UPDATED DOCUMENTATION---MOuSeFET TRANSMITTERS

Version 11 May 2022 Revised 15June 2022

New Stable VFO : Franklin Oscillator
No Temperature Calibration Procedure Required

MOSFET Transmitters for 80 Meters, 40 Meters and 30 Meters. Version 11

Updated information, Improved Circuitry.
Original article was in December, 1986 QST by Mike Masterson WN2A (formerly KA2HZA).

Winner QST Cover Plaque Award, Dec 1986 Reprinted in QRP Classics,1990
QST Editor for this article originally was Paul Pagel, N1FB- (Credited with the term MOuSeFET)
Also, Chuck Hutchison K8CH, Former Technical Editor set up the ARRL Lab tests.

These transmitters have performed extremely well over the years, with no component failures or downtime since they were built in 1985. These have been used portable on camping and vacation trips, driving a variety of antennas often with less than perfect VSWR loads. They are intended to provide a clean keyed CW signal on 80,40 or 30 Meters, yielding approximately 20W from a single 13.8 volt supply.

SECTIONS:

1. Target Specifications
2. Summary of Revisions.
3. Circuit Design Discussion
4. Schematic
5. Lists of Materials, Component Info
6. Assembly Diagrams.
7. Assembly/Test/Tune Sequence and Additional Hints.
8. Photos
9. Test Results
10. References, etc

SECTION 1. TARGET SPECIFICATIONS:

Mode: CW, 80,40 or 30 Meters. Coverage of part or all of the CW Subbands.
Power: 15-20 Watts approximate.
Power Supply: +13.8 VDC
Frequency Control: Franklin VFO controlled, Stability: 100Hz/Hour after 10 Minute warm-up.
Connectors: Power/Control 9-Pin D-Type; RF: RCA Phono Jacks.

SECTION 2. SUMMARY OF REVISIONS:

2.1 Partition Transmitter into two separate enclosures: VFO and Power Amp (PA) sections.
Very Significant improvement in Frequency Stability and testability. Use of Die-cast housings.

2.2 Replacement of Temperature-Compensated Clapp-Gouriet Oscillator with a stable Franklin Oscillator without Temperature-Compensation. Deleted Thermistor bridge and varactors, added buffer stage (Q3) to reduce loading and improve isolation for the Franklin Oscillator. The former Temperature Compensated circuit occasionally required re-calibration, and re-testing to maintain stability. The new oscillator appears to have better long-term stability if constructed and tested properly. Keep in mind that the there is no “magic” in using this type of oscillator, yet it does enable good frequency stability. Temperature stability of the frequency determining components are most important, regardless of oscillator type.

2.3 Replaced Zener Diode regulator with LM317 IC regulator for VFO stage. Also better frequency stability, and virtually no effect from +13.8 volt supply variations due to keying.

2.4 Power and Keying of VFO Stages:
a) Q1,Q2 (Franklin Oscillator) and Q3 (Buffer) are always powered, during Receive and Transmit.
This section is operating at ½ of the Transmit Frequency to reduce Receiver feed-thru and to reduce keying chirp with the high isolation obtained.
b) Q4 (Doubler) is powered during key down, which reduces receiver feed-thru. Q4 drives the Double-Tuned Bandpass filter consisting if T1 and T2 and their associated capacitors. Output of the Bandpass Filter is fed into a 5 dB (nominal) attenuator, used only on 80 and 40 meters. The output spectrum of this section is good, and should meet FCC requirements as is, but additional filtering follows.
c) Q5 (Driver) is also powered during key down. This in addition to b) above further improves the keyed signal and reduces RF leakage during receive. Q5 also drives a Double-Tuned Bandpass filter consisting if T3 and T4 and their associated capacitors. Tuning was straightforward.

2.5 In PA final stage, replaced Zener Diode and resistor used to limit Q9 gate voltage with series high-speed diodes. Less capacitance, hence slightly more Q9 drive, at higher frequencies.

2.6 Keying circuit was improved with of transistors Q6 and Q7 to control rise and fall times independently. Now able to realize ~2 milliseconds on each edge. Reduction of key clicks.

2.7 All three bands now use a common VFO topography, known as the Franklin oscillator. This is a circuit that lends itself to excellent stability, by isolation of the active component variations from the frequency-determining elements. Partly due to availability and excellent temperature stability, the use of NPO capacitors is used throughout. These are inexpensive and lend themselves to be used in parallel to reduce heating effects plus to enable fine tuning adjustments. One item was noted early in the development of these units. The earlier VFO versions used a tuned buffer stage (at the VFO frequency) with a low-u ferrite transformer to drive a balanced diode doubler. Interaction was noted between L1 and this tuned circuit, which would degrade temperature stability, given the ferrite’s TC. So, in this new VFO, tuned circuits that follow the oscillator are tuned to a harmonic of the oscillator-a simple bipolar doubler with double-tuned (at 2x the oscillator frequency) bandpass filter. Spectrum analysis showed excellent sub-harmonic and harmonic reduction The Franklin Oscillator is built on a separate sub-assembly, on single-sided PCB.

2.8 PA Output Harmonic Filter added. Very simple, easy tuning as a small separate sub-assembly.

SECTION 3. CIRCUIT DESIGN DISCUSSION:

TRANSMITTER GENERAL NOTES: The transmitter has power supply connections whose functions are listed here. I use the common 9-pin D-miniature connectors:

TABLE 1: J1 PIN-OUT:

J1 PIN NUMBER(S)	NAME	FUNCTION:
1,2	+ 13.8 T	Applies +13.8 VDC during Transmit via T/R Relay. High current.
3	+ 13.8 A	Applies +13.8 VDC, Always. Low current<100 mA.
4,5	+24 T	Provision only. Not used on these transmitters.
6,7	GROUND	(RETURN)
8	KEY	Ground this pin to spot or transmit (key-down). Open during key-up.
9	T/R	Grounded during transmit. Receiver muting. Not used on transmitters.

For the purposes of these transmitters, J1-4 and J1-5 (+24T) are provisional and not used here..

3.1 VFO Circuit Design: Refer to Section 4 for schematic.
The use of the Franklin oscillator was mentioned in section 2.8. Several subtle features are noted:

a) Franklin oscillators with proper component values and types can reduce the effect of active component variations. L1 uses an air core on a stable coil form, either ceramic or plastic pen tubes, (which did work well) and NPO ceramic fixed capacitors. The choice of CT must be made carefully, to select a stable mechanical and electrical unit. The choice of PCB material can be phenolic or fiberglass/epoxy, The Franklin oscillator sub-assembly PCB is single-sided, all other PCB's are double-sided. The Franklin Oscillator PCB has no ground foil under its components except where those components make a connection to ground. Additionally, the VFO oscillator sub-assembly needs to be mounted perpendicular to the housing floor with (3) right-angle mounts, so as to allow spacing between those components and the ground-plane of the housing.

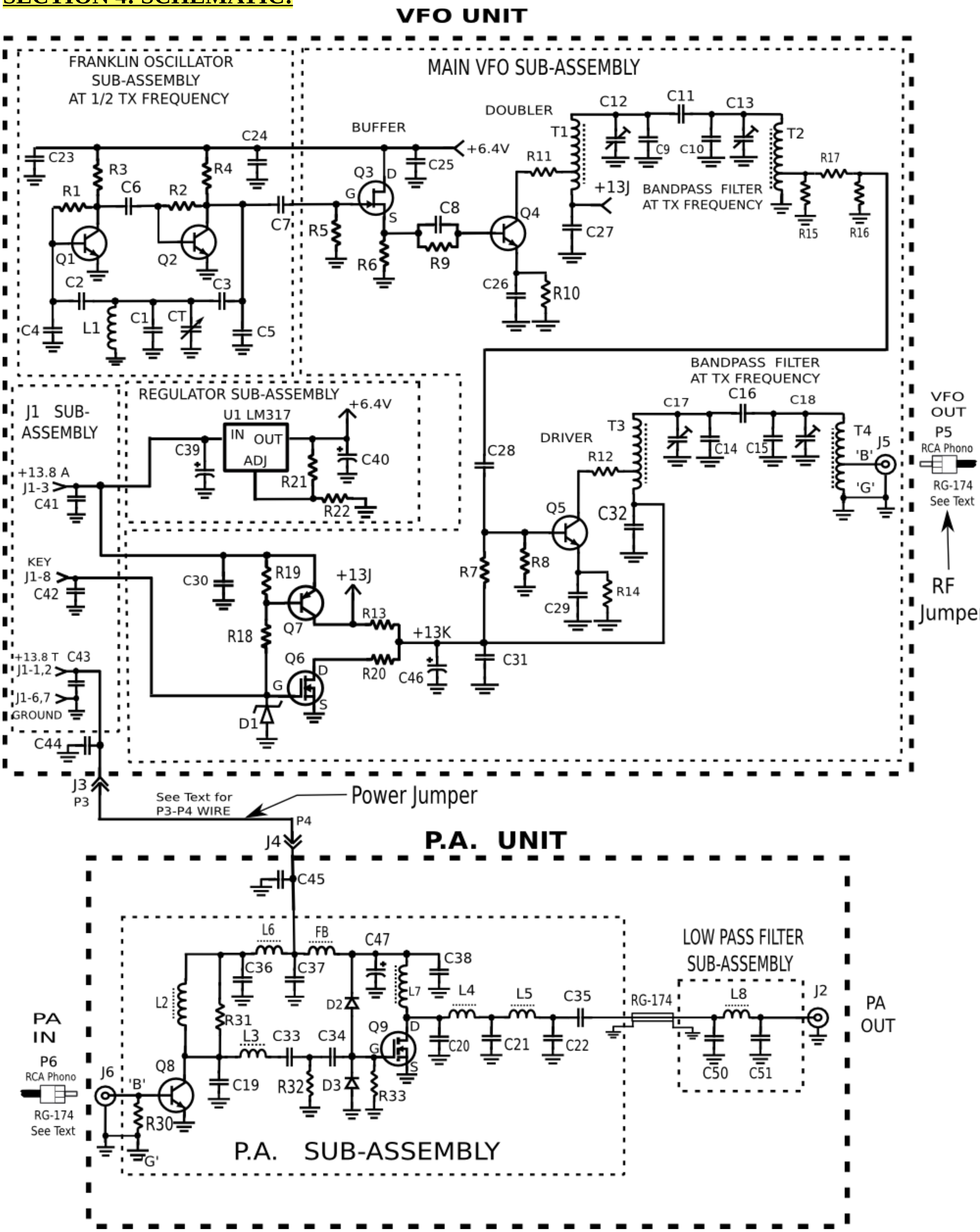
b) Doubler Q4 is biased to provide the second harmonic for the bandpass filter (T1,T2 and associated capacitors). The design of this bandpass filter resembles the driver's bandpass filter, using common components where possible. Stage stability is aided by resistor R11. The tap point at R11 to T1 can be varied to optimize output power and stability.

c) Driver Q5 provides significant gain at the RF band of choice. It provides a broadband match to the diode doubler and is followed by a double-tuned band-pass filter. Stage stability is aided by resistor R12. The tap point at R12 to T3 can be varied to optimize output power and stability.

d) The keying edges are controlled by Q7 and Q6 driving C20,with R13 and R20 setting the rise and fall times respectively. These can be modified as desired. These currently provide edges of approx ~2milliseconds. Increasing C20 capacitance increases both rise and fall times. It is best to set R13 at 51 ohms, as this affects both DC bias for doubler and driver, as well as rise time. Only adjust C20 and R20 if timing needs to be modified. The keying should be tested at the PA Unit output, J2, after integration.

3.2 Power Amplifier (PA) Circuit Design
The PA itself is largely unchanged from the original in 1986, other than items noted before. The VFO Unit drives Q8, which in turn provides the drive for Q9. Both devices operate Class-C with Q8 generating ~1W more or less for driving Q9. Q9's bias is developed by D2/D3 and is close to zero volts except when RF drive is available. This way Q9 stays off when the transmitter is not keyed. Q9's output matching network will reduce harmonics to <-45dBc, but with the Low-Pass filter the spurious and harmonics are < -60dBc, well within FCC requirements.

SECTION 4: SCHEMATIC:



SECTION 5: LISTS OF MATERIALS, COMPONENT INFO

TABLE 2: Components: Capacitors

REFERENCE DESIGNATORS	80 METERS	40 METERS	30 METERS	NOTES
C1	~738pF 2x330pF + 2x39pF	~772pF	~652pF 2x150pF +330pf + 22pF	NPO Chip, 50V
C2,C3	5pF	3.9pF	2.7pF	NPO Chip, 50V
C4,C5	100pF	47pF	50pF	NPO Chip, 50V
C6	1200pF	680pF	330pF	NPO Chip, 50V
C7	3.3pF	1.9pF	1.0pF	NPO Chip, 50V
C8	0.01uF X7R	1200pF	1200pF	NPO Chip, 50V unless noted
C9,C10	~347pF (3 x100) +47pF	100pF	68pF	NPO Chip or Leaded, 50V
C11	18pF	10pF	3pF	NPO Chip or Leaded, 50V
C12,C13	Note [1]	9-40pF	6-80pF	Trimmer, Capacitor
C14,C15	~347pF (3 x100) +47pF	100pF	56pF	NPO Chip or Leaded, 50V
C16	39 pF	15 pF	10 pF	NPO Chip or Leaded, 50V
C17,C18	Note [1]	9-40pF	5-60pF	Trimmer, Capacitor
C19	1000pF	470pF	330pF	NPO Chip or Leaded, 50V
C20	1800pF	1000pF	400pF	NPO or Silver-Mica Chip or Leaded, 100V
C21	2700pF	~1630pF (3x470pF) +220pF	1200pF	NPO or Silver-Mica Chip or Leaded, 100V
C22	1100pF	700pF (7 x 100pF)	400pF (4x100pF)	NPO or Silver-Mica Chip or Leaded, 100V
C23-C32	0.1uF, X7R Chip or Leaded 25V			VFO Assembly
C33-C38	0.1uF, X7R Chip or Leaded 25V			PA Assembly
C39,C40	6.8uF 25V tantalum Chip or Leaded			
C41-C45	0.1uF 25V Leaded			Used on Connectors
C46	33uF, 25 V Tantalum or Electrolytic			
C47	47uF, 25 V Tantalum or Electrolytic			
CT	8-48 pF Air	5-25 pF Air	4-25 pF Air	Variable Tuning Capacitors

Note [1] Trimmer Caps C12,C13,C17,C18 were not used on my 80 meter unit. These are optional.

TABLE 3: Components: Inductors

REF DES	80 METERS	40 METERS	30 METERS
L1 Note [2]	~10423nH AWG#30 59T, ~0.071”long.	~2637nH AWG#26 24T, ~0.042” long.	~1475nH AWG#26, 16T, ~0.3” long.
L2	14T on FT37-61	9T on FT37-61	9T on FT37-61
L3	1.8uH, 17T on T50-2	0.5uH, 13T on T50-6	0.5uH, 13T on T50-6
L4	0.9uH, 15T on T50-6	0.43uH, 10T on T50-6	0.3uH, 7T on T50-6
L5	2.8uH, 22T on T50-2	1.2uH, 15T on T50-2	0.9uH, 13T on T50-6
L6	14T on FT37-61	10T on FT37-61	10T on FT37-61
L7	~7.1uH, 42T on T50-6	~5.5uH, 38T on T50-6	~1.6uH, 20T on T50-6
L8	1.77 uH, 21T on T50-6	890 nH, 14T on T50-6	646 nH, 21T on T50-6
T1	36T Tap @ 11T from ground end. AWG#26 on T50-6 ~4.6uH	29T Tap @ 5T from ground end. AWG#26 on T50-6 ~3.46uH	24T Tap @ 5T from ground end. AWG#26 on T50-6 ~2.4uH
T2	35T Tap @ 6T from ground end. AWG#26 on T50-6 ~4.55uH	29T Tap @ 6T from ground end. AWG#26 on T50-6 ~3.46uH	24T Tap @ 5T from ground end. AWG#26 on T50-6 ~2.4uH
T3	34T Tap @ 11T from ground end. AWG#26 on T50-6 ~4.5uH	29T Tap @ 9T from ground end. AWG#26 on T50-6 ~3.46uH	24T Tap @ 7T from ground end. AWG#26 on T50-6 ~2.4uH
T4	34T Tap @ 5T from ground end. AWG#26 on T50-6 ~4.5uH	28T Tap @ 4T from ground end. AWG#26 on T50-6 ~3.4uH	24T Tap @ 4T from ground end. AWG#26 on T50-6 ~2.4uH
FB	Ferrite Bead 2T #28 on FB-43-101 or equiv.		

Note [2] All values are approximate.

a) L1 for all bands is an air-core coil wound on a Bic Pen Tube (“Ultra Round Stic Grip”), approx diameter 0.32”.

b) Press a #4 nut into one end of the tube. Epoxy this nut into place, being careful not to get any epoxy on the threads. This will be the ground end of the coil. I advise using Loctite Marine Epoxy and cure 24 hours @ +25°C to +35°C. This epoxy cures very well in this range, but allow the full cure time..

c) Coil is measured and if need be adjusted to value. A Dip Meter and a parallel 50 or 100pF NPO leaded capacitor can be used to tune these coils. After installation into VFO circuit, as necessary, L1 can be final adjusted, and staked *very lightly* with Loctite Marine Epoxy. Cure 24 hours at 25~35C.

TABLE 4: Components: Resistors

REFERENCE DESIGNATORS	80 METERS	40 METERS	30 METERS	NOTES
R1	100K ±5%			0603 or 0805 SMD
R2	180K ±5%			0603 or 0805 SMD
R3	1000Ω ±5%			0603 or 0805 SMD
R4	1800Ω ±5%			0603 or 0805 SMD
R5	330K ±5%			0603 or 0805 SMD
R6	470Ω ±5%			0603 or 0805 SMD
R7,R18	5100Ω ±5%			0603 or 0805 SMD
R8	1200Ω ±5%			0603 or 0805 SMD
R9	20K ±5%			0603 or 0805 SMD
R10	330Ω ±5%			0603 or 0805 SMD
R11,R12,R13	51Ω ±5%			0603 or 0805 SMD
R14,R20	100Ω ±5%			0603 or 0805 SMD
R15,R16	180Ω ±5%			0603 or 0805 SMD
R17	33Ω ±5%			0603 or 0805 SMD
R19	10K ±5%			0603 or 0805 SMD
R21	200Ω ±5%			0603 or 0805 SMD
R22	820Ω ±5%			0603 or 0805 SMD
R30	51Ω ±5%	68Ω ±5%	68Ω ±5%	¼ watt Carbon Film
R31,R33	2700Ω ±5% 0805 SMD or Carbon Film			0805 SMD or Carbon Film
R32	33Ω ±5%	33Ω ±5%	51Ω ±5%	½ watt Carbon Film

TABLE 5: Components: Semiconductors

REFERENCE DESIGNATORS	P/N	NOTES
D1	16 VOLT ZENER	1N5246 or SMD: MMBZ5246B
D2,D3	1N4148, MMBD914	
Q1,Q2,Q4,Q5	2N2222A, MMBT2222A	
Q3	2N5486, MMBF5486	
Q6	2N7000,2N7002	
Q7	2N2907, MMBT2907A,2N3906, MMBT3906	
Q8	80M: TN3053; 40M: 2N3053; 30M:2N1711	Many equivalents can be used for Q8
Q9	80 M: IRF523; 40 M/30 M: IRF510	IRF510 should also work for 80M
U1	LM317T, LM317LM	

TABLE 6: Parts Common to All Bands. Components leaded or SMT, unless noted.

REFERENCE DESIGNATORS	DESCRIPTION
J2,J5,J6	RCA Phono Jacks, Switchcraft 3501FPX
J3,J4	Banana Sockets, Red, Pomona 2854-2
P1	9-pin Female D-type connector Amp 747905-2 for power cable.
P3,P4	Banana Plugs, Red Pomona 1825-2 . Wire these together with PVC Insulated AWG #18 or #20 approx 7”long to make the **Power Jumper**.
P5,P6	RCA Phono Plugs, Shielding, Pomona 6881 or equal. Wire these together with RG174/U approx 7’long to make the **RF Jumper**.

TABLE 7: LOW-PASS FILTER: Note[3]

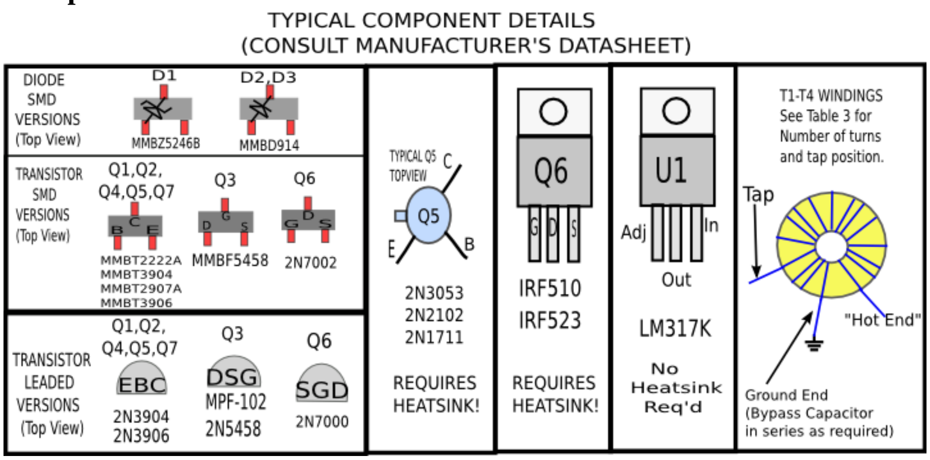
REFERENCE DESIGNATORS	80 METERS	40 METERS	30 METERS	NOTES
L8	21 T T50-6 ~1776 nH	14T T50-6 ~890 nH	11 T T50-6 ~646 nH	
C50,C51	1800 pF	910 pF	620 pF	NPO or Silver-Mica Chip or Leaded, 100V
F Resonate [MHz]	3.98 MHz	7.91 MHz	11.25 MHz	[3]

Note [3] PRE-TUNE LOW-PASS FILTER: With all components C50,C51 and L1 installed on the Low-Pass Filter, and no connections made to the Low-Pass Filter input or output sub-assembly, use a DIP meter to adjust L8 for the indicated resonate frequency (F Resonate).

NOTES ON PCB Materials:

Franklin Oscillator Sub-Assembly: Single-Sided Epoxy Fiberglass or Phenolic 0.031 to 0.062" Thick.
(The use of a double-sided board has been found to make for poor VFO stability)
All Other Sub-Assemblies: Double Sided Epoxy Fiberglass or Phenolic 0.031 to 0.062" Thick.

Figure 1. Some Component Outlines:



Franklin Oscillator, Main VFO, Regulator Sub-assemblies
Refer to Figures 2,3 and 4 for layouts and Figures 7 and 8 for photos.

A variety of assembly methods that can be used for both 80 meter and 30/40 meter versions, the 40 Meter version is shown here, as it is likely to produce repeatable results. Whether one uses primarily SMT or leaded or some combination of each, the results have been found to be equivalent. I would encourage one to use SMT if possible, since it makes for a neater, less cluttered result. Note that if you do use SMT, avoid overheating these parts as termination de-wetting also known as "leaching" can result. Also space the SMT components away from the corner mounting screw. It could result in SMT device cracking when installing the Boards.

PA, Low-Pass Filter Sub-assemblies
Refer to Figures 5 and 6 for sub-assembly details and Figure 9 for photos.
As with the VFO Assembly Boards, one can use a combination of Leaded and SMT components on this board. The soldering issues are the same, but these PA boards have also been built successfully using SMT ceramic capacitors and resistors. In this case Double-Sided PCB, ~0.060 inch thick FR-4 (G10) or Phenolic FR-2 has been used. Use copper foil to supply low-inductance ground wrap-rounds from the ground plane to the top, around the board periphery. Q5 will need some kind of small heatsink, whereas it is best just to use a mica or Kapton insulator between Q6 and the metal housing. A *very* small amount of heatsink grease can be applied to both sides of the Kapton or polyimide insulator.

Unit Integration
Keep the VFO and PA sub-assemblies in *separate* shielded enclosures. The enclosures are interconnected with DC Power from J3 to J4 with the Power Jumper and RF Power from J5 to J6 with the RF Jumper. See Table 6 for this information.
I operate the units without direct metal contact from each other. I assemble them together as a stack, spaced apart from each other with small thermally insulating blocks made from "mouse-pads" or styrofoam, using duct tape or whatever is convenient to hold them as a stack vertically with the VFO unit on the bottom, PA unit on top.

SECTION 6 ASSEMBLY DIAGRAMS

Figure 2 VFO Board Assembly Drawing. (Scale to Dimensions Shown)

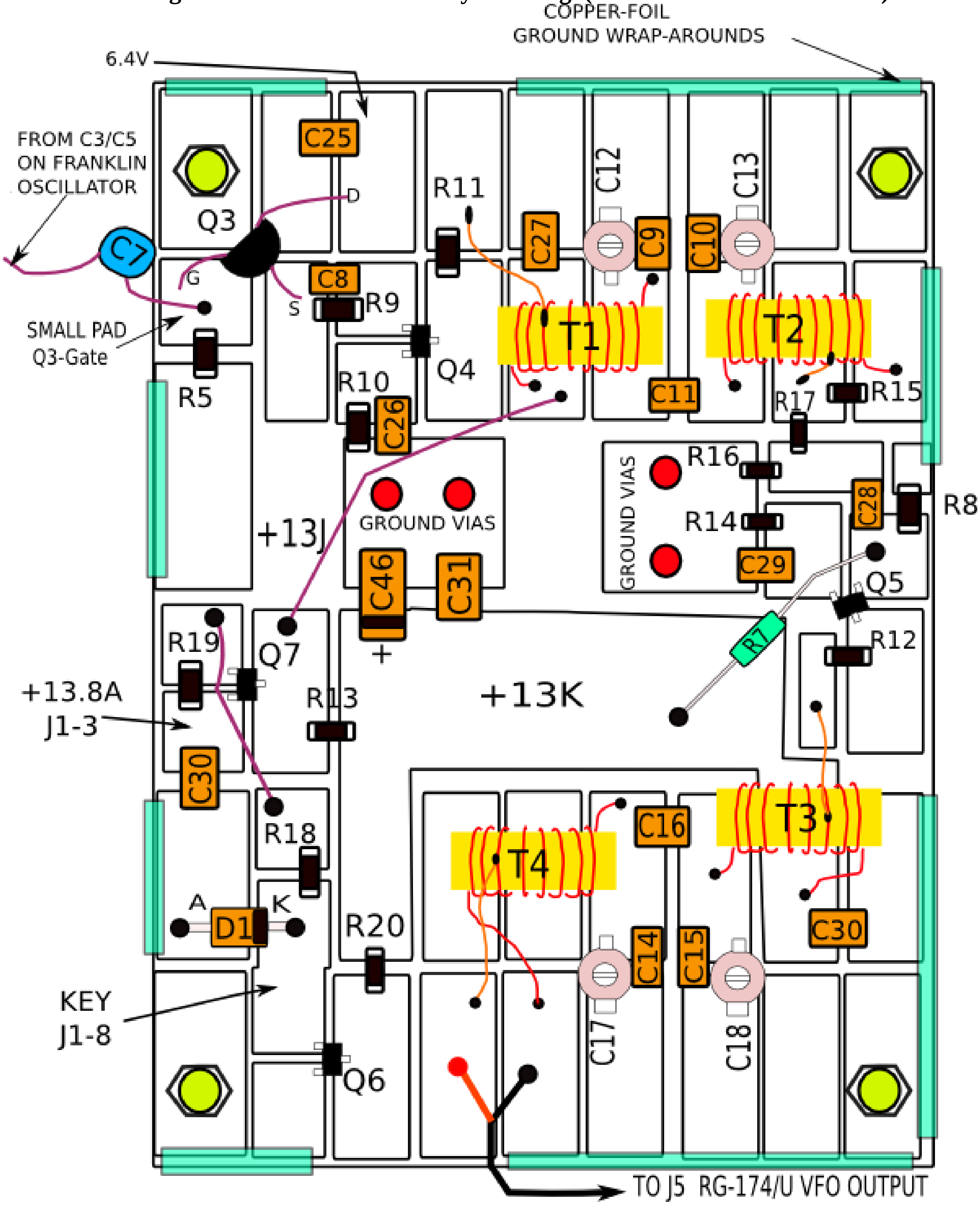


Figure 3: Franklin Oscillator Sub-Assembly

Note: Single Sided PCB used for this sub-assembly.

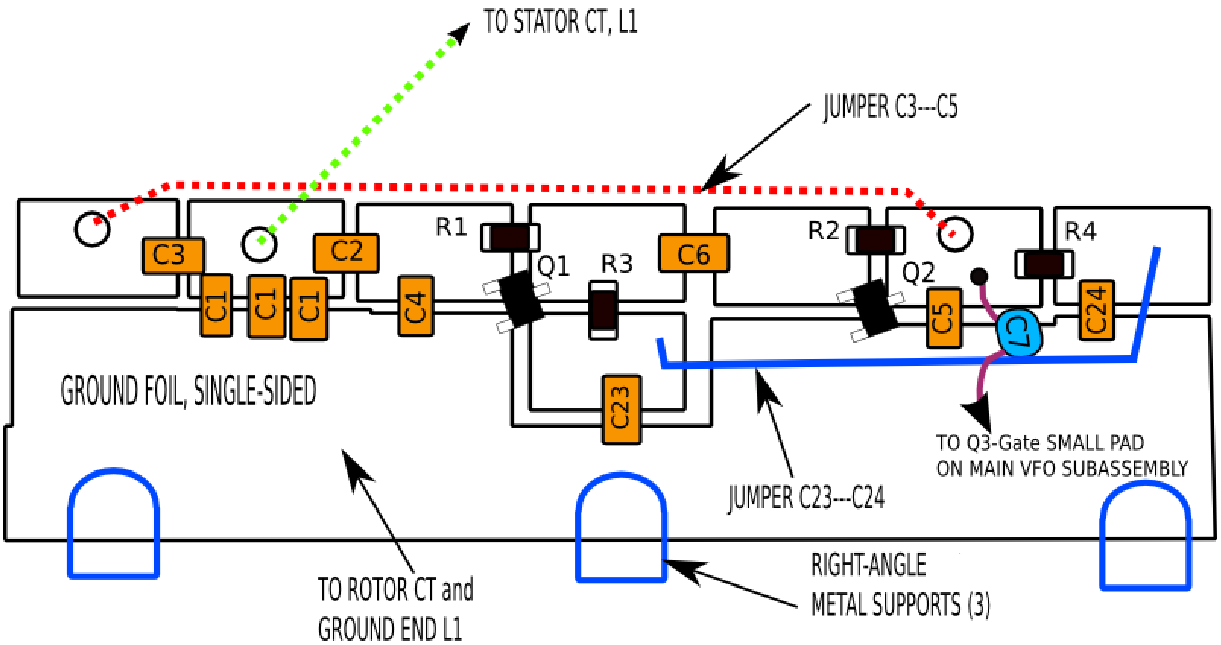


Figure 4: Regulator Sub-Assembly

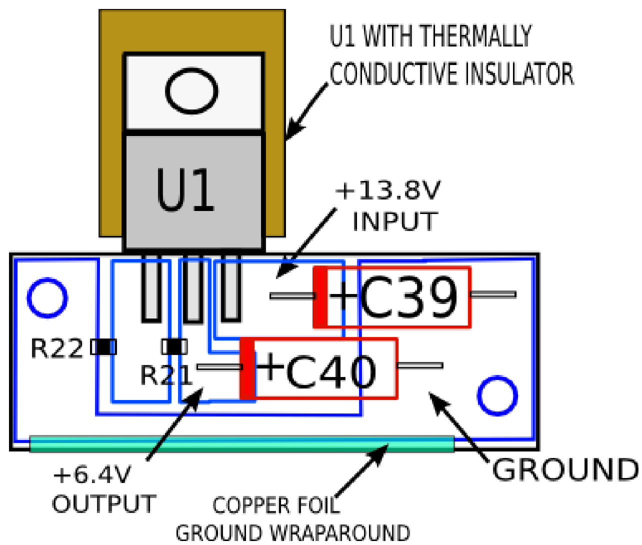


Fig 5. PA Sub-Assembly

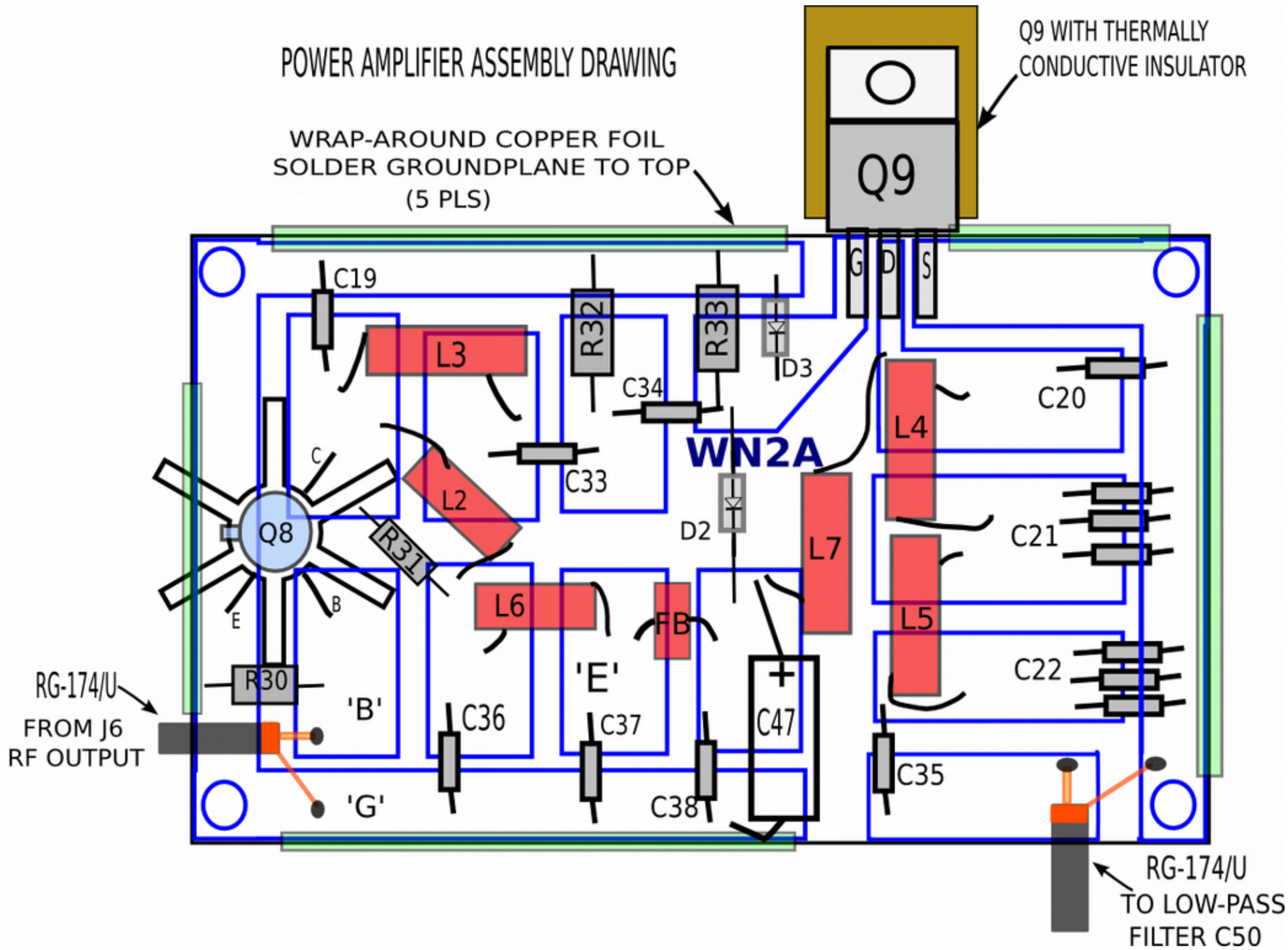
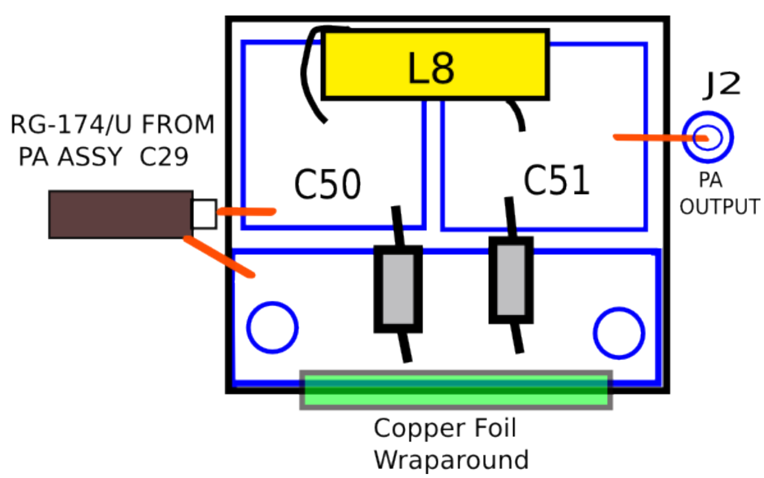


Fig 6. Low-Pass Filter Assembly



SECTION 7: ASSEMBLY/TEST/TUNE SEQUENCE, and Additional Hints

Suggested Sequence:

1. Align all unpopulated Etched (or Dremeled) PCB's to housings and mark all mounting hole locations. Drill holes in housings and temporarily mount each PCB into the housing to confirm fit.
For the VFO Unit, drill out holes for J1 (9-Pin D-Type), J5 (RCA Phono), and J3 Banana Socket. For the PA Unit, drill out holes for J2,J6 (RCA Phonos), and J4 Banana Socket. Install all connectors.

2. Assemble Regulator Sub-Assembly. Apply +12~+14 V to input. Regulator output should be 6.4 volts. Install into VFO Housing.

3. Assemble Franklin Oscillator sub-assembly. Assemble L1 (see Table 3) and install CT. Install the Franklin Oscillator into the VFO Housing. Per the schematic and drawings, connect the Regulator output to the Franklin Oscillator sub-assembly and make the connections to L1 and CT. Apply +12~14V to the regulator input. Using an RF probe or oscilloscope, you should be able to detect RF at C7, where it it connects to Q3-gate. A frequency counter can also be used to measure frequency, which should be at approximately ½ the Transmit Frequency.

4. Assemble the Main VFO sub-assembly. Install into the VFO Housing with the Regulator and Franklin Oscillator sub-assemblies. Install J1 with C41,C42 and C43 and J3 with C44. Install J5. Make all interconnections between sub-assemblies and connectors per the schematic.
Check all connections.

5. Per the schematic, using a current-limited power supply, apply +12~+14 V to J3-3, and ground to J1-6,J1-7,J1-8. Connect J2 to a RF milliwatt power meter with a full-scale range of ~250 mW. With the Franklin oscillator running (as #3 above), sense the RF voltage with an RF probe or "sniffer", starting with Q3-gate, proceeded to Q3-source, Q4-base, Q4-collector, Q5-base and Q5-collector. Progressively testing and tuning each bandpass filter should result in increased readings on the RF milliwatt meter connected to J5.
   a) Tuning the doubler bandpass filter comprised of C12/C13 with T1/T2 should result in increased RF voltage when probing Q5-base. Slight adjustment of T1 and/or T2 Tap points.
   b) Tuning the driver bandpass filter comprised of C14/C15 with T3/T4 should result in increased RF power at J5. Slight adjustment of T1 and/or T2 Tap points.

6. The final tuning and *light* staking of L1 can be done with a frequency counter connected to J2.
Be sure to have the housing cover attached, so its effect on tuning can be taken into account.

With a completed and covered VFO Unit, compare your measurements to mine in Section 9.Set aside VFO Unit.

7. Assemble PA sub-assembly. Check all connections. Assemble Low-Pass Filter sub-assembly. Using a dip-meter to tune L8 to resonate at frequency specified in table7. Install PA Unit and pre-tuned Low-Pass filter into housing. Make all connections to J2,J5 and J4.

8. Referring to Table 6, using the cables specified "RF Jumper" and "Power Jumper",connect VFO unit (from #6) to PA unit. Connect PA Output (J2) to a power attenuator and a RF milliwatt power meter. I suggest using a 20dB attenuator rated for 25-50 Watts continuous. The RF milliwatt meter should be able to read approx 250mW full scale.

9. With J1-8 *open*, connect J1-6 and J1-7 to ground, Apply +12~+14 V to J1-1,J1-2 and J1-3 with a supply rated for 4~6 amps. Monitor the power meter and *briefly* connect J1-8 to ground. You should obtain indication of RF power. Tuning L3,L4 and L5 should peak the RF power. Going back to the VFO unit, carefully re-tuning C17/C18 may help, followed by retuning L3,L4 and L5 again. Slight tuning of L8 might help, but if L8 was pre-tuned properly, it usually does not need to be re-tuned.

10.With Both Units completed, compare your measurements to mine in Section 9.

Additional Hints:

a) As noted, for the VFO Unit, build up the VFO sub-assemblies, starting with the Regulator Sub-Assembly, then the Franklin Oscillator sub-assembly, lastly the Main VFO Sub-Assembly.

b)Testing the VFO assembly is easier with an RF power meter connected to J5 and a simple RF voltage probe. With +13.8 V applied to J1-3, and J1-8 grounded, use the RF probe to check each node for RF voltage from Q1 thru Q3, while monitoring VFO board RF power output with the RF power meter. This helps find wiring faults and was very helpful in tuning C12/C13 and C17/C18. The selectivity of the double-tuned tank circuits is such that you may not detect RF power on the meter until you “sniff” with the RF voltage probe. This tuning can be a slightly critical, and one may need to find *a* different tap point on T2/T3 to get best results. Don’t vary tap point too much from that specified, or you may make Q5 unstable. Resistors R11 and R12 aid Q4 and Q5 stability, respectively.

c)Add or delete a turn to L1 windings to center CT tuning range. Do this prior to *lightly* staking L1!
~3500-3580 kHz for 80 Meters
~7000-7080 kHz for 40 Meters
~10100-10150 kHz for 30 Meters (All are measured at J5 with a Frequency Counter.)

d) If you use an RF Probe in the PA Unit, be certain it is rated for high RF voltages. RF probes could easily see diode failure, as most RF diodes do not have high reverse voltage ratings.

e) RF output power will be a function of many factors, some of which we can control easily, others not so easy. I was able to obtain more power without sacrificing other performance goals just by raising the DC voltage from +12.0 to +13.8 VDC. This is been long pointed out by others, and Q9 MOSFET operation at +24 VDC may result in still better efficiency *with modified circuit design*. The builder may obtain results that differ from mine in Section 9 for other reasons, such as layout and grounding differences. “Tight” grounding is required for the PA board due to high RF currents.

f) Components will affect the performance, especially the transistors in the RF path. To a large degree, the transistors in the RF path will determine how much RF power we will obtain. Each device from the Franklin Oscillator stage (Q1,Q2) through the PA final (Q9) will affect the output. The doubler Q4 and driver Q5 need to have high gain at the output frequency, so sufficient Ft is required, but not so high as to become a stability issue. The parts specified work with Ft of ~250 MHz, so don’t use a microwave device here. The same advice goes for Q8, the PA Driver. This is a stage where too “hot” a device will cause problems. Since several of the devices specified for Q8 are metal can TO-39 parts, and may be in short supply now, the SMD devices in SOT-89 or SOT-223 type package, properly heat-sunk in accordance with manufacturer’s datasheet, potentially will provide an alternative. A brief search will show many such candidates. The PA stage (Q9) requires a power MOSFET with relatively low interelectrode capacitances and high transconductance, without resorting to more expensive RF MOSFETS. The IRF510 is (still) one of the better choices, even 30+ years after the original article. There are other choices that may be able to give us better gain/ output power especially up to the higher bands, but the IRF510 works well, is economical and commonly available.

g) Tuning is crucial to obtaining desired output power. As noted before, C12/C13 and C17/C18 tuning, and the tap adjustments on T1 thru T4 determine J5 output level. Likewise the PA tuning is determined by tuning L3 inter-stage and for the PA output, L4 and L5. I generally find it is worth the time spent to pre-measure the fixed capacitors with a simple C meter. Have the correct capacitance values in place on the board before attaching the inductors or transformers. Also, make sure you do not substitute the wrong type of ceramic capacitor (like a X7R or Z5U). Use NPO or Silver-Mica, as specified.

SECTION 8: PHOTOS

Figure 7. Photo of My 40 Meter VFO (Upper) and PA (Lower) Assemblies (For Reference Only).

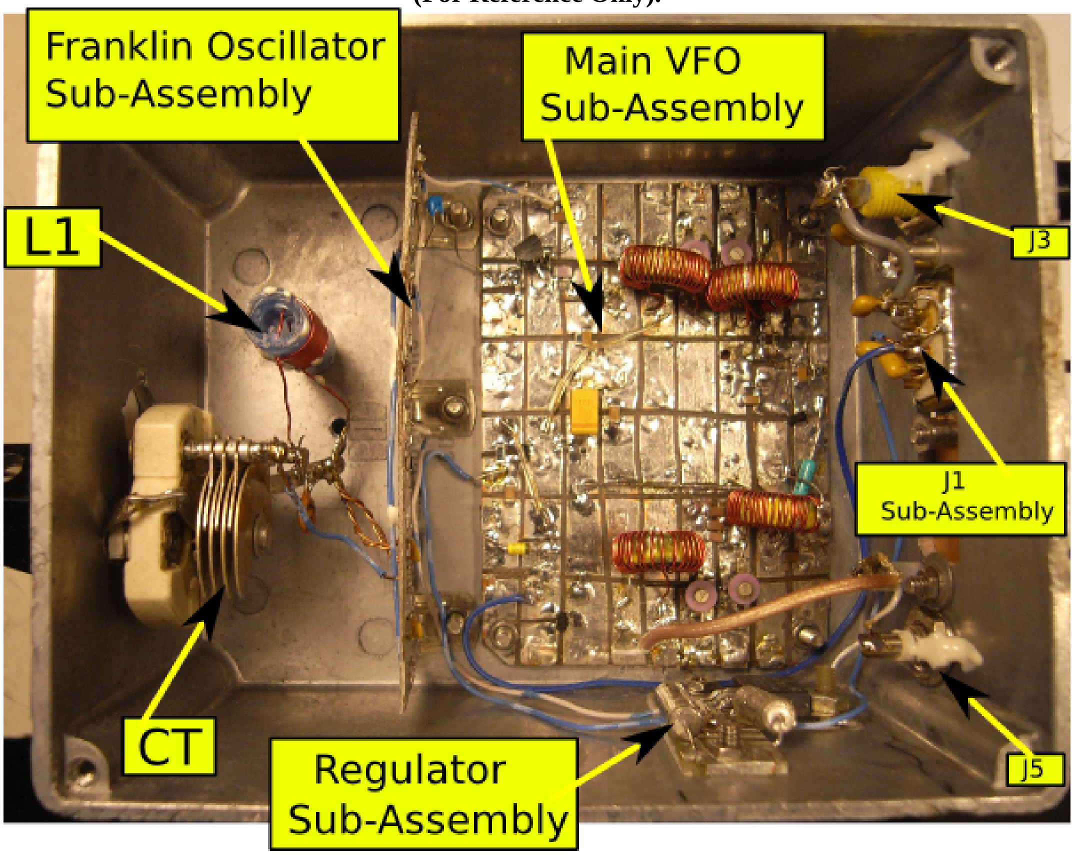


Figure 8.Franklin Oscillator Assembly Detail View

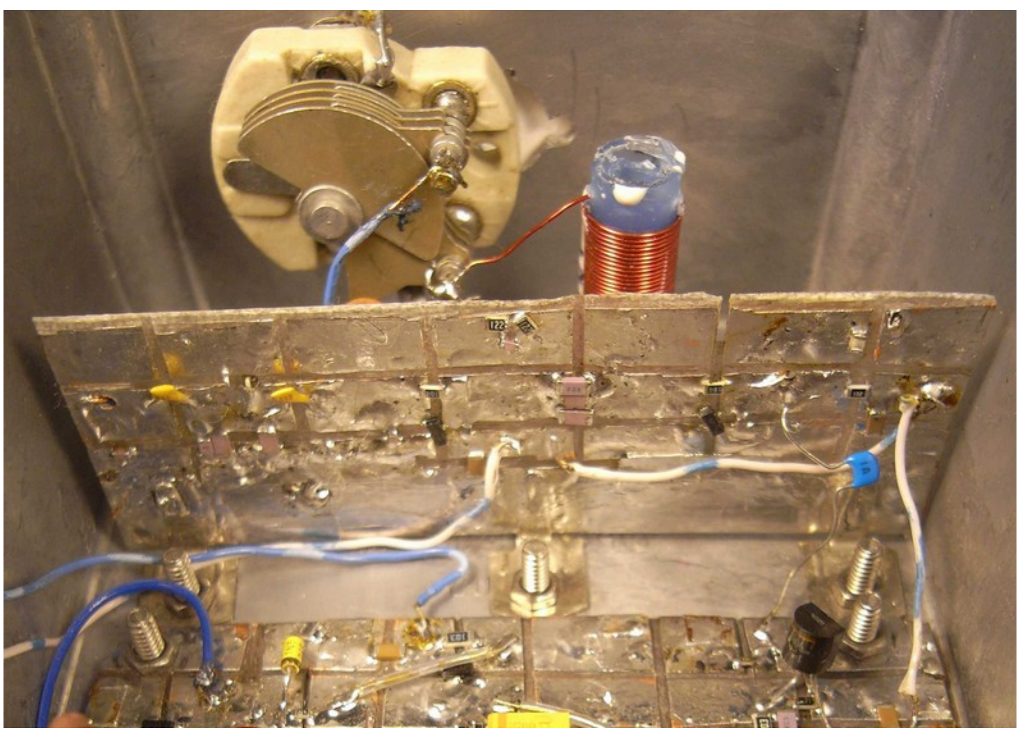
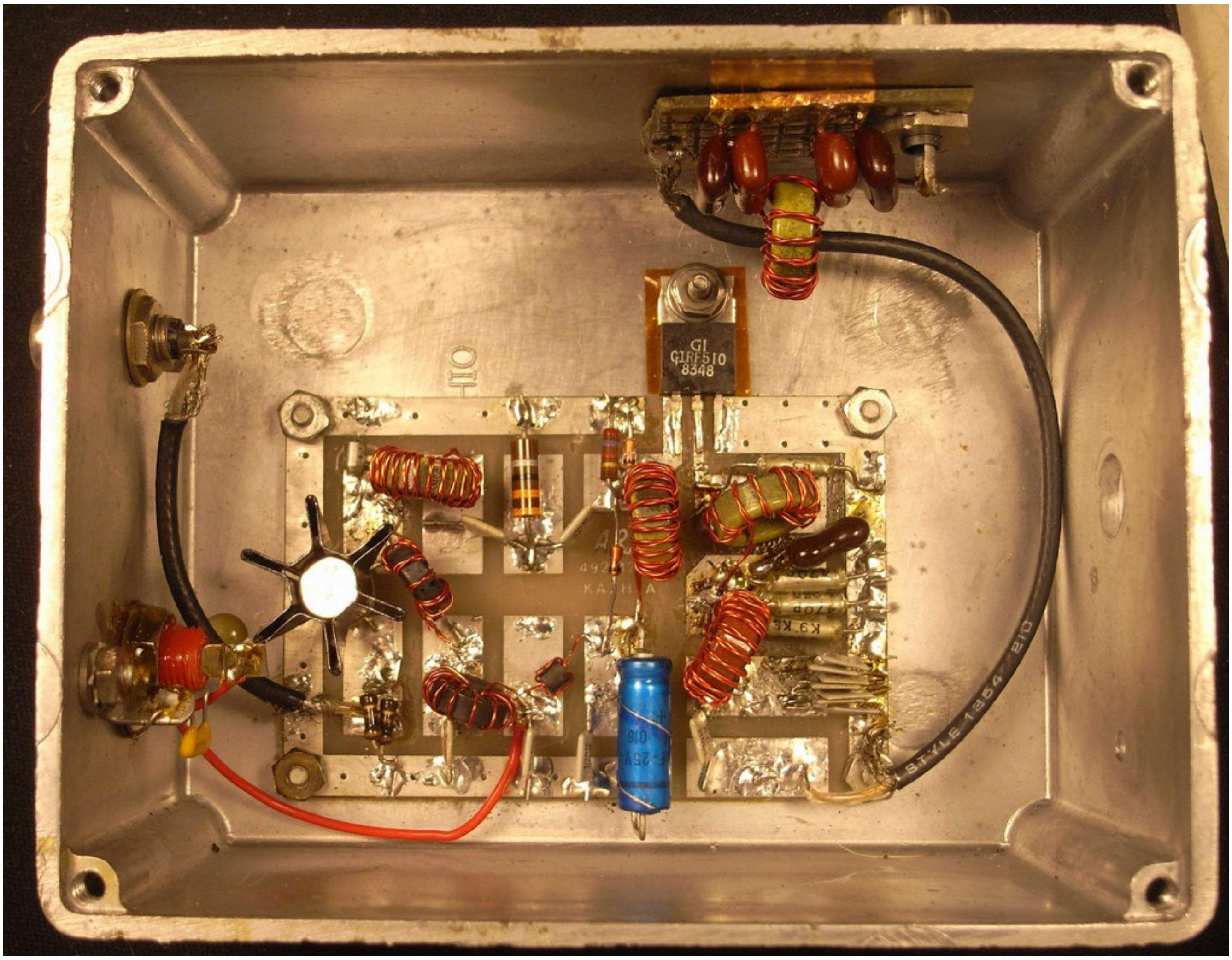


Figure 9. Power Amplifier Assembly Detail View



SECTION 9. TEST RESULTS

Table 8. Measurements on my Version 11 Transmitters. These measurements taken with Homebrew and Commercial test equipment. Your results may vary from these approximate values.

Operating Parameters: +13.8 VDC nominal supply @ Room Temp. Note [4].

Transmitter Measurement (VFO + PA Board) at J2	**80 meters**	**40 meters**	**30 meters**
Power output [Watts/dBm]	22.2Watts/ 43.46dBm	21.0Watts/ 43.22dBm	19.5Watts/ 42.9dBm
Subharmonic (1/2 F) [dBc]	<-60	<-60	<-60
Second Harmonic (2F) [dBc]	<-60	<-60	<-60
Keying Waveform (Attack [msec] /Decay [msec]) Approx.	2/2	2/2	2/2
DC Voltage measured at J4 [V]	13.2	13.2	13.2
PA Unit Current (Transmit Key-down) [A]	2.8	2.65	2.45
PA Unit DC Power [W]	36.9	35	32.3
PA Unit Efficiency @ J4 input DC Power.	~60%	~60%	~60%
PA Unit (Class C) Gain [dB]	~24.5dB	~24.4dB	~25dB

VFO Unit Measurements, at J5. +13.8 Applied to J1-3; Ground J1-6,7,8.	**80 meters**	**40 meters**	**30 meters**
Power out (VFO Stage) [mW/dBm]	77.6mW/ 18.9dBm	75.8mW/ 18.8dBm	60.3mW/ 17.8dBm
Subharmonic (1/2 F) [dBc]	<-60	<-60	<-60
Second Harmonic (2F) [dBc]	~-55	<-60	<-60
RF Feedthru (dBc)	<<-70	<<-70	<<-70
VFO Unit DC Current [mA] (Key Up/Key Down)	16.3/58	16.3/52	16.3/45

Note [4]: Temperature ~ 20C (RT) . Test Equipment:
Spectrum Analyzer HP8558B/HP182T,
Oscilloscope Tektronics 2215A, Homebrew 13.8VDC Supply. DVM:Simpson 461-2.
Homebrew RF Power Meter

Table 9: Approximate DC Voltages for Debugging. DVM: Simpson 461. +13.8A applied.

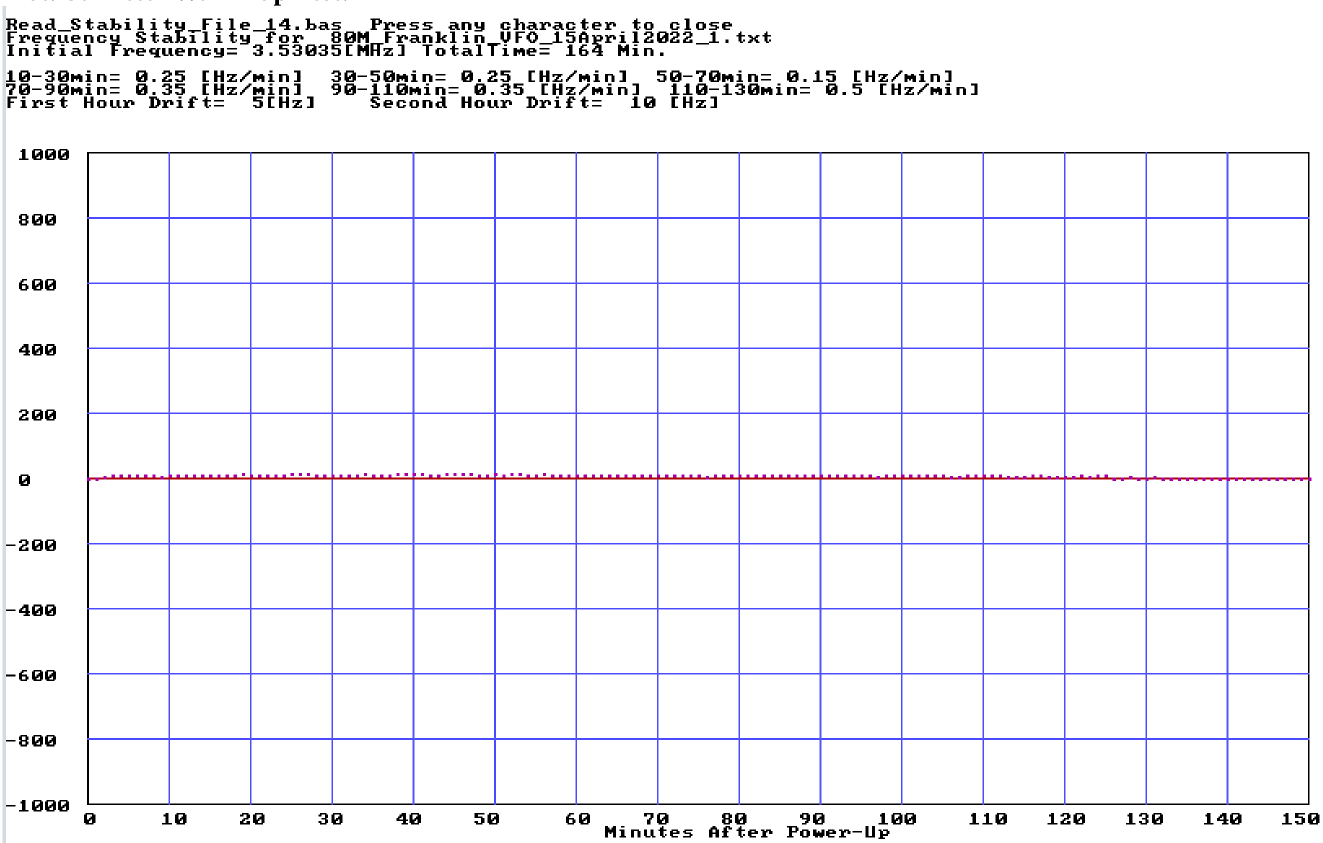
U1 Regulator voltage [V]	6.4V	6.4V	6.4V
+13J LINE (Key Down/Key Up) [V]	13.6/0	13.6/0	13.6/0
+13K LINE (Key Down/Key Up) [V]	12.3/0	12.3/0	12.5/0
Q9 Gate DC Bias (approx.) Measured thru a 100K resistor when keyed and driven.	+5.8	+6.3	+6.3

TABLE 10: Warm-Up Test Data Summary

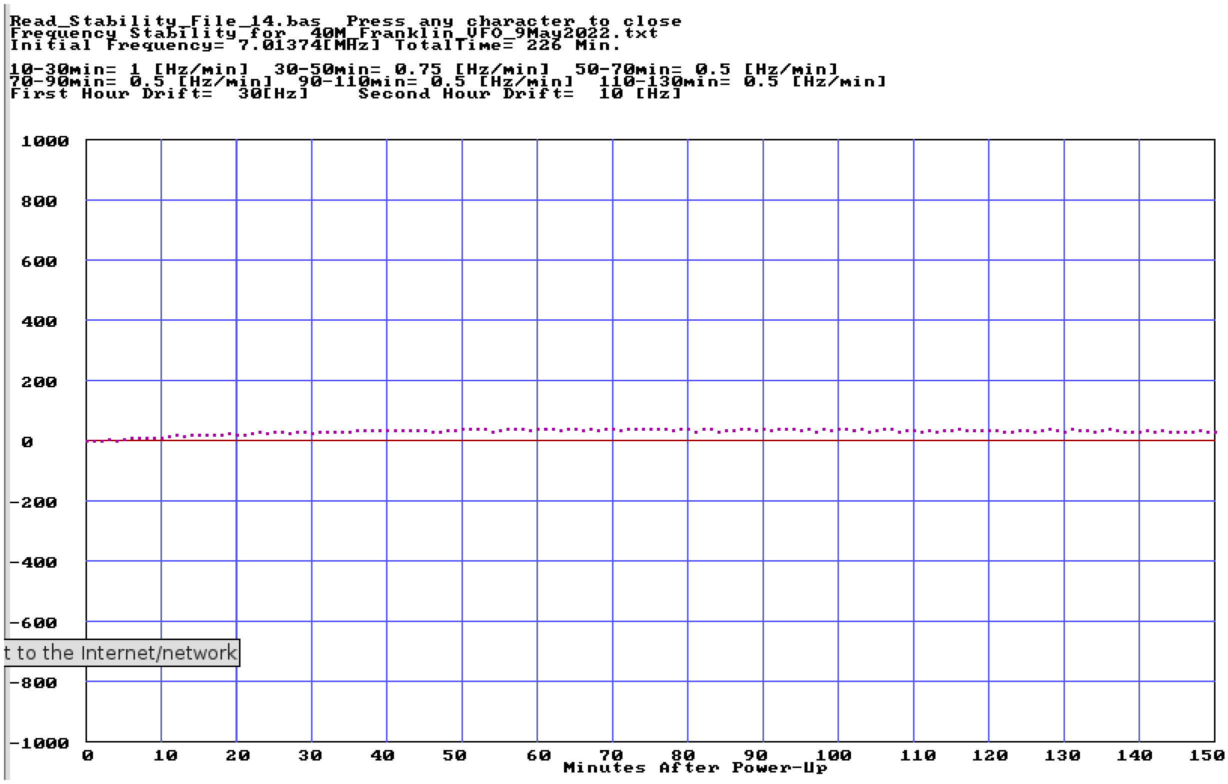
BAND	Test Frequency [MHz]	First Hour Drift[Hz] Minutes 10-70 Note [5]	Second Hour Drift[Hz] Minutes 70-130 Note [5]
80	3.53035	5	10
40	7.01374	30	10
30	10.10132	20	7

[5] First Hour Drift = Drift over minutes 10 thru 70. Second Hour Drift= Drift over minutes 70 thru 130.

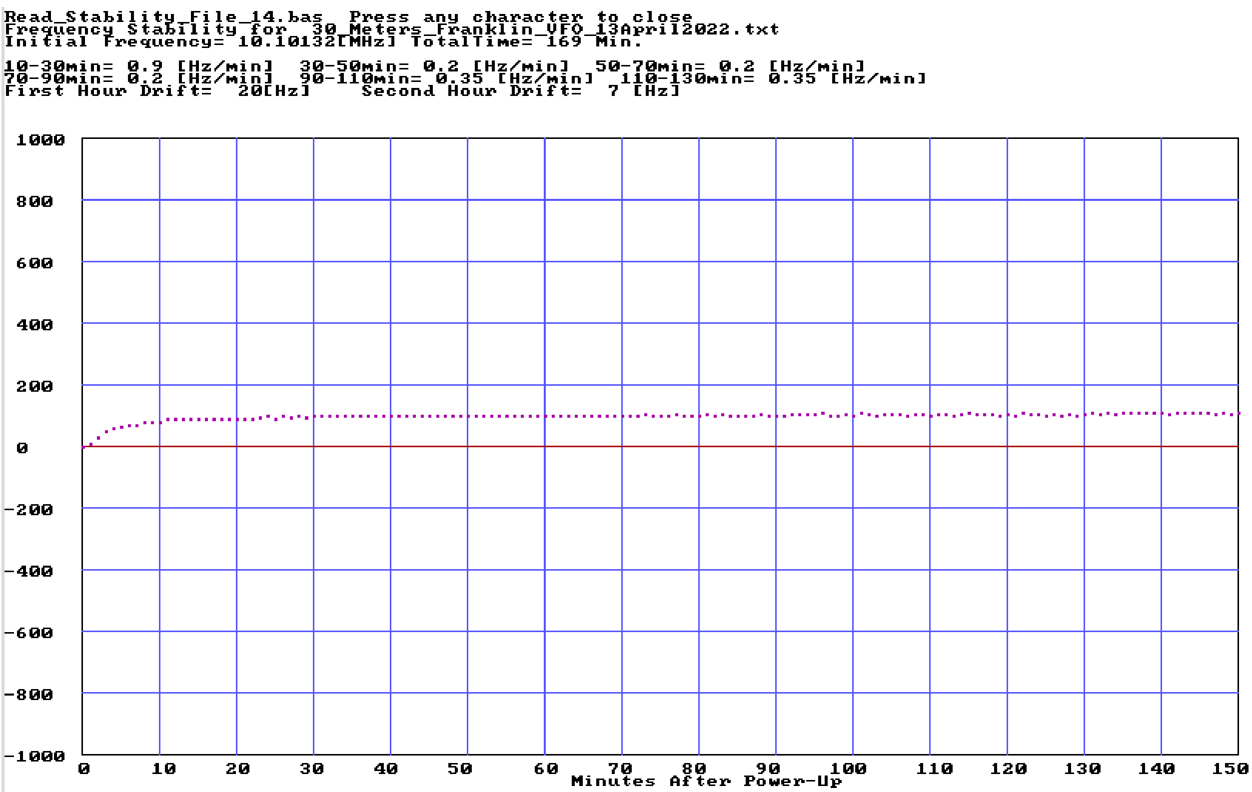
Plot: 80 Meter Warm-Up Test:



Plot: 40 Meter Warm-Up Test:



Plot: 30 Meter Warm-Up Test:



SECTION 10: REFERENCES, etc:

1) The ARRL HANDBOOK-especially Construction Practices
2) Solid-State Design for the Radio Amateur (ARRL). A landmark text as far as QRP/Homebrew is concerned.
3) QRP CLASSICS, ARRL. Numerous articles bring out tips to home-brew construction.
4) Experimental Methods in RF Design (ARRL)
5) Crystal Sets to Sideband copyright 2010 Frank W. Harris Rev 10.
6) Radio Handbook, 1975, William Orr W6SAI, Chapter 11.
7) Radio Communications Handbook, RSGB, 1994, Chapter 5.6 Franklin Oscillator
8) Ham Radio, January 1972. Article on Franklin oscillator using PNP transistors.
9) The "Super VFO" As stable as a crystal! by SV3ORA Link: http://www.qrp.gr/supervfo/index.htm
The website http://www.qrp.gr/ has more useful information.

Software Used in Revision 8:
LibreOffice 5.1.3.2 used for creating this document in .odt format and convert to .pdf
Inkscape 0.45.1
MT Paint 3.44.73
QucsStudio 4.2.2
OS: Slacko Puppy Linux Rev 6.3.2.

The author would like thank those who have build these transmitters and provided valuable feedback, particularity Rob Vijfschaft, PA3EQB. Also credit William Johnson, W0MS for his nice article “A Modified MouseFET Low Power Transmitter” in August, 2011 QST.

Mandatory Reading:
[1] *Crystal Sets to Sideband copyright 2010 Frank W. Harris Rev 10.*
Better yet, download the whole book and read it end-to-end. Very well written.