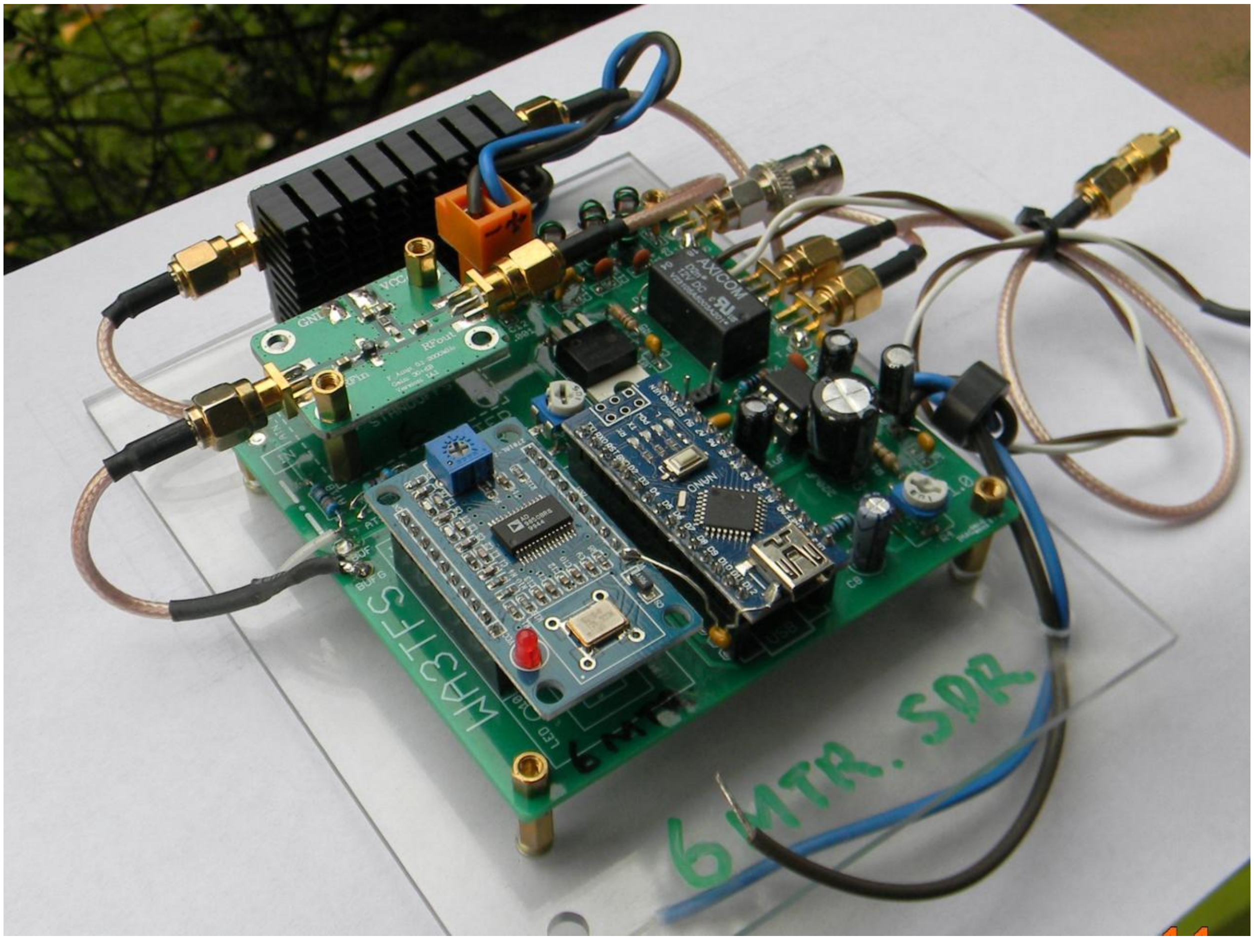
WA3TFS SUPER SIMPLE 6 METER SDR FM TRANSCEIVER

ASSEMBLY, ADJUSTMENT AND USAGE MANUAL



This manual details the construction, adjustment and usage of the high performance FM SDR transceiver. The transceiver is programmed and controlled by a DDS module that produces the output frequency directly at the transmit frequency so as to not require mixing. Microphone input is amplified and digitized in the Arduino NANO microprocessor and combined with the proper control data fed to the DDS module in such a way as to produce high quality frequency modulation. Pre-emphasis is added to the analog microphone amplifier before digitizing. The DDS module and the microprocessor are powered by the USB connection to the computer. Control is provided by any serial program connected to a USB port on the computer.

An adjustment potentiometer is provided to adjust the microphone audio level as necessary. This adjustment is not a deviation adjustment but only an audio level control. Deviation is controlled by the software. The purpose is to set the microphone level below the point where there is distortion on the output that is caused by exceeding the limits in the A/D conversion in the NANO microprocessor.

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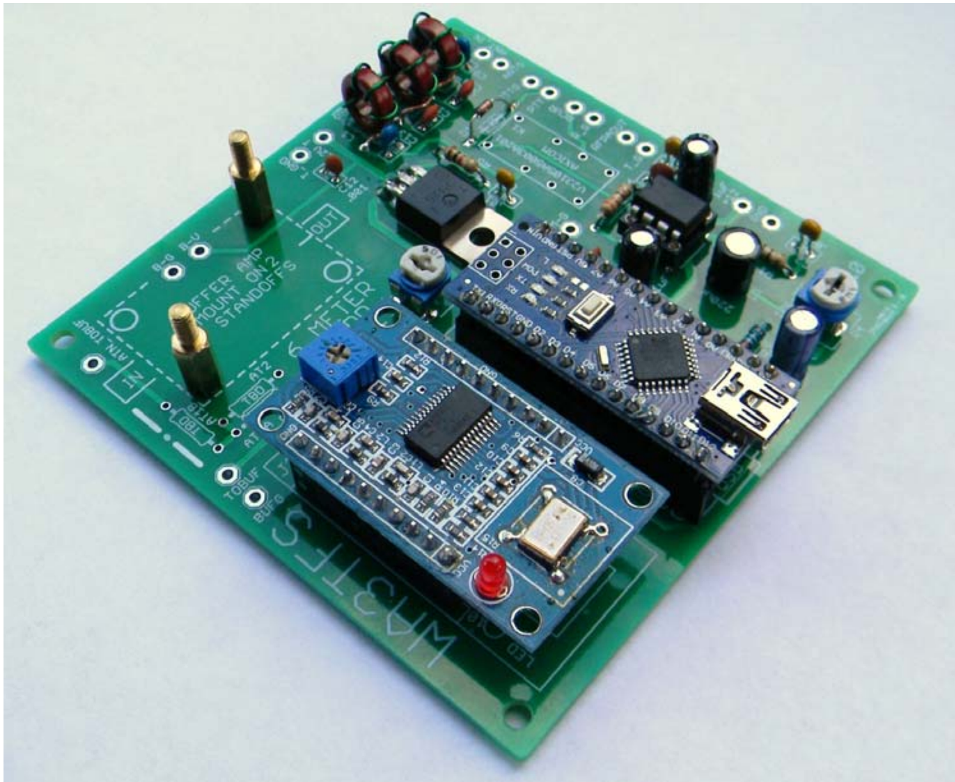

This is the assembled printed circuit board requiring only the relay and buffer amplifier to be added. If an attenuator is necessary (to not overdrive the final amplifier of choice), three resistors may be added at locations AT1A, AT1B and AT2 to form a T attenuator. Values for the resistors for the attenuation necessary can be found in the *ARRL Handbook* or other publications. Typically, for a final amplifier drive level of 1 dBm, the attenuator should be -15 dB. For -15 dB resistor values for AT1A and AT1B are 35 Ω and AT2 is 18.4 Ω . ¼ watt resistors are sufficient. Don't overdrive the final amplifier!

ADDENDUM: The Arduino microprocessor has been programmed to supply a sub-audible tone for repeater access or squelch control. The microprocessor outputs a 50% duty cycle square wave on pin D3. This square wave is run through a low pass filter (R7, R8, R9 and C16, C17 and C18) to obtain a sine wave. The output of this tone level is set by R10 and applied to the microphone input on the board through R11. Set the level for about 2 kHz deviation as viewed on the receiver software. The tone will be on any time the microprocessor is active. If you do not want the tone, comment out the command on the line noted in the software. The note frequency is also set in the software and may be changed as necessary for your application. The default frequency is 72 Hz. It cannot be set exactly to some frequencies, but will be within a half Hertz, which is close enough for its use. The minimum frequency that can be set is 30 Hz.

The microphone gain (R4) should be set just below the point where distortion is generated in the voice. This is not a deviation setting but only sets the audio level so as not to exceed the A-to-D converter range in the microprocessor.

This design makes extensive use of five re-purposed modules to simplify the design and keep parts count and cost to a minimum while still producing a high performance design. Filtering is supplied on board and is used for both transmit and reception. Antenna changeover and power is controlled on board.

The DDS output is around -22 dBm so must be amplified to be useful. Output does vary a bit from one module to another. A simple TV amplifier provides up to 30 dB gain. This may be too high for driving a final amplifier so provisions have been made on board for an attenuator before the buffer amplifier stage. Typically the output amplifier will require 0 to +5 dBm to produce full output power. There is no advantage in over-driving the amplifier as it will stress the amplifier and add to spurious output levels.

Construction:

Check the parts list to assure all parts are on hand before beginning construction. It is recommended that the board be assembled in the following order. Resistors, capacitors, headers, relay, power switching transistor, inductors and integrated circuit. Be sure to mount the electrolytic capacitors, diode and integrated circuit with the correct polarity indicated on the board. Then, mount the buffer amplifier and any additional hardware. Do not install the DDS module or NANO at this time. Locations for all components are shown on the circuit board silkscreen.

Inspect all solder connections and parts values to assure the board has been assembled correctly.

Apply 12 volts and ground to the marked locations near the integrated circuit. Temporarily ground the PTT connection to the adjacent ground pad and assure the relay is being energized. Remove 12 volts.

If you are using the specified buffer and final amplifier, it may not be necessary to attenuate the drive to the final amplifier. Overdrive also generated spurious emissions. If your amplifier requires less drive, wire in an attenuator consisting of three resistors. A -3 dB ‘T’ attenuator consists of two 8.2 ohm resistors in series and one 150 ohm resistor shunt, for example. (Actual -2.86 dB) Consult the ARRL Handbook or on-line calculators for other values.

The ‘T’ attenuator for -15.9 dB consists of three resistors, AT1A 33 ohm/1/4 watt, AT1B, also 33 ohm/1/4 watt and AT2, 15 ohm/1/4 watt. The pads for these parts are located on the input side of the buffer amplifier. Note that the attenuated output to the buffer input is located near the mounting hole. The shield for the coax can be soldered on the underside of the board to the B-G pad and the center lead of the coax to the ATN-TOBUF pad. When using the attenuator, the TOBUF pad is not used. Resistor values for other levels of attenuation may be found on line or in the ARRL Handbook.

At this point, complete the wiring except for connections to the final amplifier. Also at this time, connect the RTL Dongle, DDS module, and NANO. See **figure 1**

Attach USB cables to both the NANO and the Receiver dongle. The LED on the NANO and DDS should illuminate when the cables are attached indicating they are receiving power from the computer.

Download and configure HDSDR software and your serial terminal program (Termite) on your computer.

Upload the control software for the transceiver to the NANO. When complete, activate the terminal program and configure it as shown in **Figure 2**. It will be necessary to determine the proper USB port in the settings menu. On the main screen, type in 51200000 and hit enter. The screen should answer back "transmit accepted" if all is correct. If not, select a different USB port until the proper one is found.

Always enter the frequency using 8 digits.

Activate and calibrate the HDSDR software using a known station such as the local weather or public service frequency.

Tune the HDSDR software to receive NFM, and frequency of 51200000. Adjust the bandwidth of the filter to 15 kHz. You should see a signal being generated by the transceiver and it may or may not be on frequency. The frequency calibration will be done at a later time by adjusting the software. At this point, just tune the software to the transmit frequency as generated by the DDS and make note of the actual frequency.

Attach a microphone to the transmitter. Just about any low impedance dynamic microphone may be used. The level is provided to attenuate a microphone that has excessive output. Normally, the adjustment can be set to maximum with most microphones. If audio is distorted, set it to a lower level.

Speak into the microphone and you should hear yourself with a slight delay. Your signal should be clear, with no distortion and fill the 15 kHz bandwidth of the filter. Adjust the gain control just below the point where distortion is noted.

If you wish to transmit a sub-audible tone, it can be adjusted for level at this time. The default is set to 72 Hertz but can be adjusted for any frequency. You can set the level at this time by observing the DDS signal in the IF display screen on the HDSDR software. As you rotate the R10 (TONE LVL) control, observe the width of the signal increasing and decreasing in width. Adjust for a width of 200-400 Hertz. That is setting to a compatible level for most repeaters. This adjustment must be made with a microphone attached to the transmitter.

If all is well at this point, it is time for frequency calibration.

Activate the Arduino programming software and open the transceiver control software. Locate the line **frequency = frequency + (2.5 * mic) – 102; //1024800 this is the Frequency Modulation. The -102 calibrates frequency. Higher number lowers frequency approximately 52 Hertz per number.**

Tune the HDSDR to the calibrated 51200000 frequency and note the frequency from the DDS as being higher or lower than the set frequency. Carefully change the -**102 to a bit higher or lower** and upload the program to the NANO each time. Activate the control program, reprogram 51200000 and note the DDS frequency will have changed. Continue doing this until the transmit frequency matches the calibrated tuned receive frequency. Once the proper number is found, (it will change approximately 52 Hz for each number increment or decrement), no further adjustments are needed. You will find the programmed frequency will now match the calibrated receiver frequency. Expanding (Zoom) the display makes it easier to see the exact frequency. Save the Arduino file. Note that to upload the program to the NANO, it may be necessary to set the Arduino software to the same port as the control program. If so, it will be necessary to close the control program until uploading is complete and then re-activate the control program to set the frequency.

Next, if you desire transmit a sub-audible tone, locate the line, near to beginning, The 72 sets the sub audible tone to 72 Hertz. Adjust the tone deviation using R10 on the board. Typical setting is 200 to 500 Hertz deviation but set to whatever is required by the repeater. (only whole numbers are accepted)

> **unsigned int subtone = 72** //SET THE SUBAUDIBLE TONE FREQUENCY IN HERTZ HERE, May not set exactly but within ½ Hertz , **NOTE: Whole numbers only.**

You can change the frequency for the sub-audible tone in this line. If changed, upload to the NANO and save the file.

Your transceiver is now calibrated. Now, attach all connections to the final amplifier. Connect 12 volts DC, a microphone, and a resonant antenna or dummy load.

Set the repeater output frequency on the HDSDR program and the repeater input frequency on the NANO input. When you press the microphone PTT switch, the transmitter will shift from receive to transmit. Set your squelch level on the HDSDR software as necessary. RF output should be on the order of 1-3 watts to the antenna depending on the final amplifier gain. Higher level amplifiers may be added to boost output. The output will typically be lower than the amplifier rated output after filtering through the low pass filter since it attenuates harmonics.

THIS COMPLETES THE ASSEMBLY AND ADJUSTMENTS OF YOUR TRANSCEIVER. IF YOU HAVE ANY COMMENTS, PLEASE CONTACT ME.

73, JIM FORKIN WA3TFS

REQUIRED SOFTWARE:

TFS_6FM_SDR_R1_0.ino	Control software to be uploaded to the Arduino Available on request from jforkin@verizon.net
HDSDR, receive software	free download from www.hdsdr.de
Termite, serial program	free download from www.compuphase.com/software_termite.htm

ADDITIONAL NOTES: This rig may be used on 10 meter FM by simply changing the low pass filter values and running a different version of software. Change C9 and C13 to 40 p, C11 and C14 to 180 p, L1 and L3 to .312 Uh (8T), and L2 to .482 uH (9T). Software- TFS_10MTR_FM_SS_SDR_R1.ino

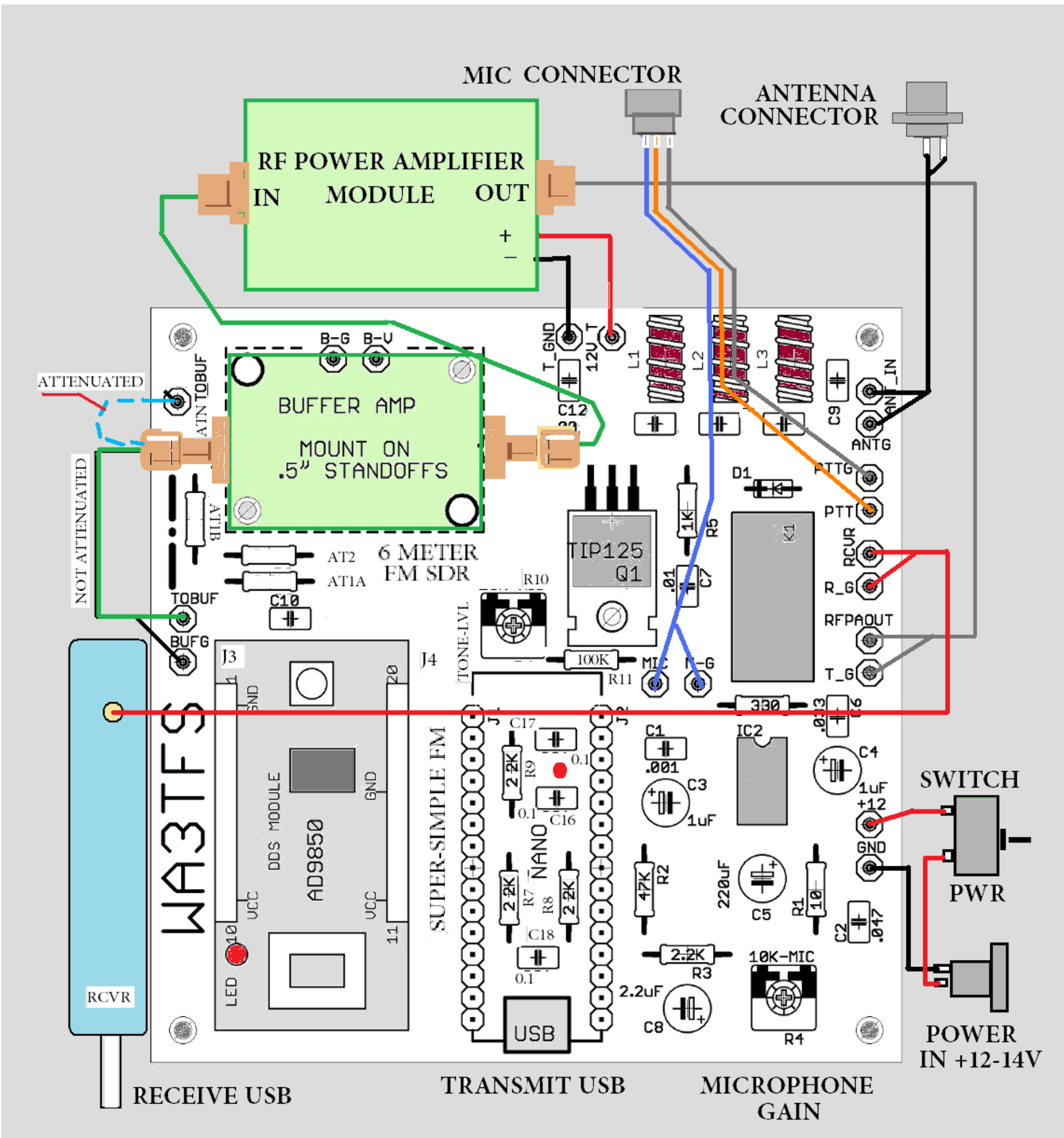

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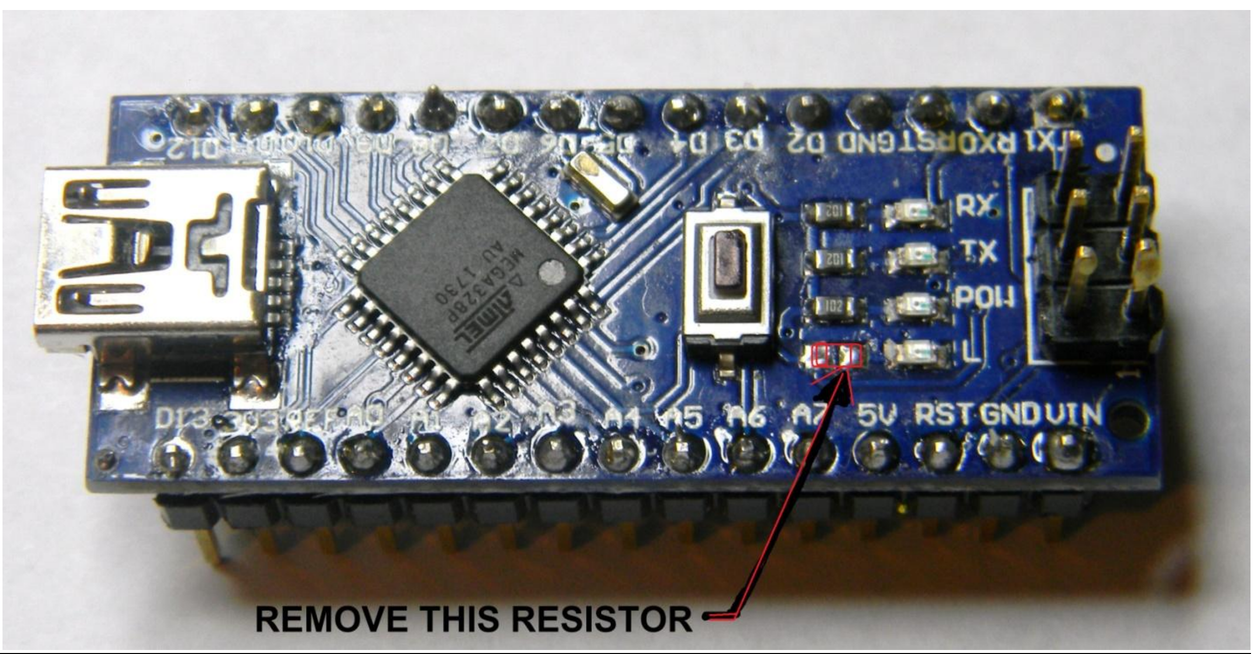
Figure 1

Figure 2 Serial control software, Port may change for your computer



Arduino NANO, Make modification shown above

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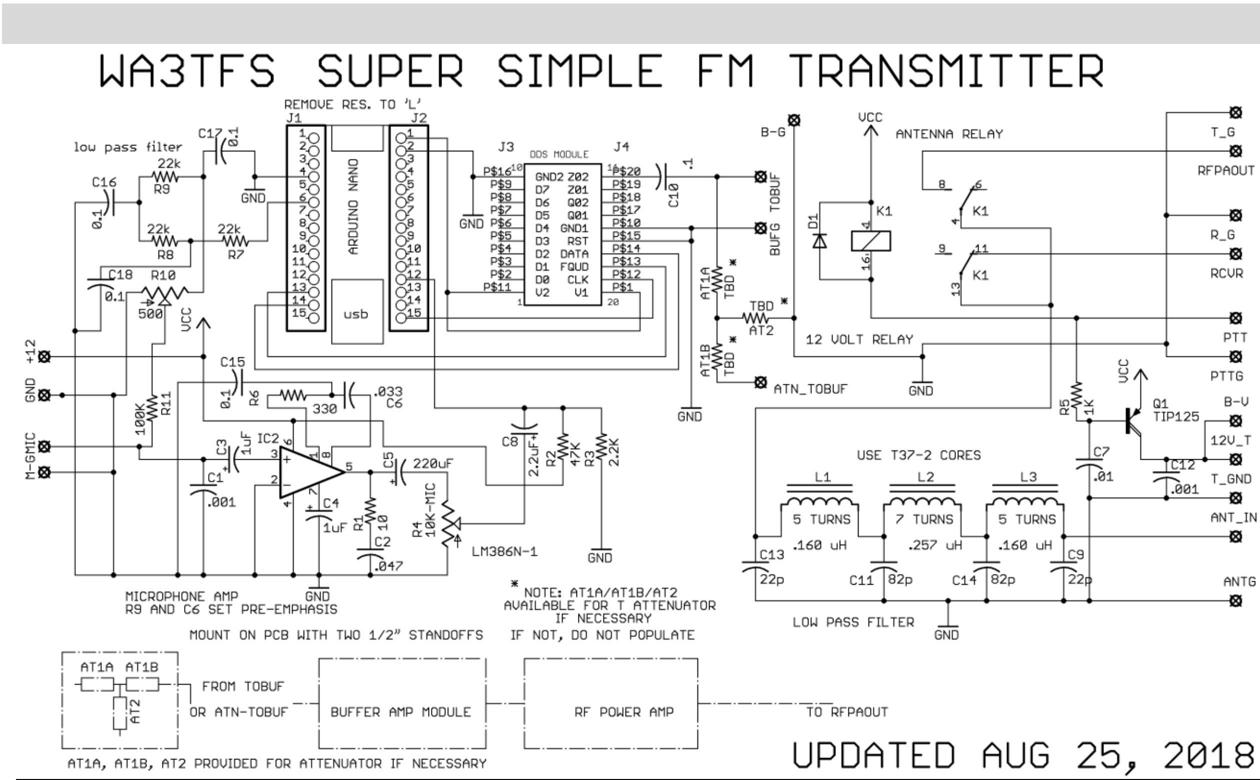
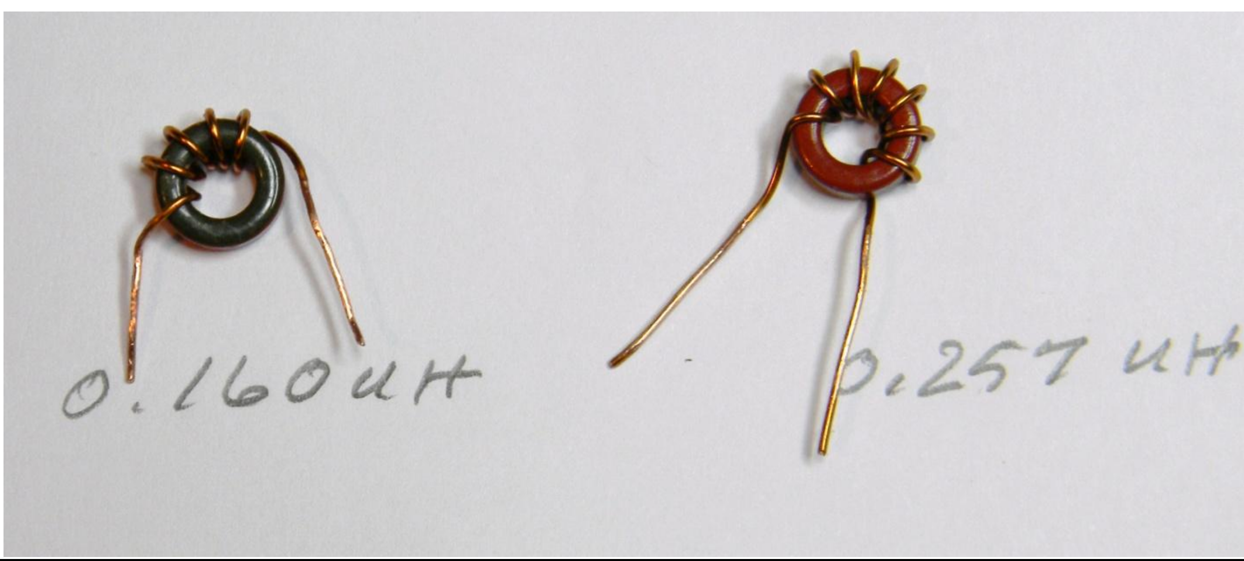
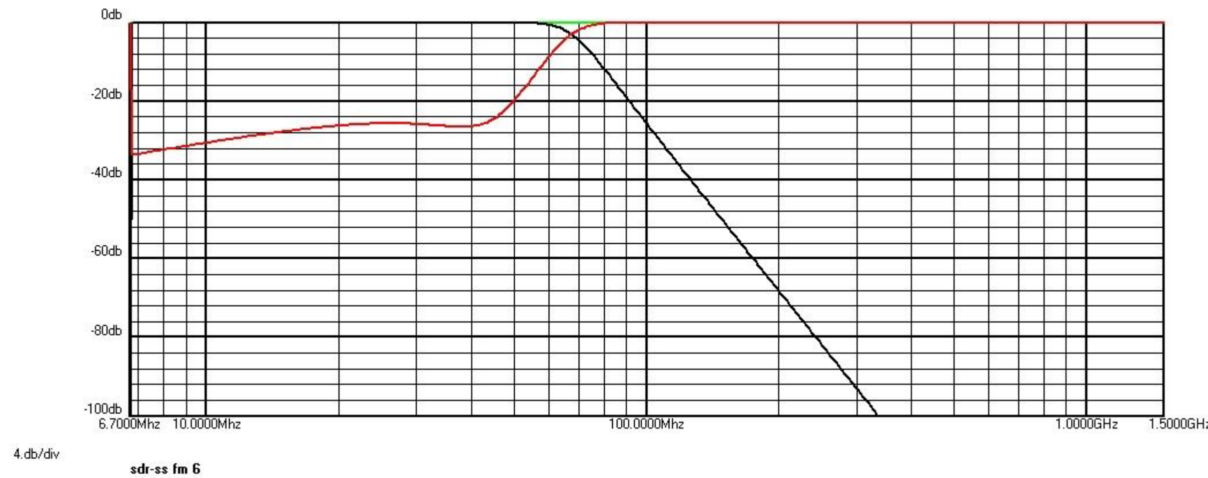
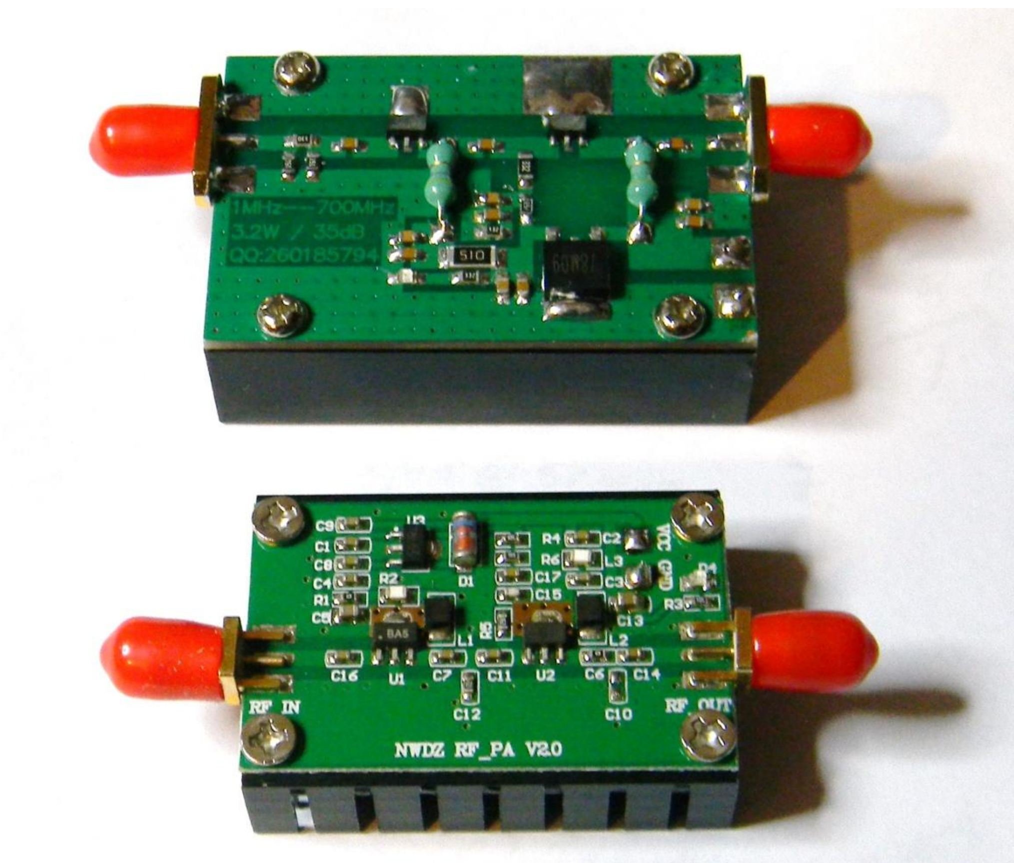


<u>Inductor values, L1 and L3 = 0.16 uH, L2 = .257 uH. Wind on t37-2 toroid cores. Compress or expand turns as necessary. Typically wind over about 50% or the core</u>



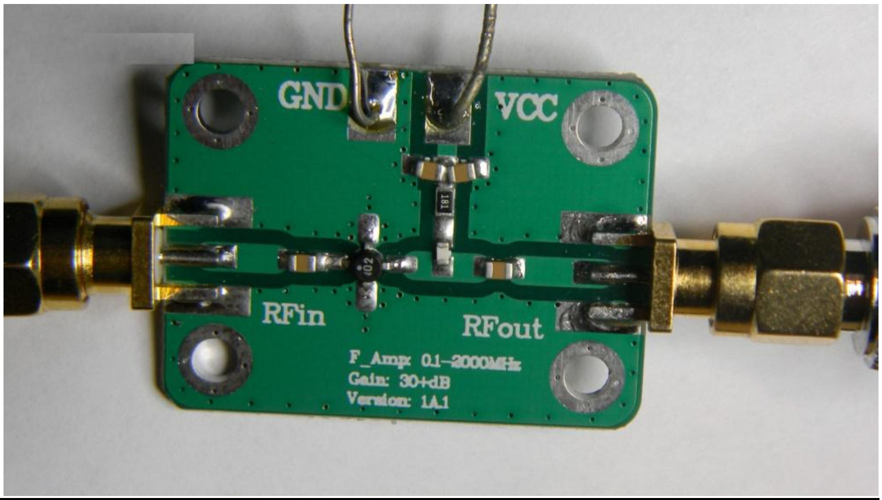


Frequency response of the low pass filter L1, L3 = .16 uH, L2 = .257 Uh for 6 meters



Two different final amplifiers suitable for use with this transceiver. Either will put out 1-3 watts.

Replacement devices for these amplifiers are Input-MMIC, SBB2089Z and Final-LDMOS, AFT05MS003NT1. Both available from Mouser Electronics, Final only from DigiKey



Recommended Buffer Amplifier. It may be necessary to construct a shield over this side if unwanted RF is coupled to other componants or wiring. Construct from copper or tin and ground to connectors at each end and unused mounting holes. Avoid VCC.

MODIFICATION DRAWING FOR C19||R11

REPLACE R11 (100K) RESISTOR WITH THIS COMBINATION. 0.1 uF CERAMIC CAP ACROSS A 4.7k ¼ WATT RESISTOR. THIS MODIFICATION HELPS ISOLATE THE TONE GENERATION FROM THE MICROPHONE INPUT AND CANCELS SOME DIGITAL NOISE ON THE TONE INPUT.

ITEM NO.	VALUE	DESCRIPTION	QUANTITY	DIGIKEY PART NO.	NOTES
C1, C12	0.001u	CERAMIC CAP/50V	2	BC1072CT-ND	
C2	0.047u	CERAMIC CAP/50V	1	399-4189-ND	
C9, C13	22p	CERAMIC CAP/50V	2	399-9723-ND	
C11, C14	82p	CERAMIC CAP/100V	2	490-7490-1-ND	
C6	.033u	CERAMIC CAP/50V	1	399-4179-ND	
C7	.01u	CERAMIC CAP/50V	1	BC2662CT-ND	
C10,C15,C16,C17,C18	0.1u	CERAMIC CAP/50V	4	478-3192-ND	
C19-MOD*	0.1u	CERAMIC CAP/50V	1	478-3192-ND	SEE MOD
C3, C4	1u	ELECTROLYTIC/25V	2	493-10419-1-ND	
C8	2.2u	ELECTROLYTIC/25V	1	493-10503-1-ND	
C5	220u	ELECTROLYTIC/25V	1	P13131-ND	
D1	1N4148	SWITCHING DIODE	1	1N4148FS-ND	
IC2	LM386N	AUDIO AMP IC	1	296-43960-5-ND	
K1	DPDT/12V	RELAY	1	PB384-ND	
Q1	TIP125	PNP DARLINGTON	1	TIP125GOS-ND	
R1	10 OHM	RESISTOR/.25 WATT	1	CF14JT10R0CT-ND	
R2	47 K	RESISTOR/.25 WATT	1	CF14JT47K0CT-ND	
R3	2.2 K	RESISTOR/.25 WATT	1	CF14JT2K20CT-ND	
R4	10 K	RESISTOR/TRIMMER	1	3319P-103-ND	
R10	500 OHM	RESISTOR/TRIMMER	1	3306F-501-ND	
R5	1 K	RESISTOR/.25 WATT	1	CF14JT1K00CT-ND	
R6	330 OHM	RESISTOR/.25 WATT	1	CF14JT330RCT-ND	
R7,R8,R9	22 K	RESISTOR/.25 WATT	3	CF14JT22K0CT-ND	
******R11******	4.7 K	RESISTOR/.25 WATT	1	CF14JT100KCT-ND	SEE MOD
J1-J4	PIN HEADER	10 POSITION/MALE	2	952-1905-ND	CUT TO FIT
				PARTS ABOVE DIGIKEY	
NANO	ARDUINO	MICROPROCESSOR	1	EBAY/ON LINE	
AD9850		DDS MODULE	1	EBAY/ON LINE	
BUFFER		LNA MODULE	1	EBAY/ON LINE	
RF AMP		RF POWER AMP	1	EBAY/ON LINE	
L1, L2, L3	T37-2	TOROID CORE/RED	3	AMIDON	5 T AND 7 T
RECEIVER	DONGLE	DVB-T-DAB+FM	1	EBAY/ON LINE	NO.24 AWG
OPTIONAL		8 pin DIP socket	1	Under IC2	

The completed transceiver in a housing. The only front panel controls necessary are a power switch and, if desired, a power and transmit LED indicator. On the rear panel, provide access for two USB connections, a power input, a microphone connector and either an RF connector.

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