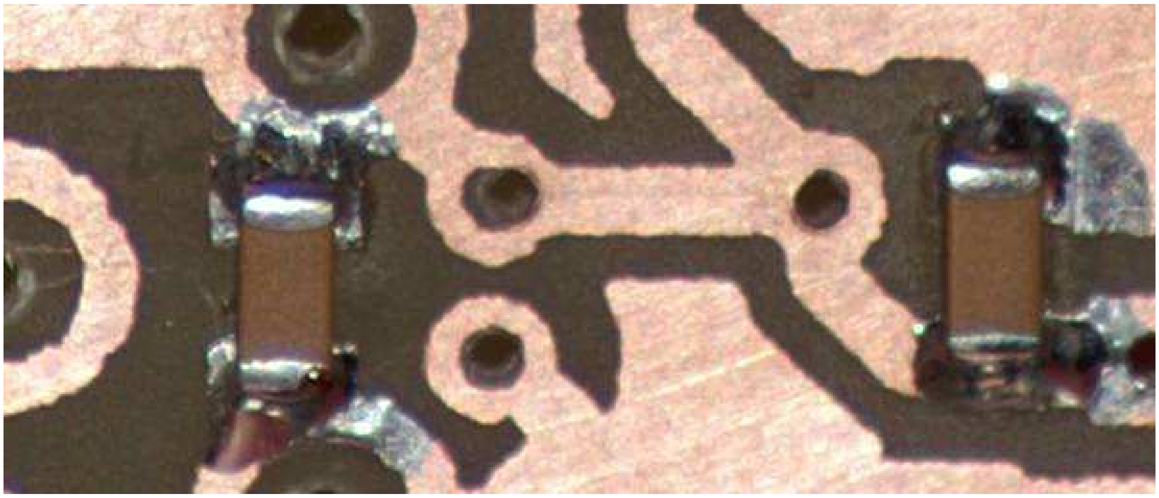
There are a total of 12, .1 uf SMD caps in this project; they are most likely labeled in the package as 10,000 Pico Farad 1206 SMD Chip. Pre-solder the following pads on the board shown here in the photo below. Make sure your board is clean from any oils or residues and give it a quick clean with a Scotch Bright pad to remove any oxidation before you solder anything.

The parts listed from his original parts list show these caps as: C1, C4, C9, C12, C13, C14, C15, C30, C31, C32, C33, C35 10n SMD 1206 (Ceramic). 10N can be either shown as 10nf, .1uf, 10,000pf, or 103; they are all the same value.

Some SMD capacitors don't even show a value. In this case you not need to worry we are working with only one value here.



Use some solder wick to take up all the excess solder and use cotton swabs (Q-Tips) and rubbing alcohol to clean up the flux, this will prep the board for the parts.



OK, now gently with a pair of tweezers, place one of the caps onto the pad and with your clean soldering iron just hit it with a small dap of solder and tap one side of the cap to secure it in place. Now apply a small amount of solder to the other side of the capacitor and then retouch up the first side.

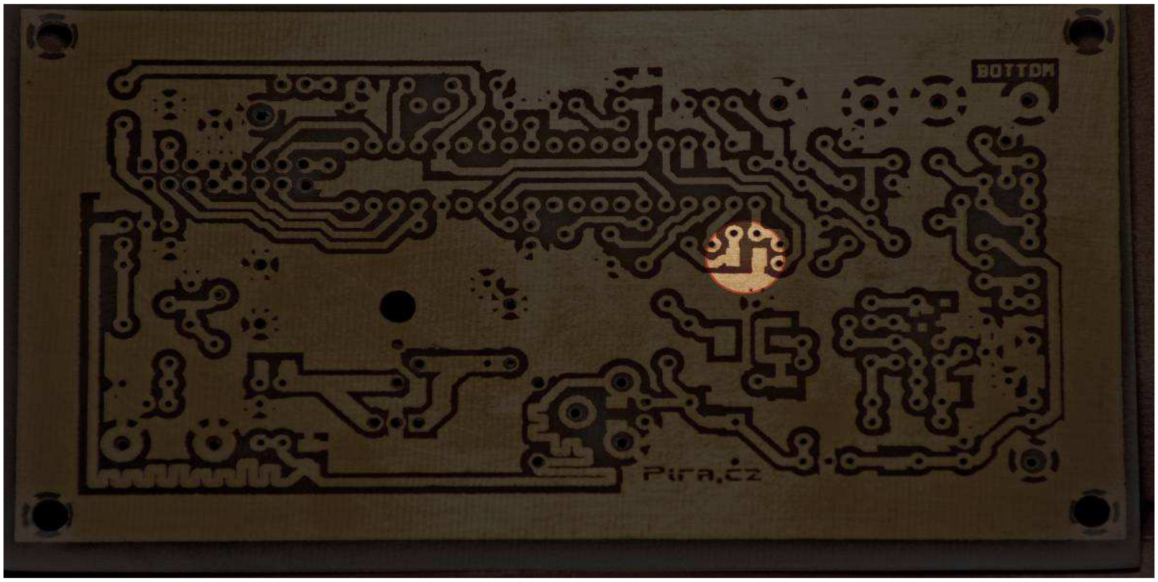
Make sure you do not use too much pressure with the tweezers or with the soldering iron as these chips can break. Less is more with surface mount devices; you're not trying to weld an I-beam. Using an iron with a conical tip is best, but if you have soldered surface mount devices before, use the method you prefer.

Once soldered in place, clean up the joints with a cotton swab (Q-Tip) and some rubbing alcohol to remove the flux. It is much easier to clean off right after soldering than after it has cooled off.

Repeat these steps until you have all 12 capacitors soldered in place

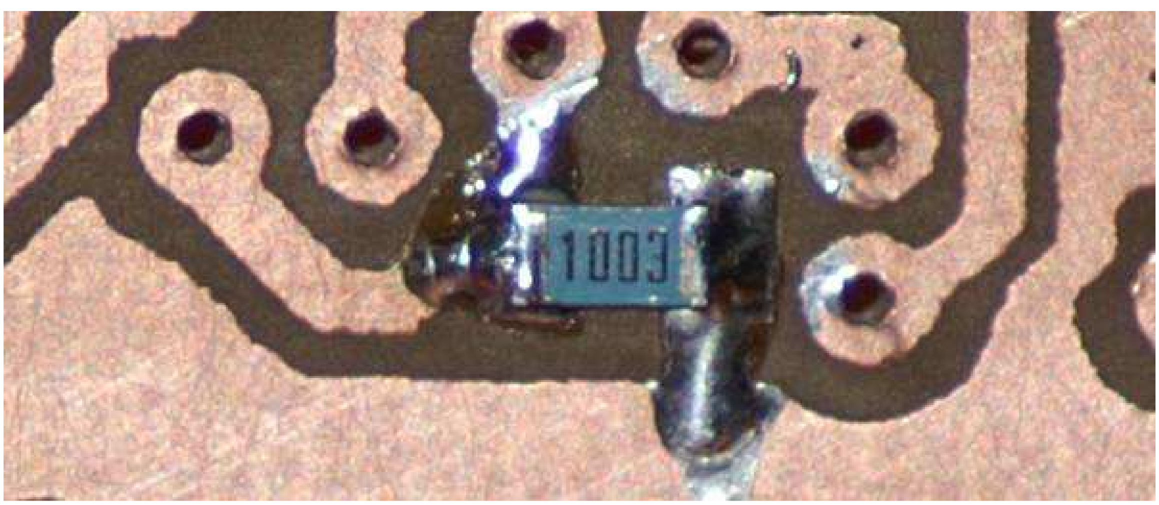
OK, let us take a short break and then we will go to the only SMD 100K resistor and the RF transistor on the board.

Section B: 100K Ohm SMD resistor



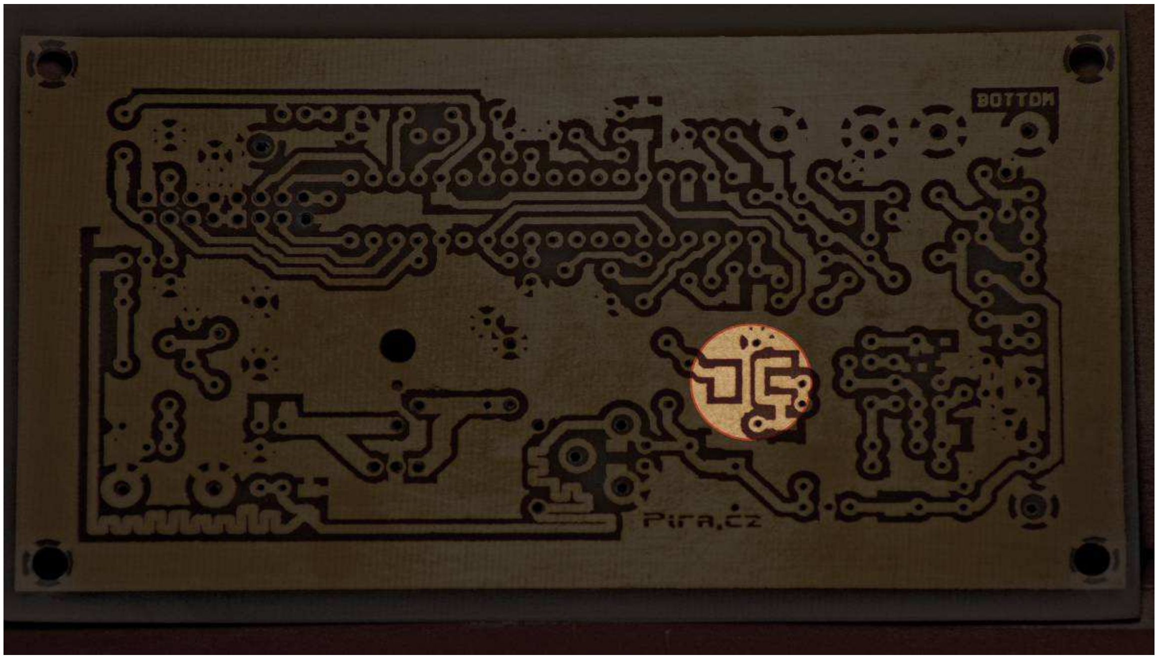
Following the same steps from the earlier instructions, pre-solder the area where the (R19-100k SMD 1206) resistor will go, then remove the excess with solder wick and then clean the area.

Using the tweezers, place the chip and take your pre-wetted soldering iron to tack one side in place. Then solder the other side of the resistor and retouch the first side … should look similar to this photo:

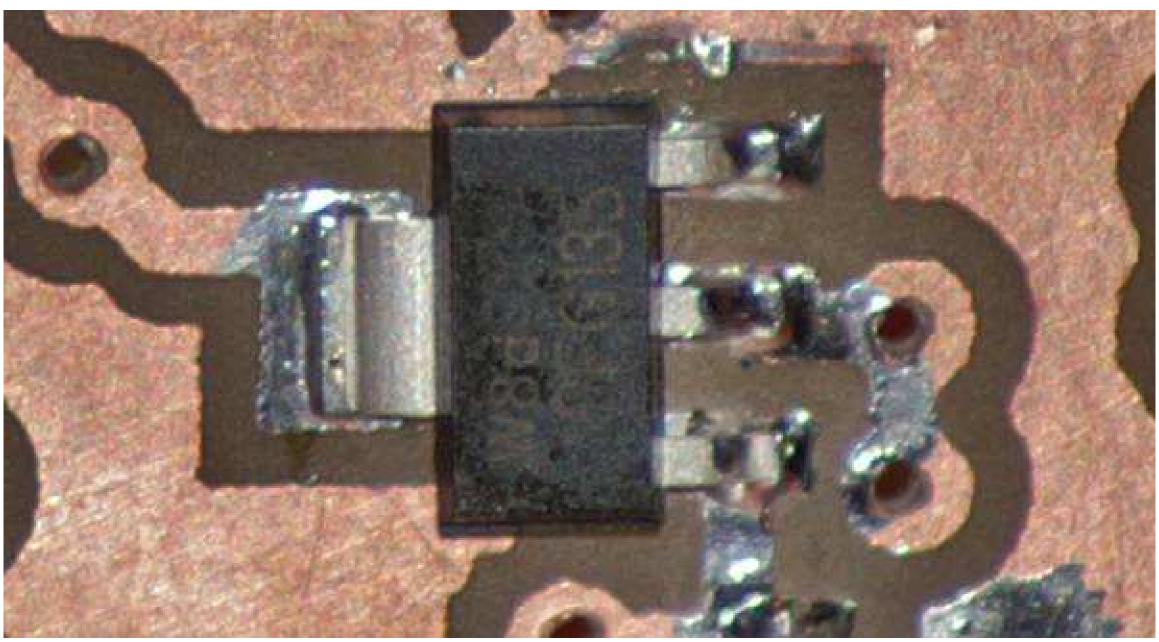


Section C: BFG135 NPN 7Ghz RF transistor

OK, now let's solder the (Q2-BFG135) transistor. This one is rather simple because it is larger in size than the capacitors we have been working with.



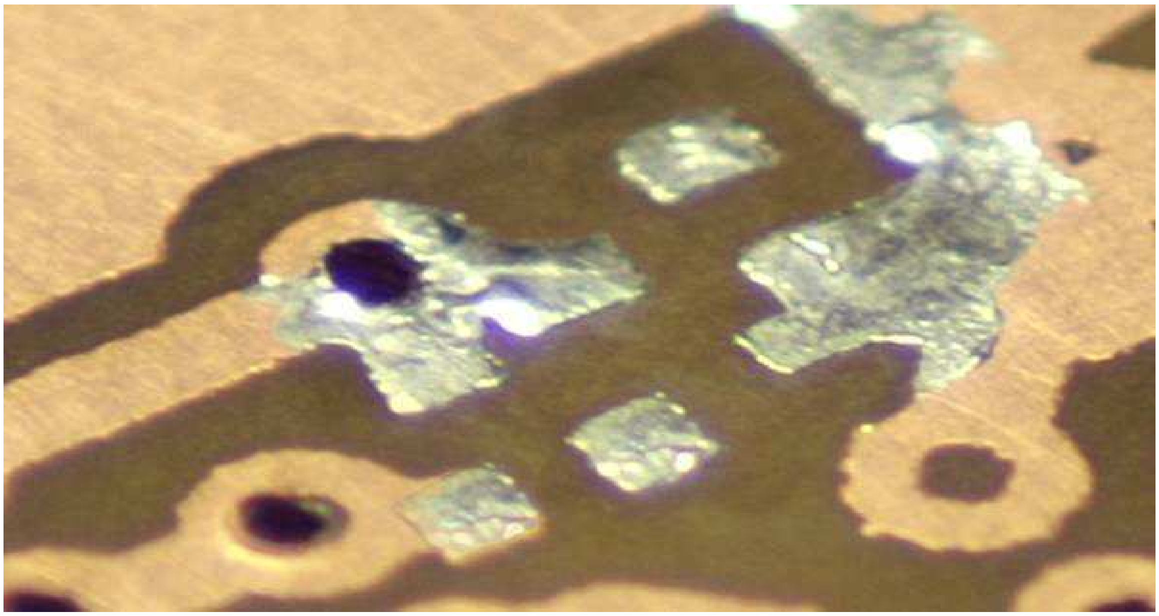
Again, apply the same technique, but be careful to align all the pads. It is best to first tack on of the smaller tabs to secure it in place, then solder the rest.



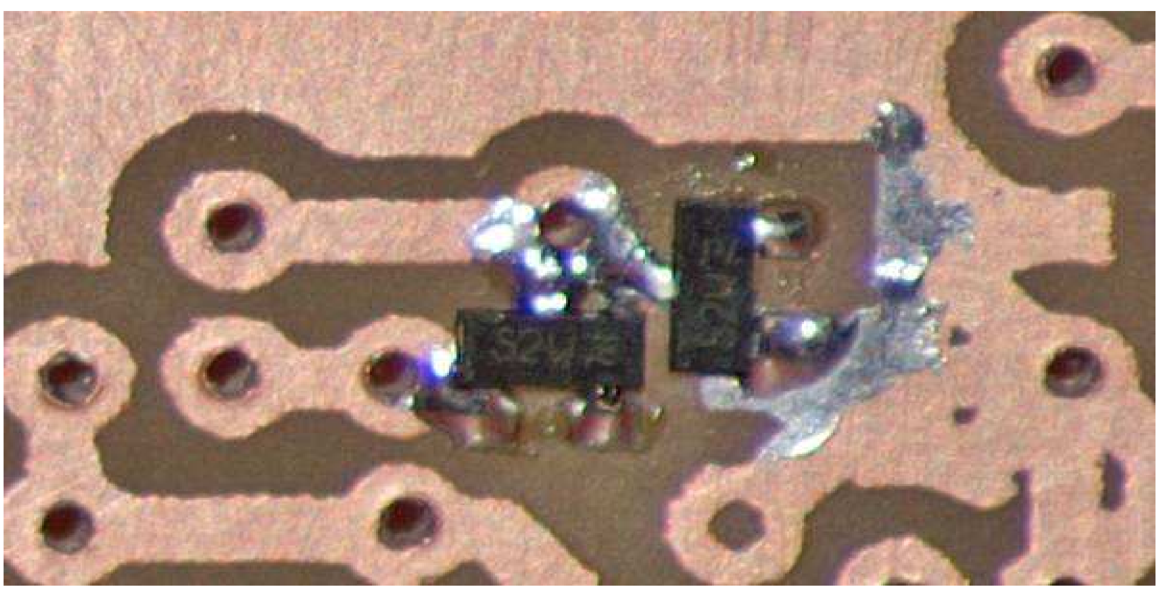
OK, let's take another small break; next, two little diodes will be the most interesting yet.

Section D: BBY40 VHF variable capacitance diodes

First, prep the area with solder, then remove the excess solder with wick and clean the area with a cotton swab (Q-Tip) and alcohol. You can see on each diode there is a pad that goes nowhere. These pads are of no use other to help keep the part secured to the board.

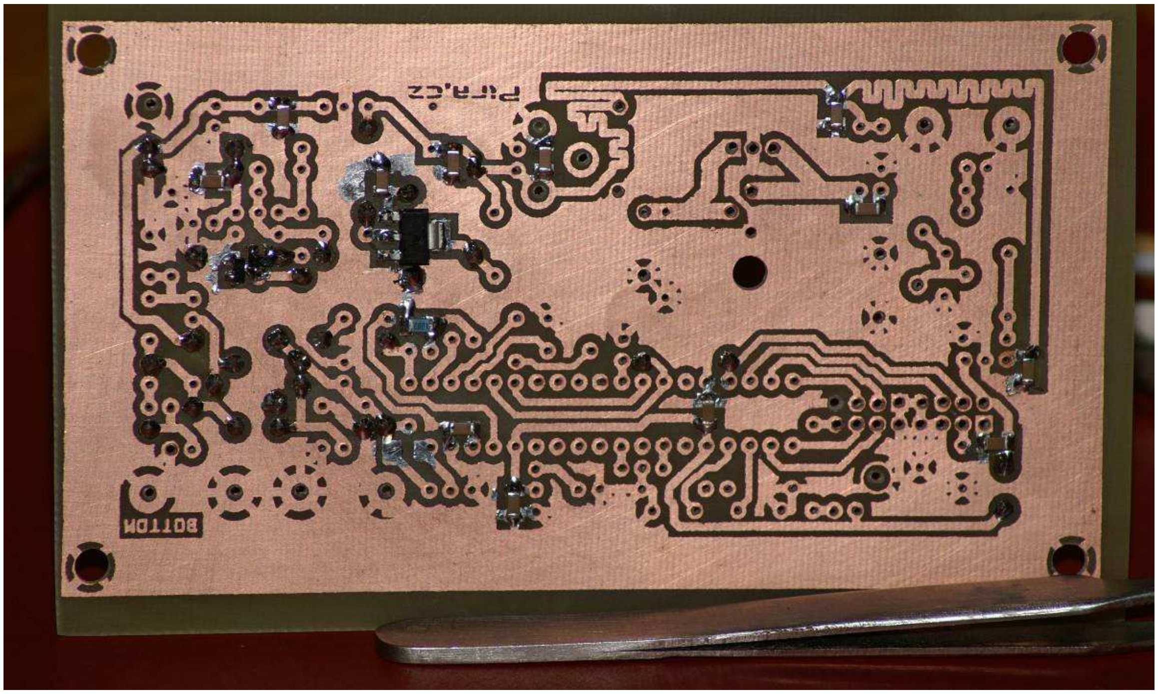


Carefully place the diodes on the board and with the pre-wetted soldering iron, tack the first diode in place. Make sure the printed side is up. Then add a little solder to the other remaining pads.

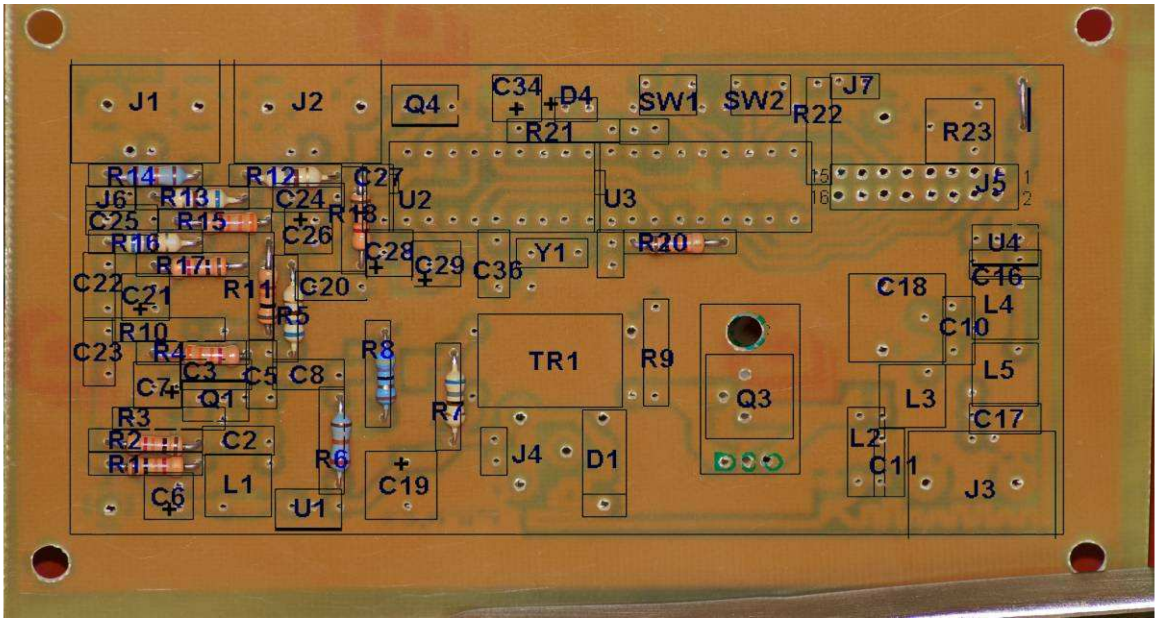


The Pira 150mw modified transmitter

OK, now that all the hard work is out of the way, the rest is a piece of cake. Be proud of the work you have done — soldering surface mount devices can be tricky, but can be easy if you take your time.



Part 2: Resistors

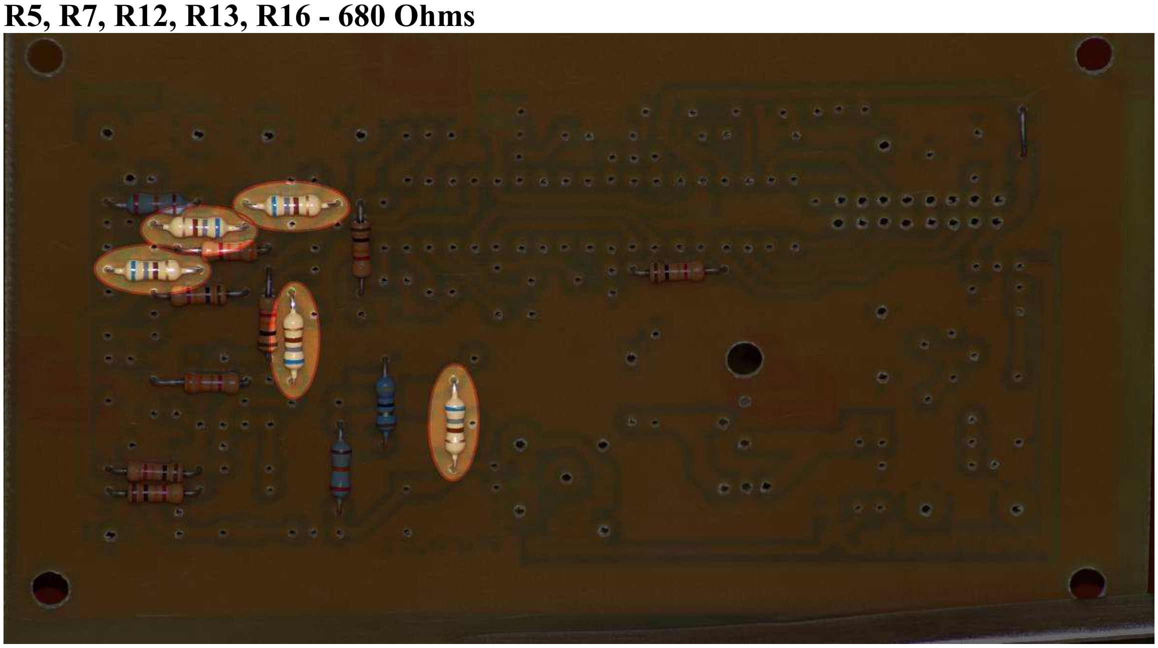


Parts Layout

The following images will show the placement of the resistors on the component side of the project.

There is one resistor that will not be used, "R9" (18 Ohms, quarter watt). It has been removed for the 150mw modification and is not used in this design.

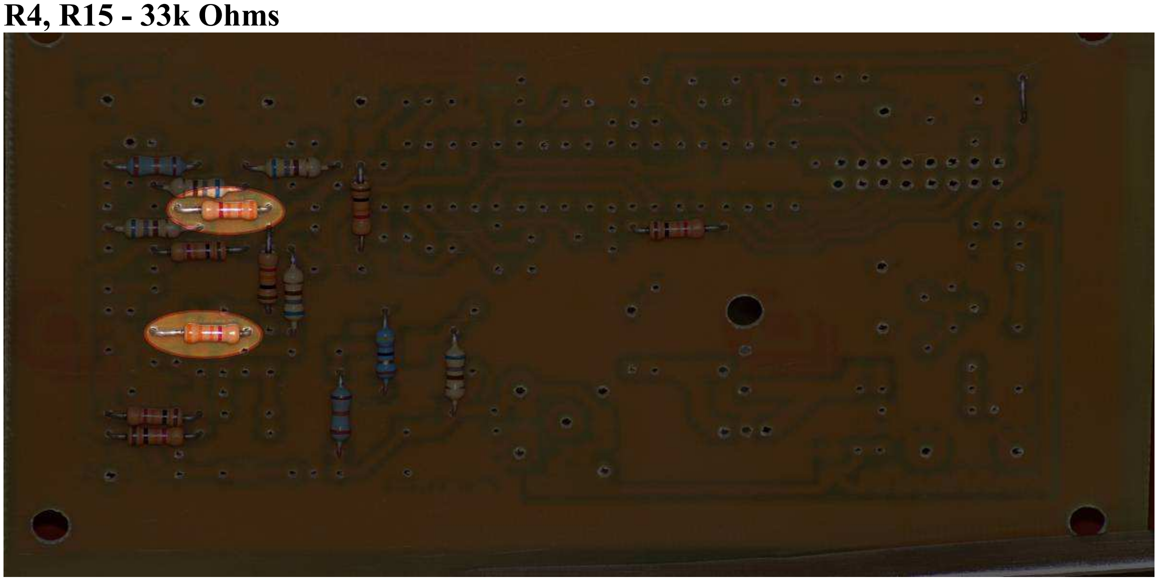
R5, R7, R12, R13, R16 - 680 Ohms



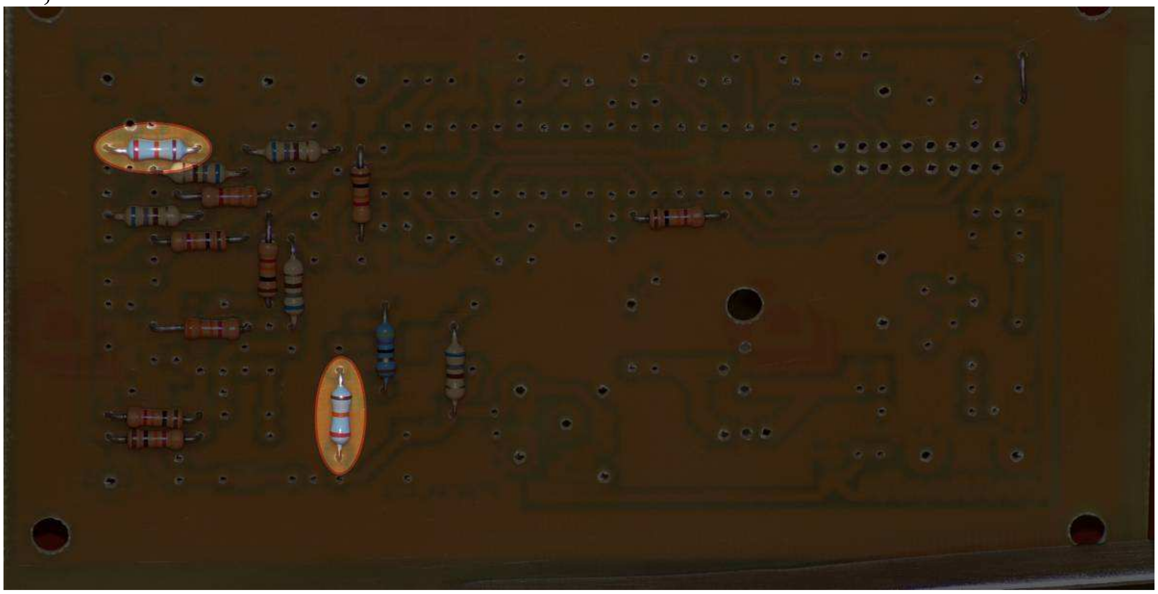
The Pira 150mw modified transmitter

R1, R2, R11, R17, R18, R20 - 10k Ohms

R4, R15 - 33k Ohms

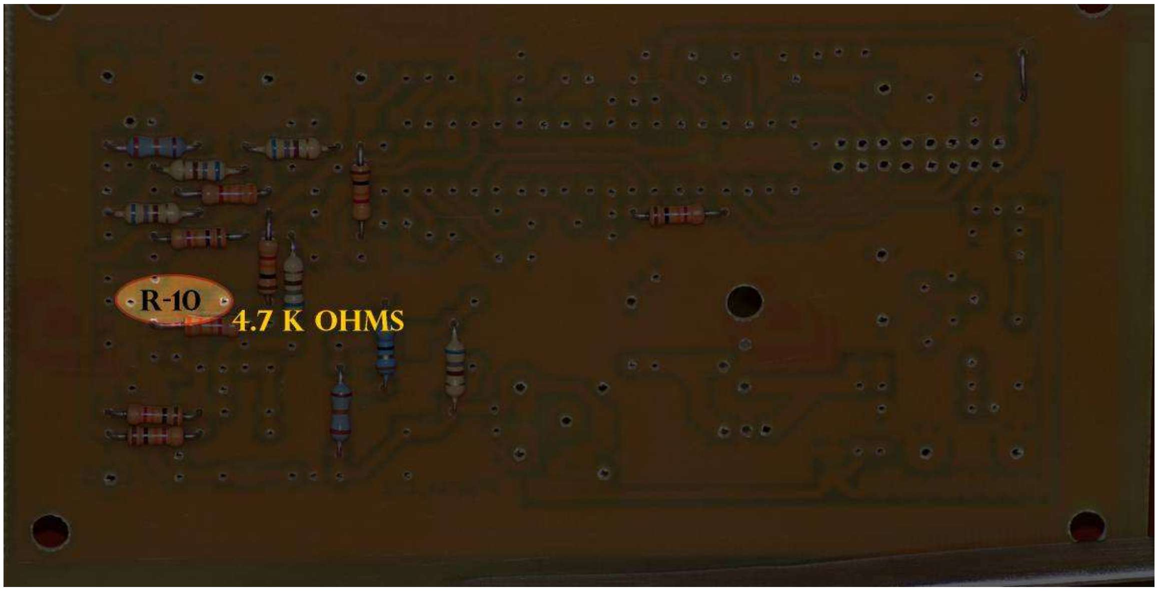


R6, R14 - 18k Ohms



R3, R21 – 270 Ohms

R10 – 4.7 K Ohms

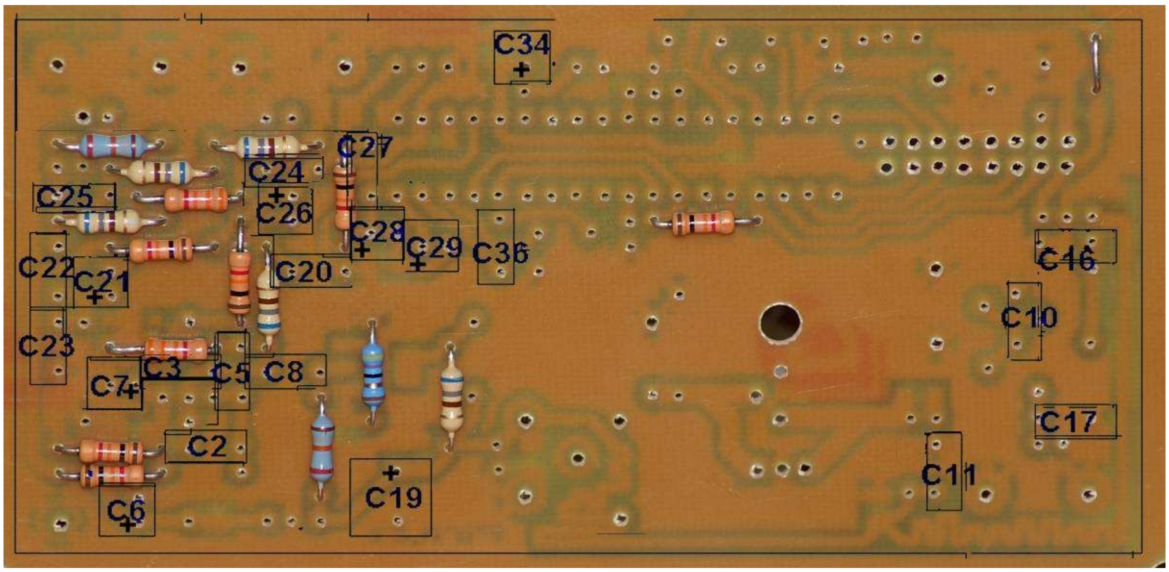


R22 – 91 Ohms

OK, that pretty much takes care of all the resistors, Let's take a small break to refresh ourselves and then we'll finish the remaining capacitors.

Part 3: Capacitors

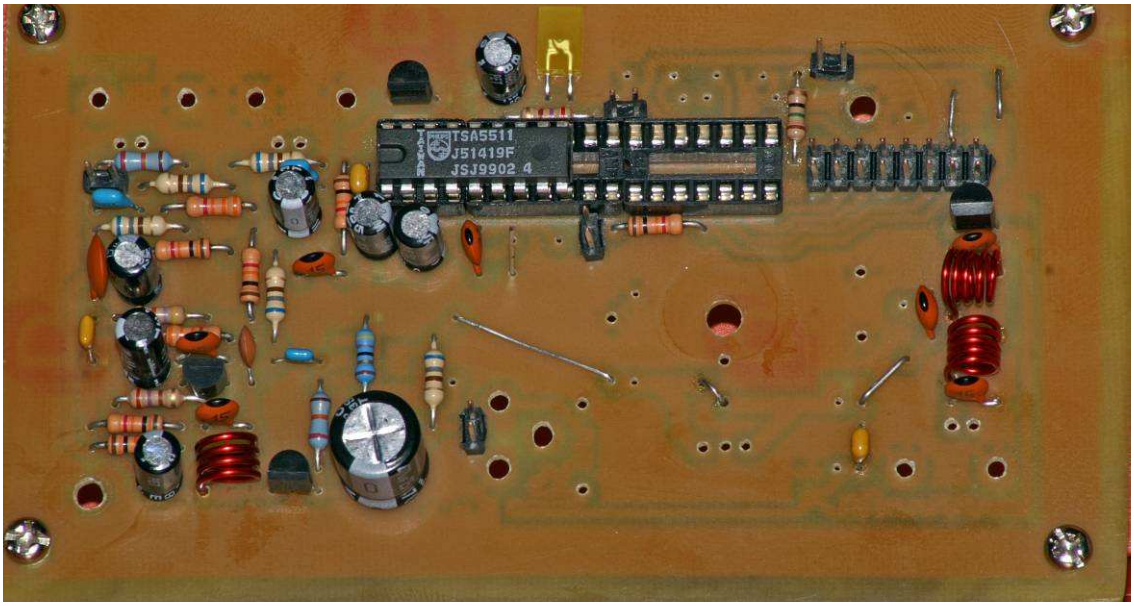
Because this is a modified version of the transmitter, there is one capacitor that will not be needed in this project. That part is labeled “C18” and is a 50 Pico-farad trimmer capacitor.



Parts Layout

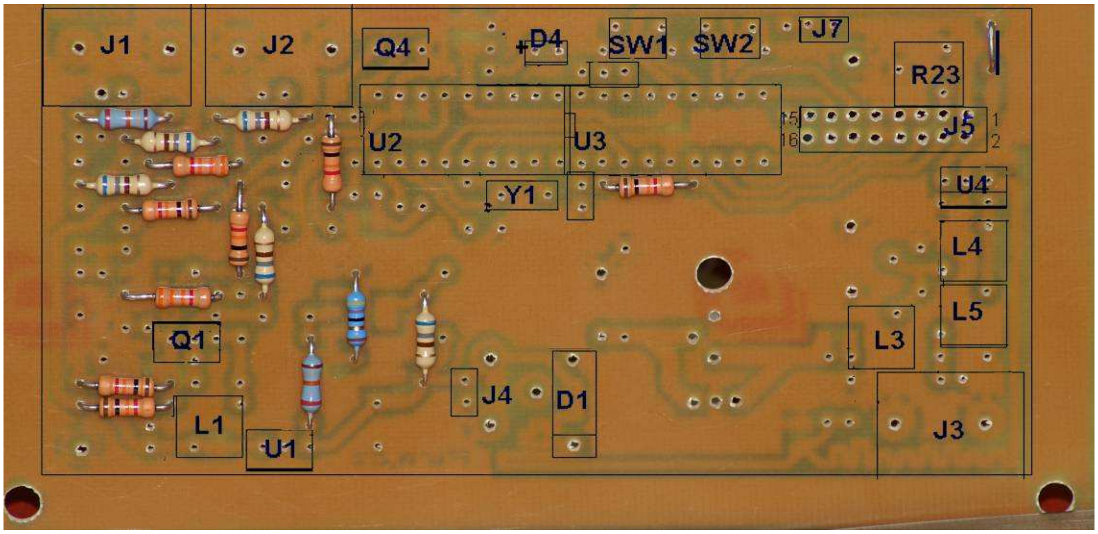
Part List	Values	Cap Code
C2, C17, C20	15pf (equivalent names: 15j)	15 or 15j
C3	10pf (15pf if the PCB is single-sided)	10* or 15*
C5	1nf (equivalent names: .001uf, 1000pf)	102
C6, C28, C29, C34	100uf 10V **Electrolytic**	
C7, C26	10uf 35V **Electrolytic**	
C8	22pf (equivalent names: 22j)	22
C11, C27	100nf (equivalent names: .1uf , 100,000pf)	104or 104
C10, C16, C36	33pf (equivalent names: 33j)	33 or 33j
C19	470uf 16V **Electrolytic**	
C21	4.7uf 50V **Electrolytic**	
C22	330pf (equivalent names: .33uf, 330n)	334 or 334
C23, C24	47pf (equivalent names: 47j)	47 or 47j
C25	3300 pf (equivalent names: 3n3, 3.3nf,)	332 or 332k
pf= Pico Farad / nf= Nano Farad / uf= Micro Farad * C3 code may be a 10 or 10j only if using double sided PCB otherwise use the value 15 or 15j		

You can install the capacitors in any particular order you would like – you just want to make sure that the electrolytic caps are inserted in the proper direction. These are polarized caps and cannot be installed backwards.



Once all the capacitors your project should look something like this. It may not be this exact picture, because of different electronic manufactures sometimes uses different kinds of coatings on their components and can vary by color. Double check everything by using the capacitor number codes.

Part 4: Transistors, crystal, jumpers and IC sockets

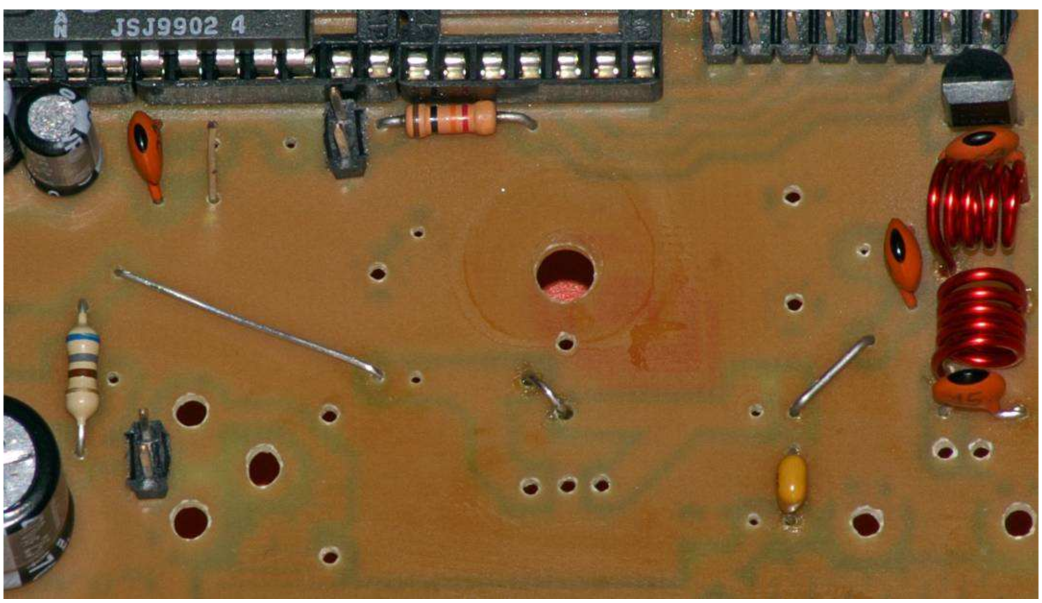


There are 3 coils **L2, L3, TR-1,** that have been removed from the project and are not needed with the 150mw version. Jumpers will be put into their places. See next page.

Part List	Values	Notes
Q1	BF240 (NPN RF transistor)	TO-92
Q4	BC547B (NPN RF – general purpose transistor)	TO-92
U1	79L09 +9Vdc voltage regulator	TO-92
U2	TSA5511 or TSA5512 PLL Synthesizer IC, I2C Control	Philips
U3*	PIC16F627A microprocessor (programmed)	Micropic
U4	78L05 +5 V voltage regulator	TO-92
Y1	3.2Mhz crystal (50Khz stepping) or 6.4Mhz crystal (100Khz stepping)	See note…
L1	20 or 22 Gauge Magnet wire / 3.5 turns on 7 mm diameter	
L4	20 or 22 Gauge Magnet wire / 3.5 turns on 6 mm diameter	
L5	20 or 22 Gauge Magnet wire / 3.5 turns on 6 mm diameter	
D1	1N5822 3A Diode (Reverse Polarity Protection)	
SW1, SW2	Micro Tactile Switch (See next page for more info…)	
J1-J3	PC Mount BNC Jack	
* PIC Programming will depend on the crystal used		

- Install The IC sockets for **U2,** the PLL chip, and **U3,** the PIC16F627A.
- Install **Q1,** with the flat part facing upward just as the photo from above.
- Install **Q4,** with the flat part facing of the transistor downward toward the TSA5511 IC, labeled as **U2**.
- Install the **U1,** with the flat part facing downward just as the photo from above.
- Install **U4,** with the flat part facing downward away from the 16-pin header for the LCD display labeled as J5.
- Install **D1,** with the silver band facing downward just as the photo from above.
- Install **Y1,** the crystal. There is a grounding pad just below the crystal, take a cut lead from a resistor and solder it between the pad and the top of the case of the crystal; this is done to shield the crystal from RF interference.
- Delay inserting the PLL chip and the PIC chip until we have finished soldering on the rest of the components.

There are three jumpers that have to be inserted where certain parts have been removed from the design:



From left to right, the jumpers replace TR-1 / Q3 / and L3.

Part 5: Making the coils

L1 calls for a coil that is 20- or 22-gauge enamel coated wire, with 3.5 turns at a diameter of 7 millimeters.

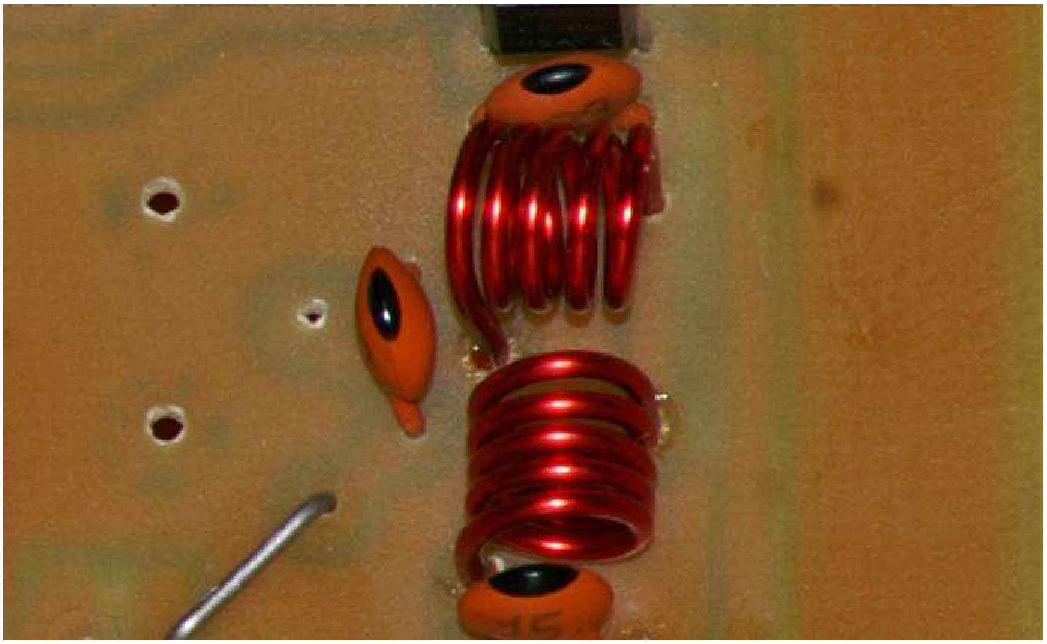
This coil is used in the PLL tuning circuit that delegates where on the dial the transmitter is. Using a mm to inch conversion gives you a diameter of just .275" about one-quarter of an inch. The best way to turn a coil this size can be easily taken from the Ramsey transmitter projects by using a bolt that is one-quarter inch (No. 20) that is at least one inch long.

Wrap 3.5 turns with the groves on the bolt. This method gives you beautifully formed coils. The coil will appear to have four complete turns if viewed from the top. The excess wire will be clipped to about one-quarter inch long for tinning and to provide suitable mounting leads.

To tin the ends of the coils to give them a good solder contact is done by melting a little solder on the end of your iron and rubbing one-eighth inch long ends with the soldering iron. The enamel will eventually burn off giving you a clean contact to solder to the board. Make sure you keep the coil on the bolt while tinning the leads so you don't burn your fingers, it will get hot and make take some time to burn off the coating.

This coil will have to be either compressed or stretched out during the tuning phase; more on that later.

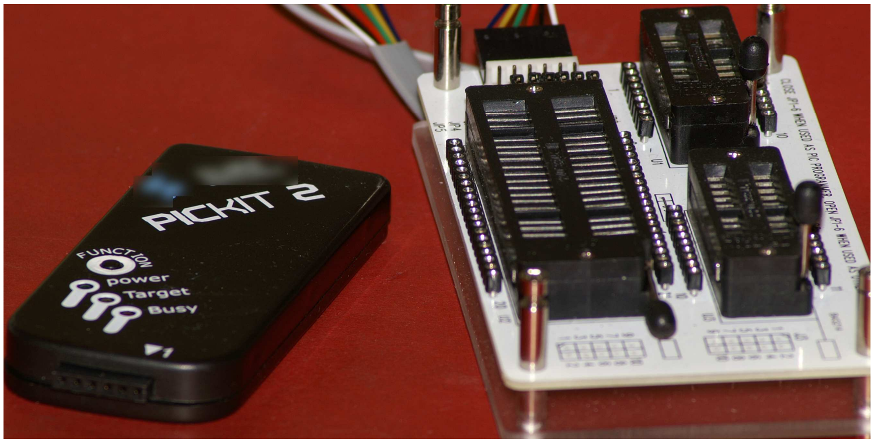
L4 & **L5** coils are 20- or 22-gauge wire with 3.5 turns with a diameter of six millimeters. Converting this to inches yields .234" – just under one-quarter inch. Not really being too critical, you can use the same method used for making the first coil.



Once you have made these two coils and have tinned them it is best to compress them; this increases the inductance values.

These two coils are part of a low-pass filter, designed to remove any unwanted, out of band, emissions. In other words, the second harmonic of the 88- to 108-MHz FM band. These work in conjunction with the three adjacent capacitors.

Part 6: Control & software for PIC16F627A



The PIC code for the transmitter can be downloaded at http://pira.cz/plltsa.zip (version 1.2). Please read included license text first.

You will need a PIC programmer to put the hex code onto the chip (if you're a novice at PIC programming, see http://www.christmasinshirley.com/wiki/images/3/38/How_to_program_a_PIC.pdf).

Files included in the zip are:

- pll64.hex - 6.4 MHz crystal 100Khz Stepping
- pll32.hex - 3.2 MHz crystal 50 Khz Stepping
- pll.asm - for any changes such as custom id in the display.
- Licence.txt

Pic Fuses: WDT: Enabled, OSC: INTRC-I/O, MCLRE: I/O.

You will use the buttons to set the frequency. After a few seconds of idle, the LED flashes briefly and then the frequency is tuned and stored to the PIC's EEPROM (icon of diskette).

Finally, after inactivity the buttons are locked (icon of key) to avoid unwanted frequency changes.

Unlocking the buttons can be done by pressing any button for more than a few seconds.

The display and LED indicate PLL in-lock state (icon of two arrows in a circle). This state is also provided at **Pin 1** of **U3**. It can be used for control of additional power amplifier, etc.

Part 7: Enclosing the transmitter

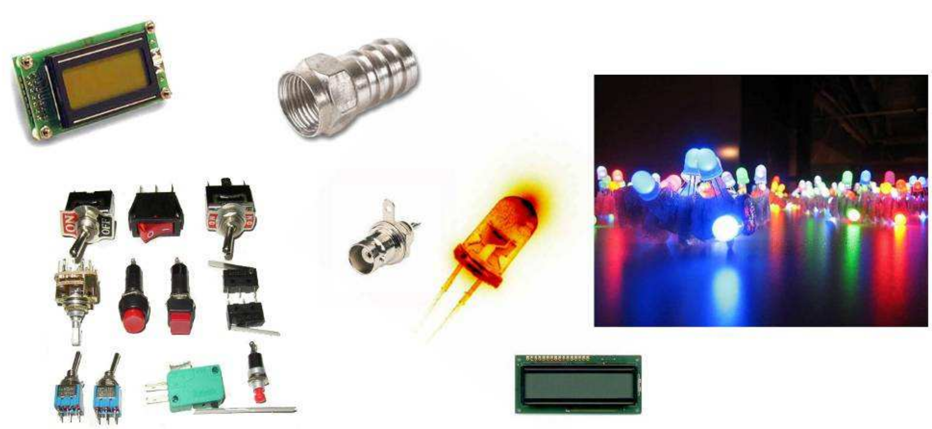
The best type of enclosure would be metal: sheet metal, brass, die-cast aluminum, etc. This is mainly for RF shielding reasons. Because this is a transmitting device, we want to prevent anything from interfering with that function and we don't want this device to interfere with anything else. The only place we really want to emit RF is at the antenna.

You want to choose an enclosure that is of adequate size to allow for proper cooling and also making it somewhat easy for you to install and troubleshoot if necessary. You will want to consider the space needed for the board, also for clearance needed below and above the circuit board and the buttons that you are using, the connectors and the LCD display.

Part 8: Options to customize your transmitter

There are a few things that can be changed according to how exactly you will want to use this transmitter.

- The buttons can be changed to use with just about any normally open, momentary contacts.
- Depending on the type of enclosure you have selected to use, the BNC connectors may also be changed out to use either a panel-mount BNC connector or a panel-mount Type F connector. If so, I recommend that you use a coax-type cable for the input and output connections.
- You may also choose to use any color LED for the PLL lock indicator.
- Wiring in a power switch or adding a fuse or a power indicator light … you get the idea.



Part 9: Initial powering and tuning

- Check that there are no shorts bridging any adjacent tracks or pads.
- Check electrolytic capacitors polarity and semiconductor parts orientation.

Make a dummy load and connect it temporarily to the antenna output connector. For example, solder two, 120-ohm, quarter-watt resistors to a BNC connector between the shield and center pin.

Start with smaller power supply voltage, for example a nine-volt battery. If nothing burns up or is something does not smoke after say 10 seconds, you're good – now let's go to a full 12-volt supply.

Now the L1 coil must be adjusted by stretching or compressing the turns. It will effect the frequency position of the transmitter, which is what the PLL uses as a reference to tune. Tune the transmitter to 107.9 MHz using the buttons. Wait for the PLL lock light to flash showing it send the data to the PLL IC.

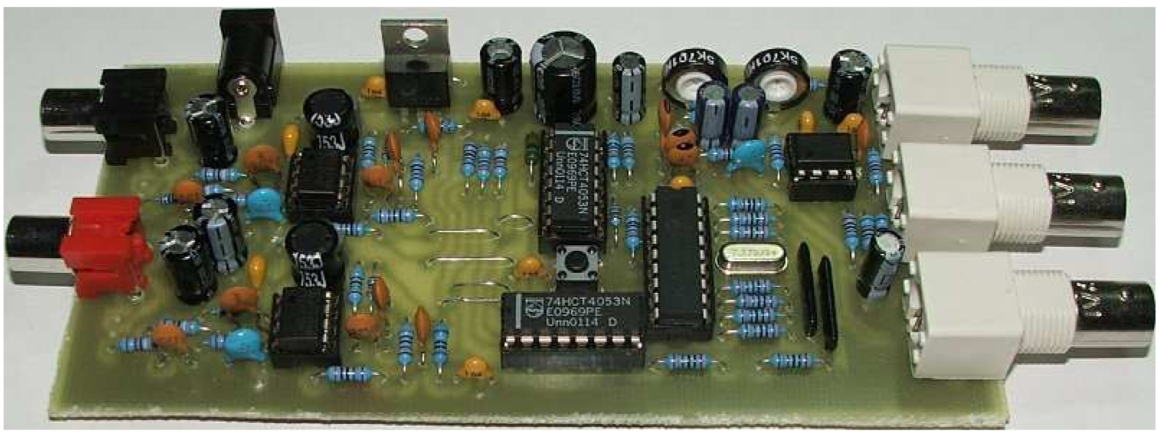
Measure the tuning voltage between the collector Q4 and ground. You will need to set the tuning voltage to 8.0 vDC by adjusting the L1 coil by stretching it out or compressing it.

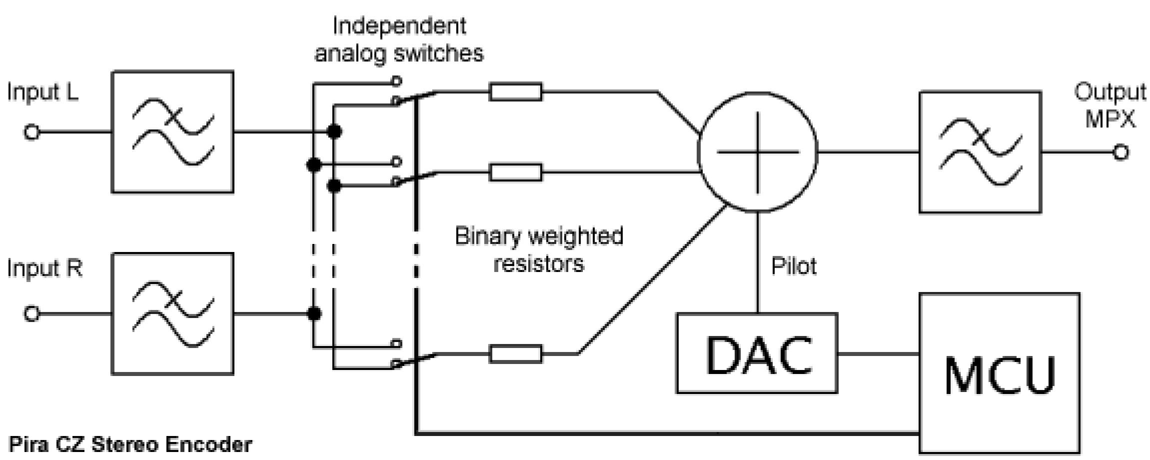
Now let's test it: hook up the transmitter to a small antenna and tune it to a desired frequency – allow the PLL light to flash showing that the microprocessor is telling the PLL chip what frequency to go to. Using an FM radio tuned to the same frequency with the auto mute or stereo mute off so you will hear the static, then as the PLL is adjusting frequency, try to lock. Eventually you should hear dead silence your radio. You might also have a light on your radio that says tuned or locked.

It may take a minute or so on the transmitter's LCD display showing that the PLL is indeed locked, and then the LED light will also say solidly lit.

Once this is done, I recommend that you prevent the coil from being changed by encapsulating it in either a non-corrosive silicone, or using a hot glue gun, in glue.

Congratulations, you have a working FM transmitter. Notice I did not say a stereo FM transmitter – now you have to build a stereo encoder if you want to be able to do stereo broadcasting (see http://pira.cz/eng/stk2en.htm for more info).





Part 10: Technical specifications (typical measurements)

- Output power: 150mW to 200mW.
- Output stage transistor: BFG135.
- Supply current: 150mA.
- Supply voltage: 11.0-13.8 V (stabilized or from a battery).
- Polarity protection: Yes (30 sec., max. 2 A).
- Standard frequency range: 87.5-107.9 MHz.
- Audio/MPX input sensitivity: 3 V pp (for 75 kHz freq. deviation).
- RDS/SCA input sensitivity: 0.3 V pp (for 7.5 kHz freq. deviation).
- S/N ratio: >60 dB.
- Signal I/O connectors: Unbalanced, BNC.
- Output load impedance: 50-75 @.
- Audio/MPX input impedance: 20 k@.
- RDS/SCA input impedance: 600 @.
- LCD connector Standard: HD44780.
- Board dimensions: 109 x 54 mm.

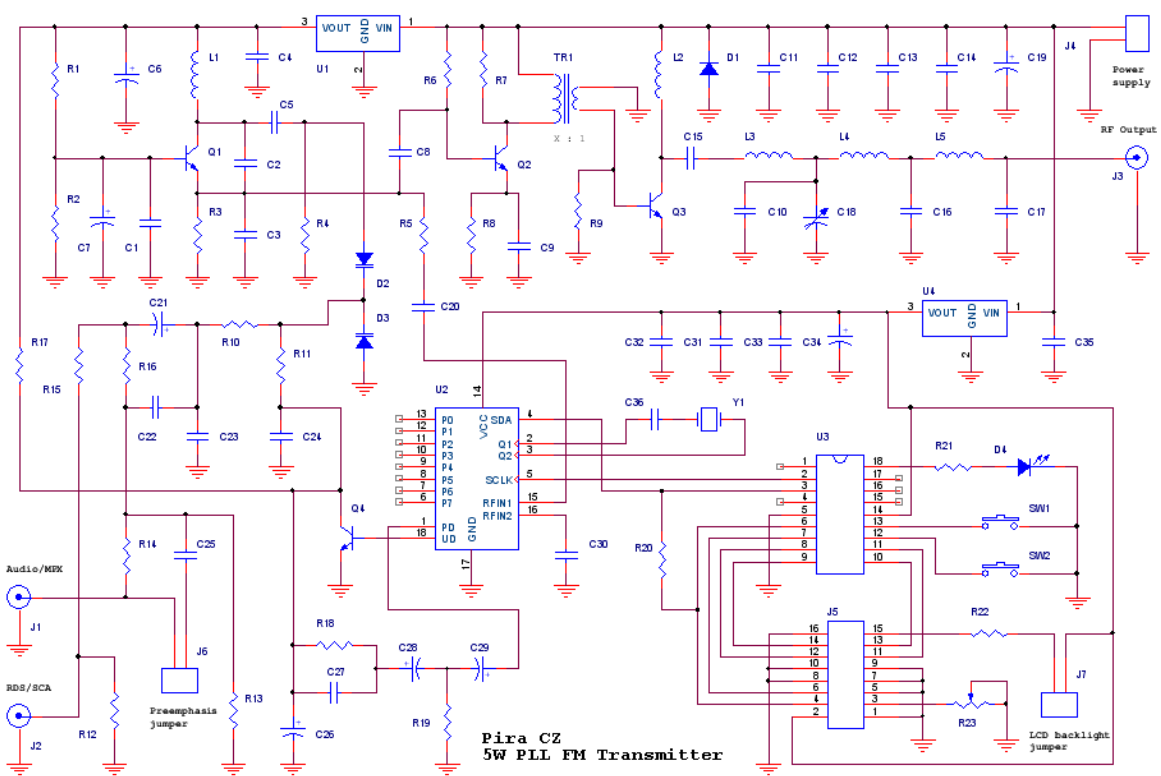
Important tips when using

- Do not operate on higher power supply voltage than specified!
- Do not touch the inductors!
- Do not short circuit the output!
- Use a current limited power supply or insert a fuse to the power supply path .5A!
- Use a properly sized enclosure for good air ventilation.
- Do not operate without a dummy load or an antenna attached.
- Not for commercial applications.

Part 11: Troubleshooting

Problem	Solution
The unit does not work; the LED/LCD does not indicate anything	Check power supply.
The output transistor is warm but the coverage range is very poor.|	Check antenna cable and the antenna.
Can't see anything on the LCD.	Adjust right LCD contrast, check the flat cable connection.
There is only silence on the frequency tuned.	Possible audio source problem.
There are a lot of treble in audio.|	Turn off the pre-emphasis.
There are almost no treble in audio.	Turn on the pre-emphasis
There is hum in audio.	Power supply problem or ground loop issues.
The audio is distorted.	Decrease the audio level. Use any FM analyzer to set right audio level precisely. Make sure the pre-emphasis is turned off when stereo encoder is used.

Schematic



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Thoughts on the legality of low-power FM transmissions in the United States

The Federal Communications Commission regulates the use of radio transmissions in the United States. While your low-powered transmitter probably falls legally within the so-called Part 15 regulations, there are some things of which you should be aware before transmitting.

First, here is a reproduction of the FCC's distillation of its Part 15 notice from its web site:

PART 15 DEVICES

> Unlicensed operation on the AM and FM radio broadcast bands is permitted for some extremely low powered devices covered under Part 15 of the FCC's rules. On FM frequencies, these devices are limited to an effective service range of approximately 200 feet (61 meters). See 47 CFR (Code of Federal Regulations) Section 15.239, and the July 24, 1991 Public Notice. … These devices must accept any interference caused by any other operation, which may further limit the effective service range. For more information on Part 15 devices, please see OET Bulletin No. 63 ("Understanding the FCC Regulations for Low-Power, Non-Licensed Transmitters").

Second, let us assume that you don't live in a hotbed of illegal radio transmissions; that is, there are no pirate radio stations in your neighborhood (see http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2009/01/05/DDOF14Q2EC.DTL). Since the FCC does not have the resources to patrol every square mile of the United States to determine if all radio signals within that square mile are legal or illegal, whether you are going to get in trouble with the FCC regarding your transmissions is a question of if one or more of your neighbors complain to the FCC.

Complaints usually stem from interference: are your transmissions interfering with the transmissions of a legal broadcaster? The burden is on you, the Part 15 transmitter's owner, to make sure nobody complains. (If they do and you are contacted by the FCC, stop transmitting immediately.)

There are a couple of ways to make sure you're not interfering with legal broadcasts: using a transmitter that doesn't drift away from the chosen frequency; one that doesn't spur unwanted signals into adjacent frequencies; choosing the correct frequency over which to transmit, and using a properly tuned and mounted antenna.

The drift issue is handled by the design of the board illustrated in this how-to; it is a phased-locked loop (PLL) that resists drift. The spur issue can be addressed by making certain you use a metal enclosure for the transmitter.

In picking a frequency, your first step is to determine where on the FM dial you're going to broadcast. Most people start out with the recommendations of Radio Locator: http://radio-locator.com/cgi-bin/vacant .

Then, go out to your car (since most of your listeners will be using car radios) and enter in the recommended frequencies; choose the one with absolutely no current transmissions on the frequency (be sure to do this in the evening, as radio transmissions are better at night). Ideally, you will have a full megahertz available on either side of your chosen frequency that does not have a legal transmission.

Taking your chosen frequency, go to an on-line dipole calculator (there are dozens; here's one: http://www.radiobrandy.com/dipole1.html) and determine the length of the wires necessary (most just use 12-gauge electrical wire for a dipole).

That RadioBrandy page also shows how to build a dipole; there are many other sites that do as well – here's Kevin Cook's pictures on how he built his dipole: http://www.c3inet.com/FM%20Transmitter/index.htm.

The board designed by Pira.cz is a five-watt transmitter, which on the face of it makes it illegal to operate in the United States. The author of this how-to, Timothy Yoos, has shown you how to drop the power of the Pira.cz transmitter down to 150mW-200mW. Unfortunately, that too exceeds the FCC's limitations. In the OET Bulletin No. 63, the FCC specifically says that Part 15 transmitters use "very little power, most them less than a milliwatt."

But you are not hosed. Since the FCC's own web site explicitly states that the range of a legal transmission is about 200 feet, you can dampen the range of your transmitter by lowering the effectiveness of your antenna. (Technically, the FCC says the measurement is the signal "must not exceed 250 microvolts/meter at a distance of 3 meters from the transmitter" [FCC rule 15.239]. Since it's doubtful you have a device that can measure microvolts per meter, the 200-foot rule will suffice.)

A 150mW-200mW transmitter's antenna should most probably be mounted at ground level or, better yet, below ground level (basement). It should not be on the second floor, on the roof or in a tree.

After mounting your antenna, turn on your transmitter, get in your car and drive 200 feet from your property line (most lots are 50-feet on the street side, so drive four houses away), tune in your frequency and determine whether your signal can be heard.

If you can't hear the signal, you are probably not going to exceed Part 15 FCC regulations.

But if you can still hear the transmitter, you need to further dampen – or "attenuate" – your signal.

BNC attenuators for radio frequency transmissions are widely available at electronics supply stores and on web sites. Many are even available on eBay. A 10db RF attenuator or a 20db RF attenuator should be more than sufficient if your broadcast transmission is exceeding the 200-foot limit. It will cost you $10-$20. After attaching the attenuator between your transmitter and antenna and repeat the 200-foot drive; you should no longer be able to hear your transmissions. If you can, add another attenuator; if you can't, you should be golden.

Two last thoughts:

• You should include a regular station identification when you are broadcasting. The FCC frowns upon made-up call letters. *Do not* broadcast something like, "This is WKRP from Cincinnati Lane." You can say, "This is 87.9 FM, broadcasting from Cincinnati Lane."

• Violating the FCC's rules on low-power transmissions can result in fines in the tens of thousands of dollars. Tim Yoos' modifications of the Pira.cz board take you 90 percent of the way toward avoiding FCC rule violations. Taking these thoughts into consideration will get you eight-nine percent further along.

The "thoughts" in this section represent the opinions of the author, who does not represent himself as a lawyer (I don't even play one on TV). I take no responsibility for whether you are prosecuted by the FCC (or any other governmental or private entity) and I expressly say that it's your responsibility to do further research on your own.

If you have questions regarding the legality of the usage of your transmitter, please visit a lawyer, preferably one licensed to practice in front of the FCC who has a degree in electrical engineering, because once you get beyond the rough recommendations here, you better have a really, really excellent representation.

— Dave Cole, http://www.dmcole.net