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MAX PRO I

MAX PRO I is a low cost, high performance FM broadcasting exciter. It was designed to offer excellent spectral cleanliness and ruggedness, as well as a fairly simple assembling procedure. High quality components and printed circuit board assure 24/7 operation for years.

Features

RF Output Power: 0 to 7 Watts, variable via on-board trimmer
Output connector: BNC
Output Impedance: 50 Ohms
Frequency Range: 86-108MHz
PLL Steps: 50 KHz
Frequency stability: +/- 200Hz
Spurious/Harmonic rejection: Harmonics: -60dB, Spurious: -80dB
Audio Frequency Response: 35Hz-75 KHz @ -3dB
Power Supply: 12-15V/2A
Dimensions:
-Panel board: 90x40mm, double-sided professional PCB
-RF board: 100x85mm, double-sided professional PCB

Thank you for purchasing the MAX PRO I!

We hope you'll enjoy it as much as we do and remember to tell your friends about it. Please feel free to send us your comments to feedback@pcs-electronics.com. For tech support please send email to support@pcs-electronics.com

From all of us we wish you happy broadcasting!

Now go get that soldering iron:-)

PCS Electronics team
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Before you start...

Let us clear up some basic things you need to know before we move on. You will find some very useful tips, a forum and tips on antennas and hooking things together at **http://www.pcs-electronics.com** so it's generally a good place to check before putting your MAX on the air.

Here is what you need to assemble MAX PRO I:

-**Soldering iron** 25-35 watt soldering iron. Weller and ERSA make excellent soldering tools. Radio Shack stuff is horrible, but will do if that's your only option. Radio Shack reminds me of The Dollar Tree in many ways, loads of cheap crap. Practice soldering a bit (if necessary) before you go and burn that beautiful PCB!

-**Antenna and/or dummy load** to setup and test your transmitter. If you don't have dummy a load, you can build them easily from BNC RF connectors and the proper wattage/value of CARBON resistors. DO NOT USE WIREWOUND OR METAL FILM RESISTORS! A useful one can be constructed with 4 -220 Ohm 1/4 watt resistors in parallel (220/4 = 55 Ohms) with center conductor to outer shell (ground) of an RF connector. That is pretty close to 50 Ohms and if you use 1/4 watt resistors you get a nifty 2 Watt Dummy Load for testing your equipment without an antenna. 2W is enough, if you restrict the duration of the testing to half a minute or so.
An antenna (J-pole, 5/8 Comet, 1/4 wave, broadband) up high makes up for lots of power...and is money well spent! Remember propagation at FM frequencies (88-108MHz) is virtually line-of-sight. City miles are longer than country miles; Forest miles are farther than desert miles. Low VSWR and antenna height alone can make up for lots of watts! For instructions regarding construction of antennas please see the end of this document or our website: **http://www.pcs-electronics.com**
You should have realized by now that antenna was, is and will always be a crucial part of the system. Special care has to be taken! It is usually a good idea to place antenna away from your transmitter, power supply and audio system. If you cannot meet these requirements, you could experience feedback and other RF problems. We cannot guarantee proper operation of MAX PRO I unless suitable antenna system is used! Interestingly, RF energy can make CD players and other digital devices go bezerk. Try placing 30W-driven antenna next to yours, most of the modern audio gear is not RF shielded.

A PIECE OF WIRE OR TV ANTENNA IS NOT SUITABLE ANTENNA FOR MAX PRO I OR ANY OTHER RADIO EXCITER!

-**Coaxial cable** the common RG-58 from Radio Shack is NOT the best you can do and will lower your effective power out! Use it only for short runs. BELDEN makes terrific coax in various qualities and with very low loss (measured in dB's…decibels)…figure 3 dB loss = 1/4 of your signal strength…either lost or gained. Watch out for the correct impedance…RG-8 and RG-58 have 50 Ohms. RG-59 and RG-6 (Low Loss Version of RG-59) have 75 Ohms. Most antennas are 50 Ohm ones. Check our web site for good coax. Don't buy more than you need to make the long run to your antenna and make up a few "jumpers" to go between your exciter, VSWR meter and your antenna as all you'll do is create a higher SWR and more line losses. Don't use cheap TV cable.

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-**BNC connector** comes between coaxial cable and your transmitter. It's a standard VHF RF connector for low power applications, just like the one used for Ethernet networks. You might get it along with your antenna. Try to find a quality BNC connector as PC type usually uses cheap plastic instead of Teflon. The good ones are usually easily recognized by much higher prices.

-**Power supply.** You will need a good 12-15 volt, 2 A regulated power supply. No "wall wart" please! You can always use a lead acid car battery and re-charge it when you are off the air. HAM or CB power supply units do the job nicely in most cases. Poor power supply can add hum to your signal! MAX PRO I gives more output power when you increase the supply voltage. We have tested it up to 16V and had no problems, but we do not recommend using more than 15V. Of course too much voltage can fry your output transistor, especially if your antenna is not well matched. You can build your own power supply or try to locate HAM or CB shops. Try our web site for finished products as well as schematics, if you want to make one by yourself.

-**Audio equipment.** For a start all you need is a simple CD player or a cassette deck. If you want that really professional sound, you will eventually need low noise audio mixer, good microphone, audio Limiter-compressor and possibly stereo - encoder (for stereo). Behringer is a well known name for such equipment. Cheap stuff will give you noise, bad channel separation, distortion, over-modulation etc. Consider using PC as your audio platform, get a good sound board and it will do mixing, MP3-playing, limiting, audio processing, CD-playing etc, all at a minimal cost (provided you already own a PC).

-**Enclosure** Use metal, allow some free space for future add-ons (stereo encoders etc.) and heat dissipation, and make ventilation holes at the top and/or back of the enclosure. Fix the PCB with all screws tightly. There should be a shield between the RF and LCD board; flat cable should be wired away from the VCO assembly (L1). See mounting pics. **MAKE SURE YOU SCREW THE RF BOARD TO THE ENCLOSURE AS THIS IS HOW THE FINAL DISSIPATES ITS HEAT!**

Finally, if you know nothing or little about electronics, I selected a few books that I find extremely useful and often read. The links to them are on our homepage. I suggest you start with the ARRL HANDBOOK, the holy bible of amateur radio and electronics in general. Extremely valuable resource for every broadcaster.

ASSEMBLING THE MAX PRO I

Step 1: Components check (KIT)

Clean-up that desk and carefully unwrap the package. First assemble the LCD board and then the RF board. Watch out, most of the parts are really small and once they get off the desk, they usually jump unbelievable far and reach darkest corners of your room. Let us know if you cannot find a part that's supposed to be in the package. Please contact us directly rather that my distributor, this will probably result in a faster resolution of the problem. If you want to speed things up a bit, purchase from one of the radio-shack outlets or try one of the many electronics components resellers on the web. On the other hand you might find some extra parts, please don't be alarmed ☺

Step 2: Soldering/assembling the KIT

Start with the LCD board since it's easier to assemble. The pictures below should help you figure out how to assemble the LCD board. Start with the resistors (note unusual placement of R2, R3 & R4), capacitors, diodes, buzzer, IC, transistor, flat cable… Note that the keys and the LCD come in from the soldering side. LED should be mounted with provided stand-offs (Distancers). Remaining cut-offs from resistors and capacitors should be used to connect the LCD to the LED board. The contrast trimmer should be placed after the keys.

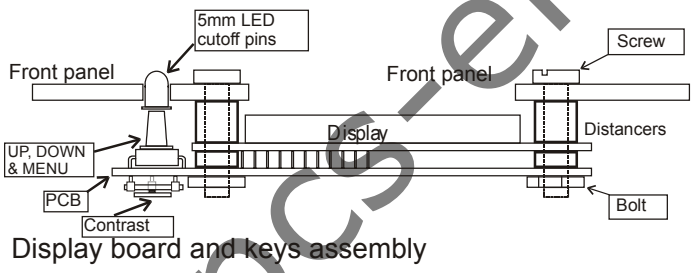

Fig 1: ***Placement of display, keys T1&T2, contrast trimmer and some tips...***

Fig 2: ***Placement of R2, R3 & R4 on the LCD board***

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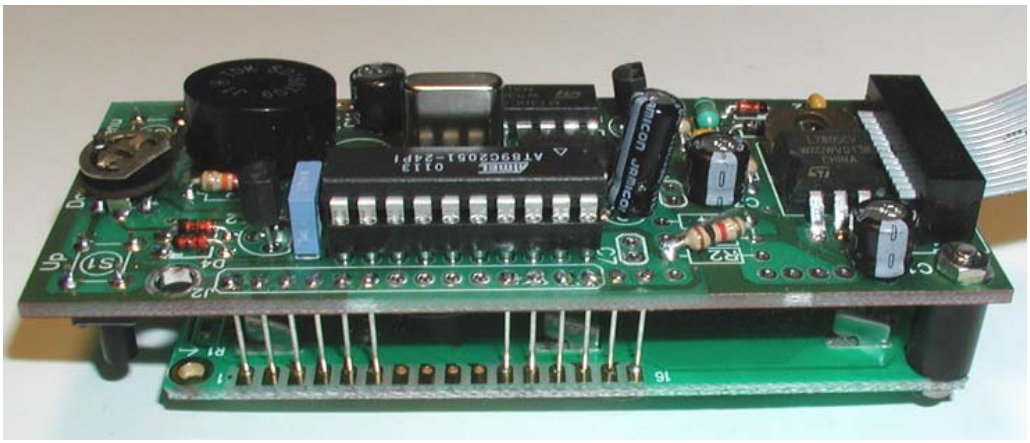

Fig 3: ***LCD connections…made of remaining resistor/capacitor legs***

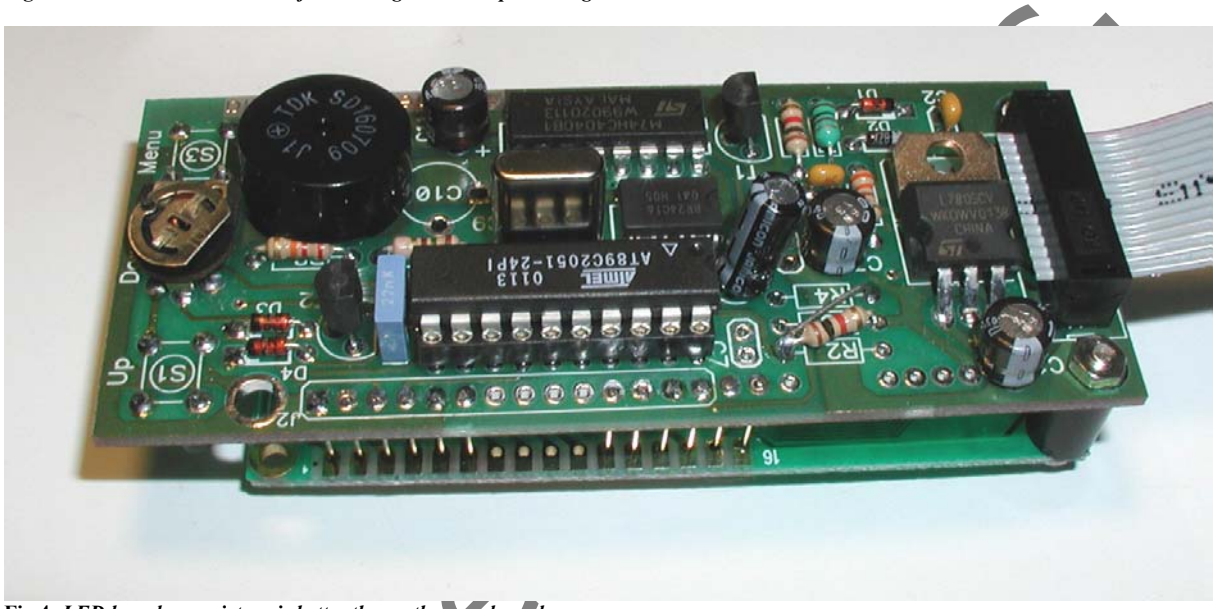

Fig 4: ***LED board, one picture is better than a thousand words…***

Fig 5: ***LED board, note how keys and the LCD are connected. It is OK to wire the missing connections, but it is not necessary.***

Then move on to the RF board. Start with coils. Make sure that the windings don't touch; there should be a 0.5 to 1mm gap between them. Spread them with the tip of a screwdriver, if necessary. Note that there is a tap on L1 (see picture), connectors, resistors and ceramic capacitors, jumpers, RFCs, trimmer resistors, transistors, sockets, IC's... Trimmer capacitors go in last! The final (T3) should first be screwed and then soldered; not doing so could result in destruction of this transistor. **NOTE THAT THERE SHOULD BE A CHOKE MOUNTED CLOSE TO THE OUTPUT TRANSISTOR.** This choke increases reliability and prolongs life of the final transistor.

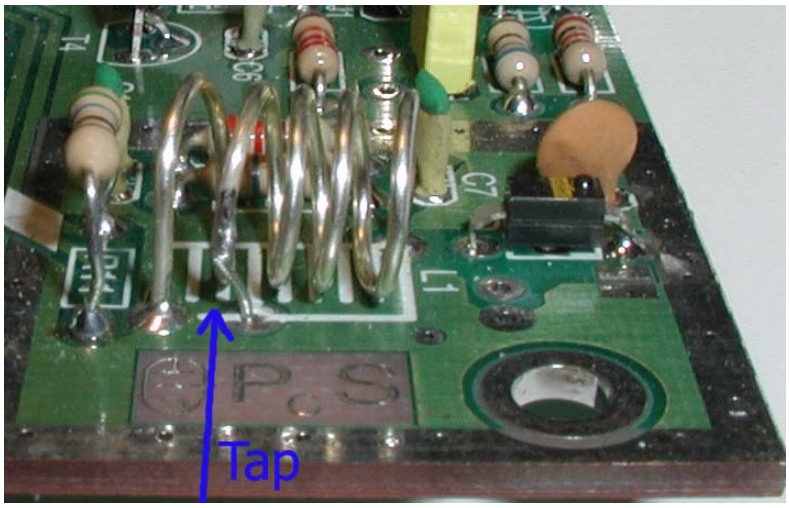

Fig 6: ***RF board, a somewhat nasty detail, a tap after the first turn of L1.***

Fig 7: ***RF board, panoramic view***

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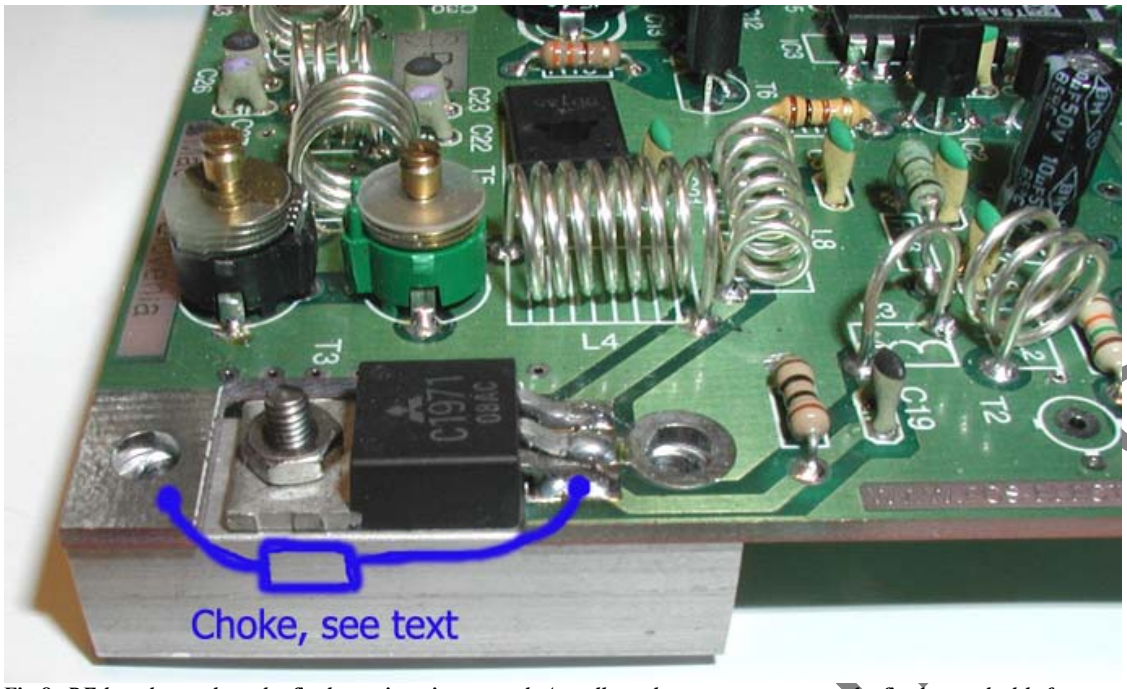


Fig 8: ***RF board, note how the final transistor is mounted. Actually, at least two screws must be firmly attached before you solder the pins. Don't forget the choke!***

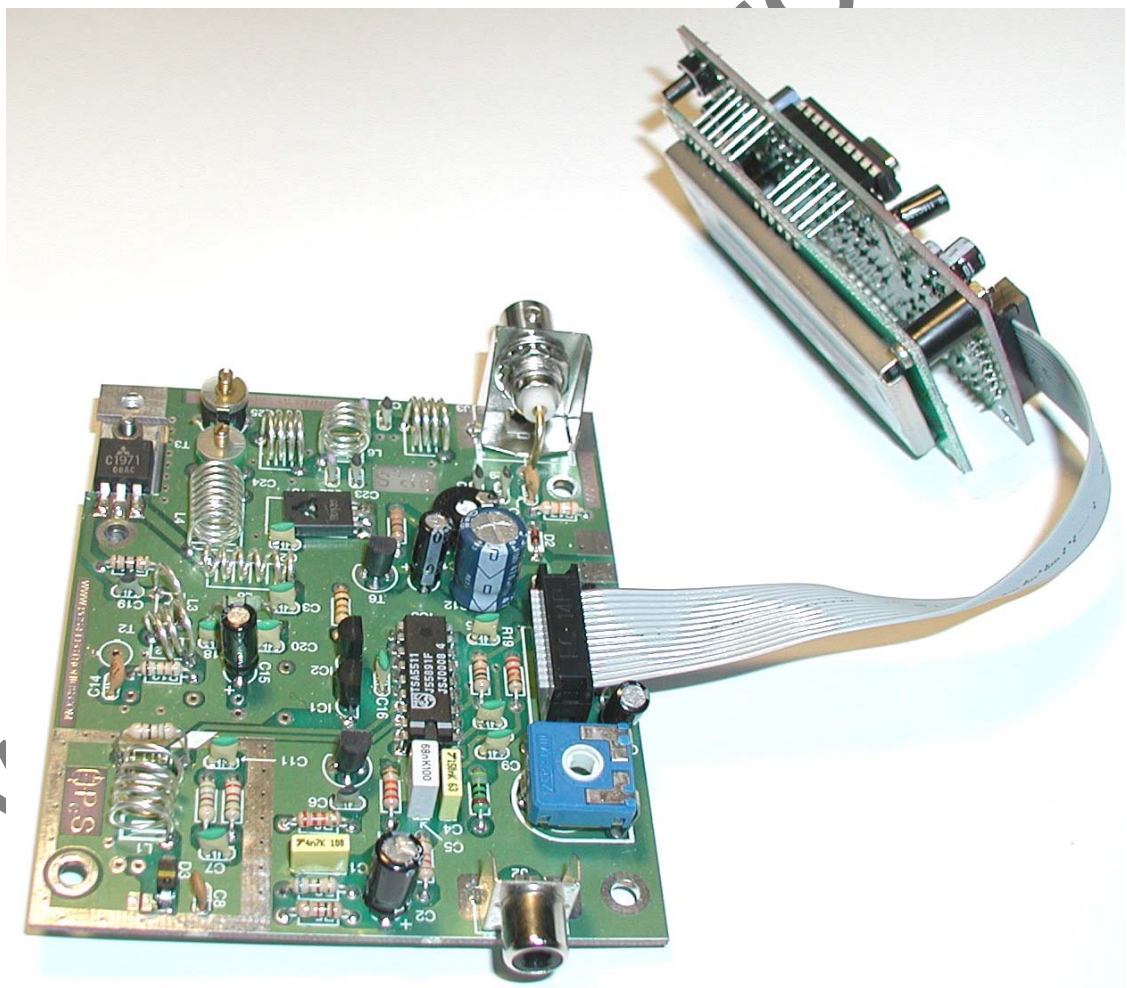
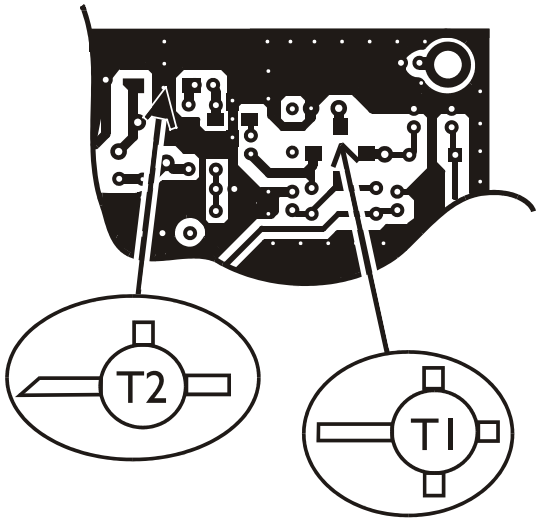


Fig 9: ***The happy couple, RF board and the LCD board!***



T1 & T2 - Markings must be visible, NOT facing the board!

- **DON'T MOVE THE COMPONENTS THAT WE HAVE ALREADY PLACED FOR YOU.**
- **TAKE CARE SO YOU DON'T REVERSE POLARITY OF ELECTROLYTIC CAPACITORS.**
- **DON'T USE IC SOCKETS FOR THE RF BOARD!**
- **REMOVE THE INTERFERING PIN ON THE BNC CONNECTOR J2 (THE ONE NEXT TO THE CENTER CONDUCTOR THAT MAKES IT IMPOSSIBLE TO INSERT BNC CONNECTOR INTO THE PCB). YOU CAN DO THAT BY BENDING IT FORWARD/BACKWARD A FEW TIMES OR CUTTING IT OFF.**
- **SOME COMPONENTS MAY NOT BE USED, EVEN IF THEY'RE DISPLAYED ON THE PCB LAYOUT. IF A COMPONENT ISN'T MENTIONED IN THE BILL OF MATERIALS THEN IT SIMPLY ISN'T USED.**

When you start working with the LCD board, make sure you place P1 on the Component side, then cut the remaining leads and place keys on the soldering side (yes, unlike other components). Have a look at the documentation. Schematic, component layout, and bill of materials are at the end of this document to help you place components where they belong. Most components should go all the way in the holes or as far as possible, especially ceramic capacitors.

Step 3: Check everything carefully (KIT)

Clean-up that desk and carefully check placing of all the components, make sure all solder-joints are OK and that there are no shorts between pins. When you're done, check everything again!

Step 4: Power up (KIT)

By the way, did you check everything as recommended? This is your last chance to save you in case of fatal error, make sure all ICs and transistors are placed exactly as on the components layout picture.

Step 5: The real power up

So did you check everything like suggested? OK, so let's proceed now. Connect dummy load to antenna connector (BNC). It's really a good idea to use dummy load for the first time. It takes only a couple of resistors to make (look under antenna above). Connect power supply wires in such manner that you can break contact or turn off power supply in case of smoke or funny smell. **Do not reverse polarity!**

Step 6: Setup

WARNING: PLEASE BE SURE THAT YOU ARE TUNING IN TO AN AREA ON YOUR LOCAL FM BAND THAT HAS NO STATION BROADCASTING ON IT, YOU DO NOT WANT TO INTERRUPT ANYONE ELSE'S LISTENTING TO LOCAL RADIO STATIONS, IT'S RUDE AND ALSO ILEGAL!

No smoke? OK, now you should see the welcome message on your LCD. You might need to adjust trimmer on the LCD to get good contrast. You will also hear a beep after power on. If you hear a beep and see nothing on the LCD, there is probably something wrong with connections to LCD. If all is OK, you can try to alter working frequency with UP/DOWN keys. Now press the menu key until TUNE-UP menu appears. Press the UP key. You will have to tune two caps (C24 and C25) for the minimum pitch of that tone. Use plastic screw driver to do this (available from Radio Shack). Repeating tuning on a daily basis is not necessary and might eventually wear down the caps. Now turn on your MP3 player, CD audio player or other AUDIO source. Turn on any fm radio and turn the tuning dial until you hear the MAX PRO I's audio through the fm radio. You will need to adjust audio level so that the sound on the radio sounds natural and without distortion. Too much volume may sound good on your radio, but will sound horrible a few hundred meters from the transmitter! You shouldn't sound louder then other FM stations; rather you should sound a bit quieter since you're not using limiters/compressors (yet). When you sound as loud as other stations and you're not using audio processing, you're actually over modulating. Unfortunately many commercial stations over modulate nowadays, it's a sad fact. You may want to try a few different frequencies because of better reception in different areas. Some spots on the dial may work better than others.

Troubleshooting

We hope you'll never get to this step. We all know bad things happen. But do not despair! First, MAX PRO I is reverse polarity protected so it should blow a fuse if you reverse polarity. If you have problems that you cannot solve yourself, please contact us directly (**support@www.pcs-electronics.com)** rather that my distributor, this will probably result in faster resolution of the problem.

Things to remember

Please remember to turn off the transmitter when not in use!
Remember that anything you broadcast through the transmitter can be heard by anyone tuning in to that frequency. Although it is unlikely certain weather conditions may allow the signal to go further than your immediate listening area so please don't broadcast anything you don't mind anyone else hearing.

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Newsletter

You may want to sign up for out newsletter so you can receive the latest news and special deals. Also check our forum and discuss tips and tricks with other users, you never know you just may learn something. You can sign up at www.pcs-electronics.com

Appendix A: Using the MAX PRO I

Basically there are three push-buttons available for the menu system, **UP**, **DOWN** and **MENU**. By pushing **UP** or **DOWN** you get a shift of frequency in corresponding direction. Hold any of these keys for a few seconds and the jumps will increase to 500 KHz. The new frequency is saved automatically. The third button (**MENU**) gives you access to several functions (**TEST**, **TUNE-UP** & **LOCK MONITOR**). If you want to select one of these functions, just press the **UP** key.

TEST function

This can be very useful for troubleshooting. First it will display PLL status and then check the 9V voltage regulator. If the PLL isn't locked, the unit suggests how one can remedy this situation.

TUNE-UP function

Just tune C24 and C25 for lowest pitch. Once you find the right setting, use the **MENU** key again to exit back to normal operation.

LOCK MONITOR function

Allows you to toggle **LOCK MONITOR** on or off. MAX PRO I doesn't check PLL lock status when this function is off and does not shut down power if the unit looses lock. When this function is On, MAX PRO I constantly checks PLL lock status and shuts down output power in case of lost lock. Unlocked PLL is also indicated by an annoying **low-pitched periodic sound**.

JUMPERS

Careful examination reveals 1 jumper on the RF board.

Jumper	Function	Default setting
J1	Preemphasis	**On** for MONO (USA standard)

AUDIO LEVEL ADJUSTMENT

Adjust audio level with trimmer (P1) on the RF board so that you sound a bit less loud than other radio stations. This prevents interference to adjacent channels as you probably do not own expensive audio equipment that radio stations usually employ to make their stations sound louder.

OUTPUT POWER ADJUSTMENT

Adjust output power with trimmer (P2). This trimmer is located close to T5.

Appendix B: The most frequently asked question: How can I increase performance?

I'm pretty sure you are all interested in this, or at least you will be after a while. First let me warn you that some of you might have stability problems if you try to push MAX too far. You'll also have to account for additional heat. Here is a list of simple things you can do to raise output power of MAX PRO I:

First and most important, the best thing you can ever do to increase performance is to get better antenna and/or move it higher!

1. Increase supply voltage to 14-16V (17 volts is UCEmax for 2SC1971, but make sure caps can take it).
2. Tune (compress or expand) L2 and L3 for maximum power
3. You can put a small metal shield around VCO (note designated square around L1/T1).
4. **Operating close to 88MHz sometimes requires that you add a 10pF capacitor in parallel with the C19 (close to the final)**

Any ideas and improvements are welcome, please let us know and we'll publish them on our home page. Some of them are already posted there.

Appendix C: The principles of operation

MAX PRO I features a Phase Locked Loop (PLL) oscillator. This combines the ease of tuning and wide deviation of a VFO with the frequency stability of a crystal oscillator. Have a look at diagram 2; a crystal oscillator is used to provide a reference frequency. This is digitally divided to a frequency of relatively low 50 KHz. A VFO provides the wanted output frequency, which is also digitally divided to give another relatively low frequency. These two low frequencies are presented to a phase comparator which basically decides which frequency is higher by comparing the phases of the two signals. The phase comparator generates an error voltage which is connected back to the input of the VFO through a low pass filter (LPF). This is the loop bit. If the VFO is running too fast the phase comparator decreases the error voltage so as to slow it down till the phases at its input are the same. If it's running too slow the error voltage is increased to speed it until the phases are the same. All this happens instantaneously, of course so the output frequency remains constant. In this way the temperature stability of the VFO isn't important as its output frequency is phase locked to the crystal oscillator, and the frequency stability of this is very good. Clever eh? Two more things to explain. How do you change the output frequency? By making the VFO's divider programmable. Say it's set to divide by the number N. The phase comparator is a simple minded sort of soul, concerned only with equalizing the phases at its inputs, it doesn't know what's really coming out of the VFO, which is N times the divided reference signal. Because this signal is so low compared to the VFO frequency N can be made to have hundreds of different values, giving hundreds of different output frequencies from the VFO. So changing the frequencies is just a matter of changing division ratio. Since this is taken care by the uCPU (IC2), all you have to do is push the button. By the way, almost all of the black boxes from the above diagram are contained in one single integrated circuit, IC 3. VFO is being frequency modulated by the audio input, so its frequency at any given instant depends on the voltage of the audio output. We don't want this variation of the VFO's frequency to be ironed out by the PLL system thus we 'iron out' the error voltage from the phase comparator, so it just contains the underlying trend rather than what's happening at any split second. This is the purpose of the low pass filter. Programmable PLL oscillators are used in majority of the professional communications equipment, including broadcast transmitters. The digital part of MAX PRO I is a small computer, based on ATMEL microcontroller. This little chip is actually doing all the »thinking« for MAX PRO I. It sets the divider ratio for PLL, directs LED and reads keyboard. All of the various settings are stored in the EEPROM IC3. Its contents remain unchanged when you turn off the transmitter. VFO is employing a single MOSFET transistor. Weak

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signal from VFO gets amplified by IC4, T2 and T3 to few watts of pure power. Output filter consisting of L5-L7 and accompanying capacitors keeps harmonics down to minimum.

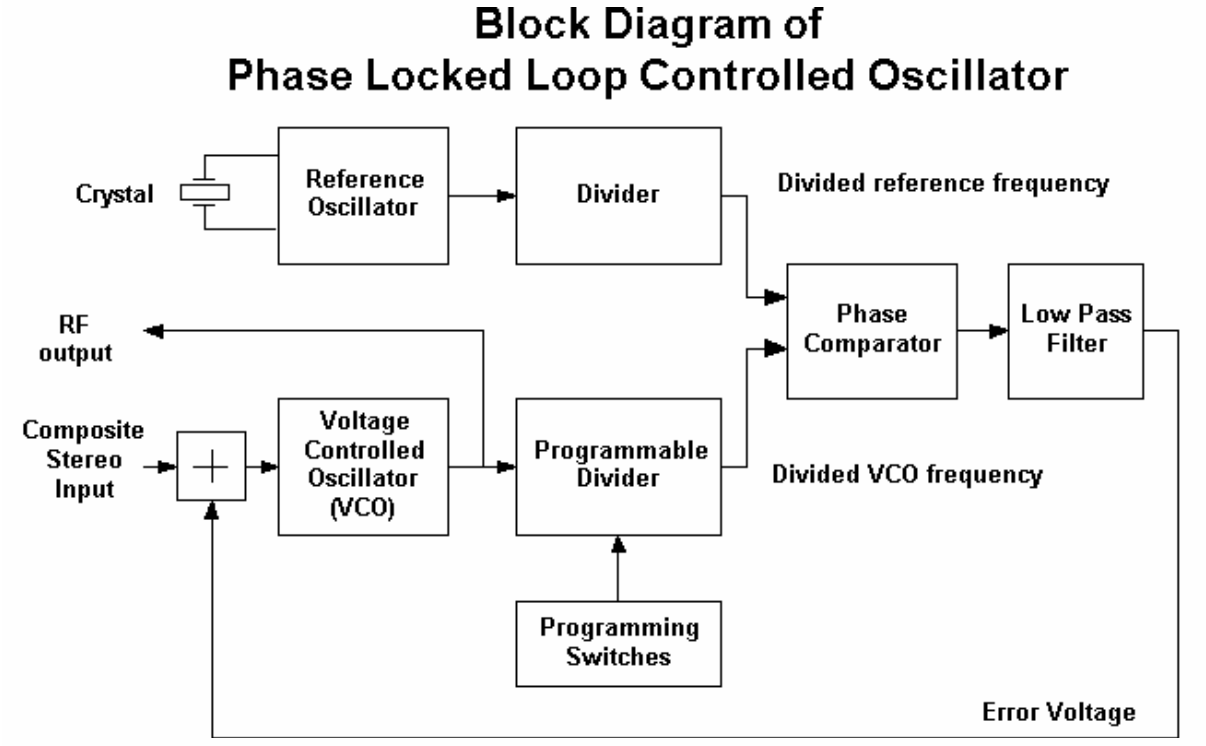

Diagram2: PLL block diagram

Appendix D: The resistor color codes

The easiest method is to get radio Shack part number 271-1210 for $1.19; it is a pocket sized card with spin dials. Just spin the dials to show the correct colored bands and read the resistance off the card. Sort of a resistor slide rule.

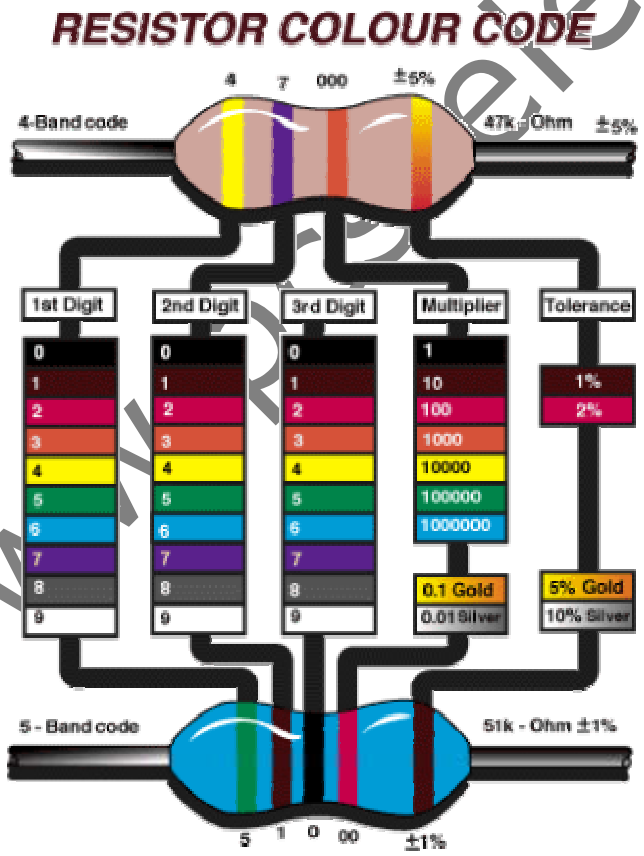

Fig 10: ***Resistor colour codes, if there are only four bands, omit the 3rd digit.***

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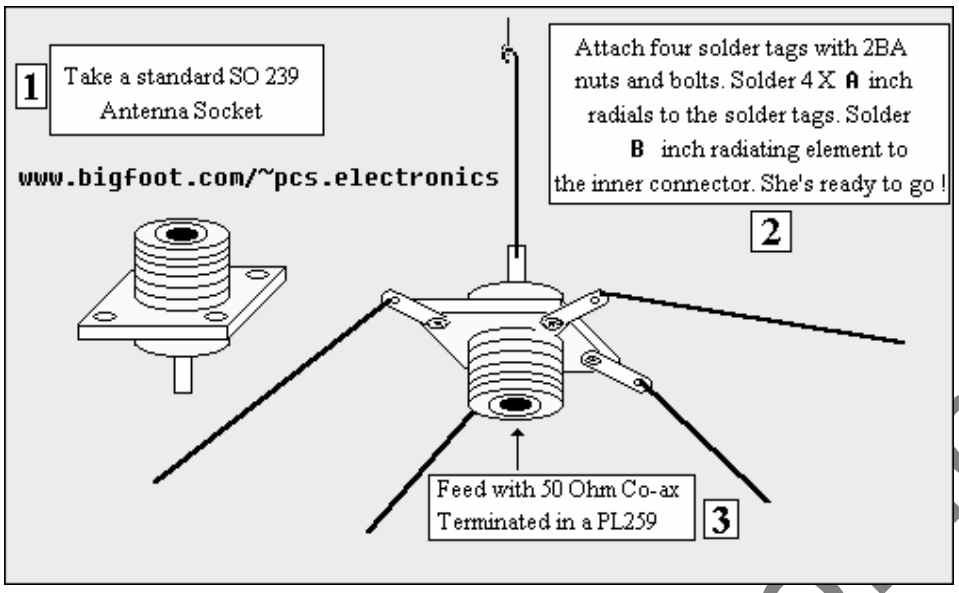
Appendix E: GP antenna design

You can build an inexpensive 1/4 wave antenna from 1 SO-239 chassis mount RF connector and 5 - 3' bronze welding rods, cut to the proper length. Here is how it looks:



If you have a SWR meter, leave a bit longer radiator and adjust it later by cutting to achieve minimum SWR.

Diagram3: »Do it yourself« GP antenna

Most designs on the web don't compensate for the fact that GP antennas are not wideband antennas. Here is a Freq/element length chart for this simple GP antenna, all element lengths are in millimeters:

Frequency	Radiator - B	Radials - A
108MHZ	660	693
104MHz	684	720
100MHz	713	749
90MHz	792	819

For other antenna designs check our web site.

Appendix F: The range

While it is not possible to accurately predict range of a transmitter, since this depends upon hard to measure parameters, for example, terrain configuration, type and exact position of antenna, receiver etc. But let's see what buyers of MAX PRO I had to say based on their experience:

R. E. from Portland, Oregon

I connected MAX PRO I to a Ramsey Antenna kit with 75 ohm coax, which is what Ramsey calls for. I have it on top of a 10 foot pole on my garage and I get a solid signal for about three miles, then fading good to poor then a marginal signal out to about 8 miles. When I climb a hill, even 10 miles away. The signal booms in like I was next door. This tells me that if I just had my antenna mounted higher, that solid signal would be cleaner much further out....

T.P. from Ohio

I am running MAX PRO I without trying to optimize power output (yet). I built an adjustable vertical double dipole antenna fed with 25 feet of 75 Ohm RG-6 cable. The antenna is currently mounted 15 feet above ground level. My wife went out with the car radio, and could easily hear MAX out to 3.5 miles. What makes this very impressive is that we live in a steep walled valley which is only 2 miles long. Thus, she was able to hear MAX at 3.5 miles without being in the line of sight!
*I might have to adjust the power output of MAX. I might have to adjust it DOWNWARDS. *grin**

Bill of Materials **MAX PRO I - Display Board**

Qty	Value	Reference	Notes
1	Beeper, small oval speaker	BUZ1	
1	7805	IC1	
1	89C2051	IC2	
1	24C16	IC3	
1	74HC4040	IC4	
2	10uF – 47uF	C1, C3	
1	0.47-1uF	C5	
2	47-100nF (marked as 473 or 104)	C2, C6	
1	47pF (marked as 47p)	C8	

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1	68pF (marked as 68p)	C9	
1	22nF, pitch 5mm (0.022)	C13	
1	Flat cable	J1	
3	1N4148	D1,D3,D4	
1	13V zener diode (silver)	D2	
1	LCD display, see pics for mounting	J2	
1	6.4MHz	Q1	
2	BC547	T1, T2	
3	Push button	S1, S2, S3	
1	10K trimmer resistor	P1	
1	1K	R2, R6	
1	1000uH, looks like an unusual greenish resistor (brown, black, brown, silver)	R5	
1	330	R7	
1	22K	R8	
1	150	R9	
2	Bolts for LCD		Opposite corners
2	Screws for LCD		Opposite corners
2	Distancers for LCD		Opposite corners
1	PCB, 90x40mm		
1	IC socket, DIL 20	For IC2	

Warning, R1, R3, R4, C4, C10, C11, C12, T3 are not used!

Bill of Materials **MAX PRO I - RF BOARD**

Qty	Value	Reference	Notes
1	8p2 (marked 8.2)	CA (under L7)	
1	4n7 (5mm, marked 4n7)	C1	
1	100uF	C2	
11	10nF (marked 103 or 10n)	C3,C7,C9,C10,C11,C15 C16,C18,C20,C21,C31	
1	150nF (5mm, marked 0.15 or 150nF)	C4	
1	68nF (red block, marked 0.068 or 68nF)	C5	
3	10pF (marked 10)	C6,C30,CB (Under L6)	
2	100pF (marked 101 or 100p) or 120pF (121)	C8, C14	
1	470uF/25V	C12	
3	22uF	C13, C15, C17	
1	39pF (marked 39 or 39p)	C19	
1	Trimmer, green	C24	
1	Trimmer, black	C25	
2	27pF (marked 27 or 27p)	C26, C23	
2	22pF (marked 22 or 22p)	C27, C22	
2	2p2 (marked 2.2 or 2.2p)	C28, CC (Under L5)	
1	6p8 (marked 6.8 or 6p8)	C29	
1	1N4001	D1	
1	BAT85	D2	
1	BB809 – A plastic diode with yellow strip	D3	
1	78L09 or 78L10	IC1	
1	78L05	IC2	
1	TSA5511	IC3	
1	Jumper, Preemphasis	J1	
1	RCA connector	J2	Audio
1	BNC connector	J3	Antenna
1	14-pin connector, connects to LCD via flat cable	J4	
1	5 turns, tap after first turn	L1	
1	3 turns, two unmarked holes next to L2	L2	
1	2 turns (or 1 U-shaped turn)	L3	

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1	8 turns	L4	
1	4 turns	L5	
1	4 turns	L6	
1	4 turns	L7	
1	6 turns or VK200 (black oval with 6 holes)	L8	
1	470 ohms	R1	
1	680 ohms	R2	
1	12K	R3	
3	22K	R4, R6, R19	
2	1K	R5, R7	
1	1 or 2,2 ohms	R8	
1	220 ohms	R9	
1	56 ohms 1/4W	R10	
1	56 ohms, 1/4W resistor, it should be 5 mm above and in parallel with the board	R11	
1	15K	R12	
1	39-56 ohms, 1/2W. usually blueish resistor, size same as 1/4W. Mount 3-4mm above the board for improved cooling!	R13	
1	10 ohms	R14	
1	100 ohms	R15	
1	330 ohms	R16	
2	39K	R17, R18	
1	500 ohms trimmer	P1	Audio level
1	2K5 trimmer	P2	Power level
1	BF981	T1	
1	BFR96	T2	
1	2SC1971	T3	
2	BC547	T4, T6	
1	BD135	T5	
1	PCB, 85x100mm		
1	Choke, see picture 8, VK200, black oval		
2	Aluminum block, screws, and bolts for output transistor		

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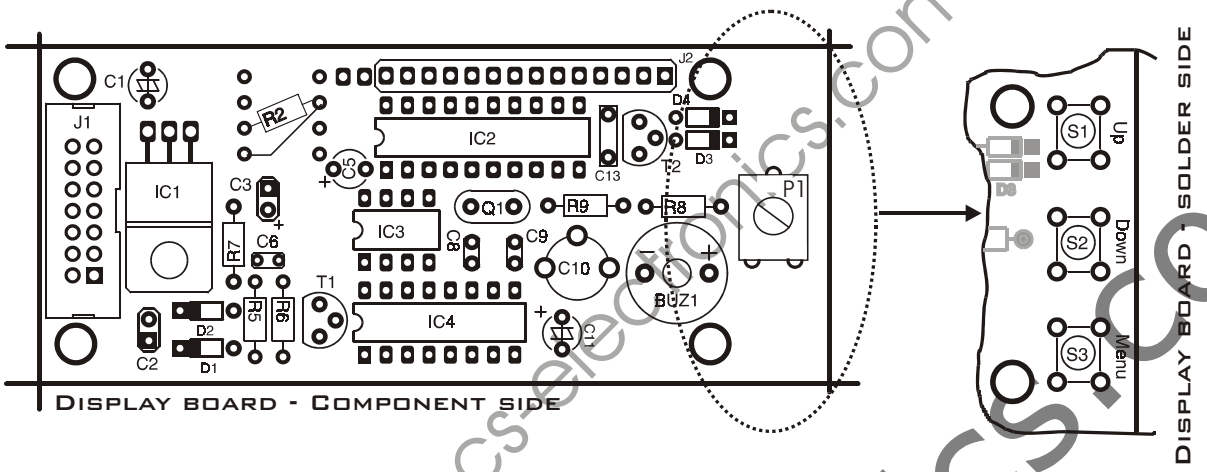
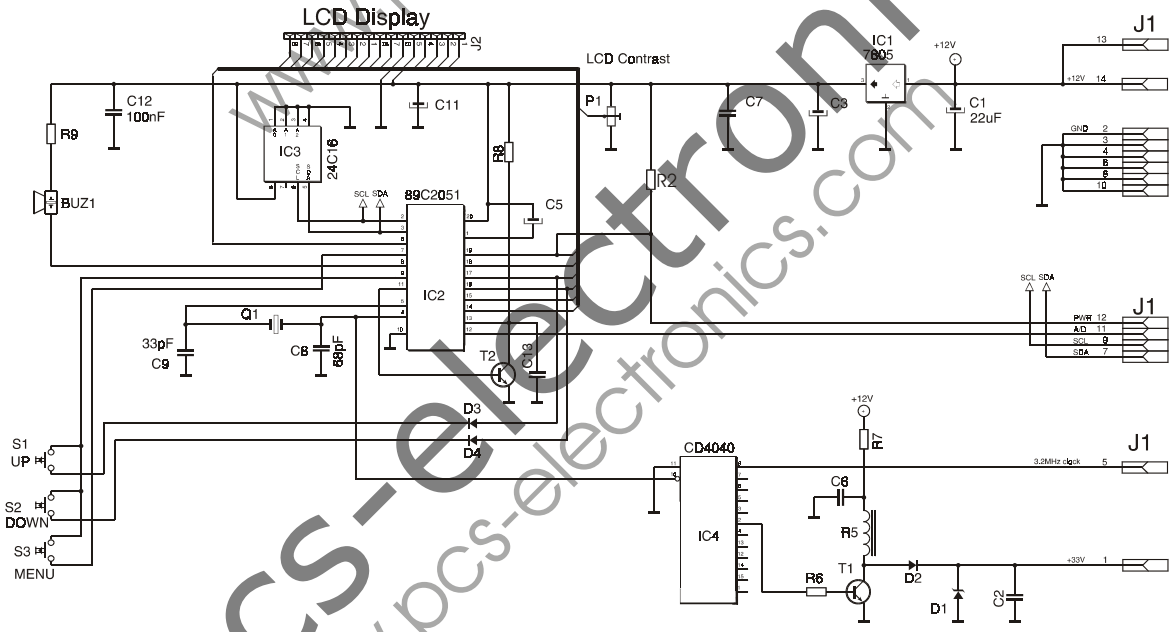
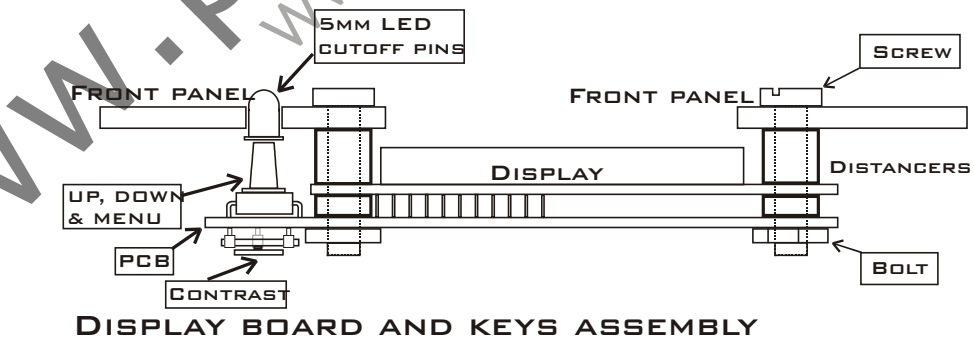
MAX PRO I display board



DISPLAY BOARD - COMPONENT SIDE



DISPLAY BOARD - SCHEMATIC DIAGRAM



DISPLAY BOARD AND KEYS ASSEMBLY

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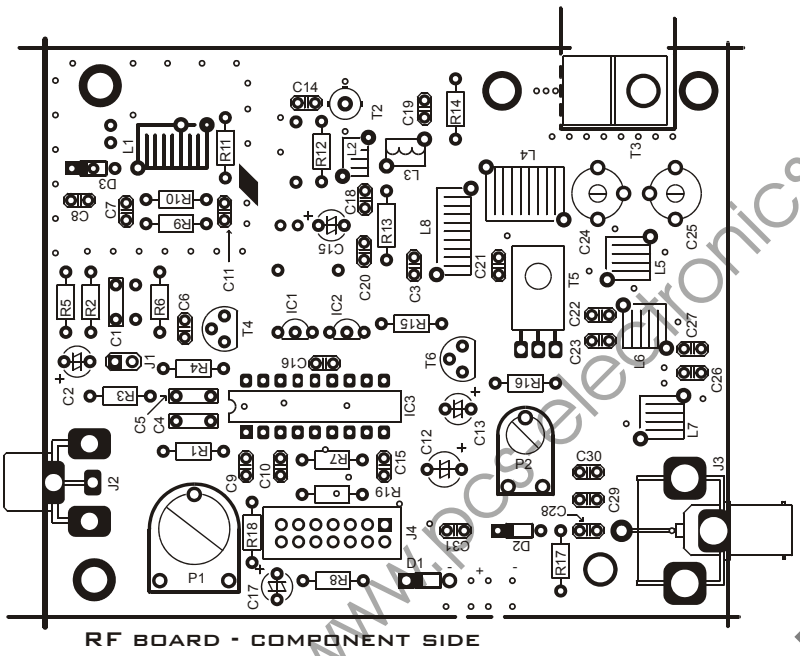

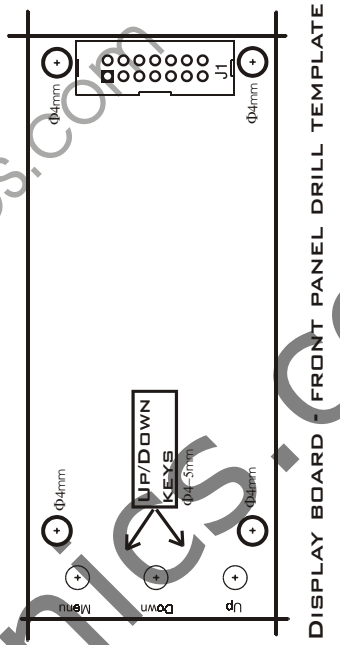

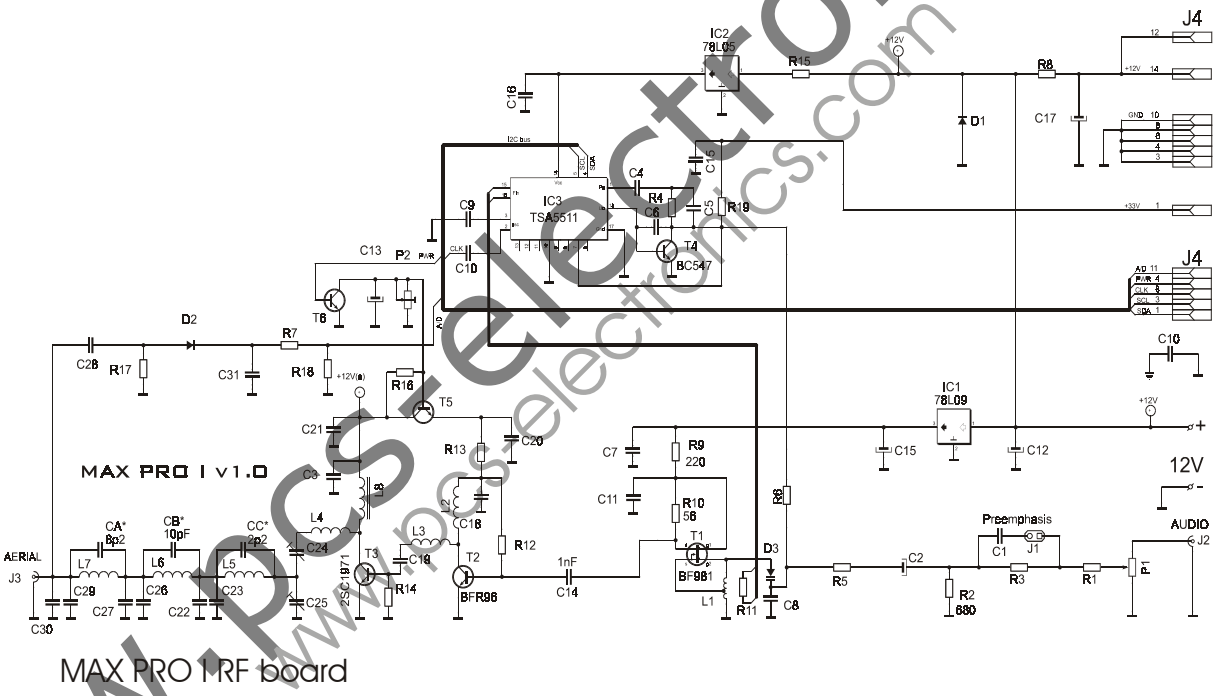

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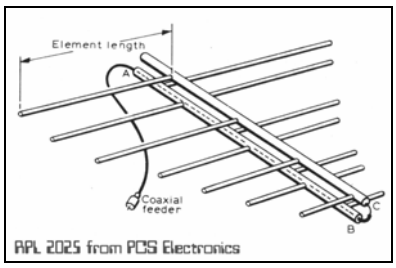

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