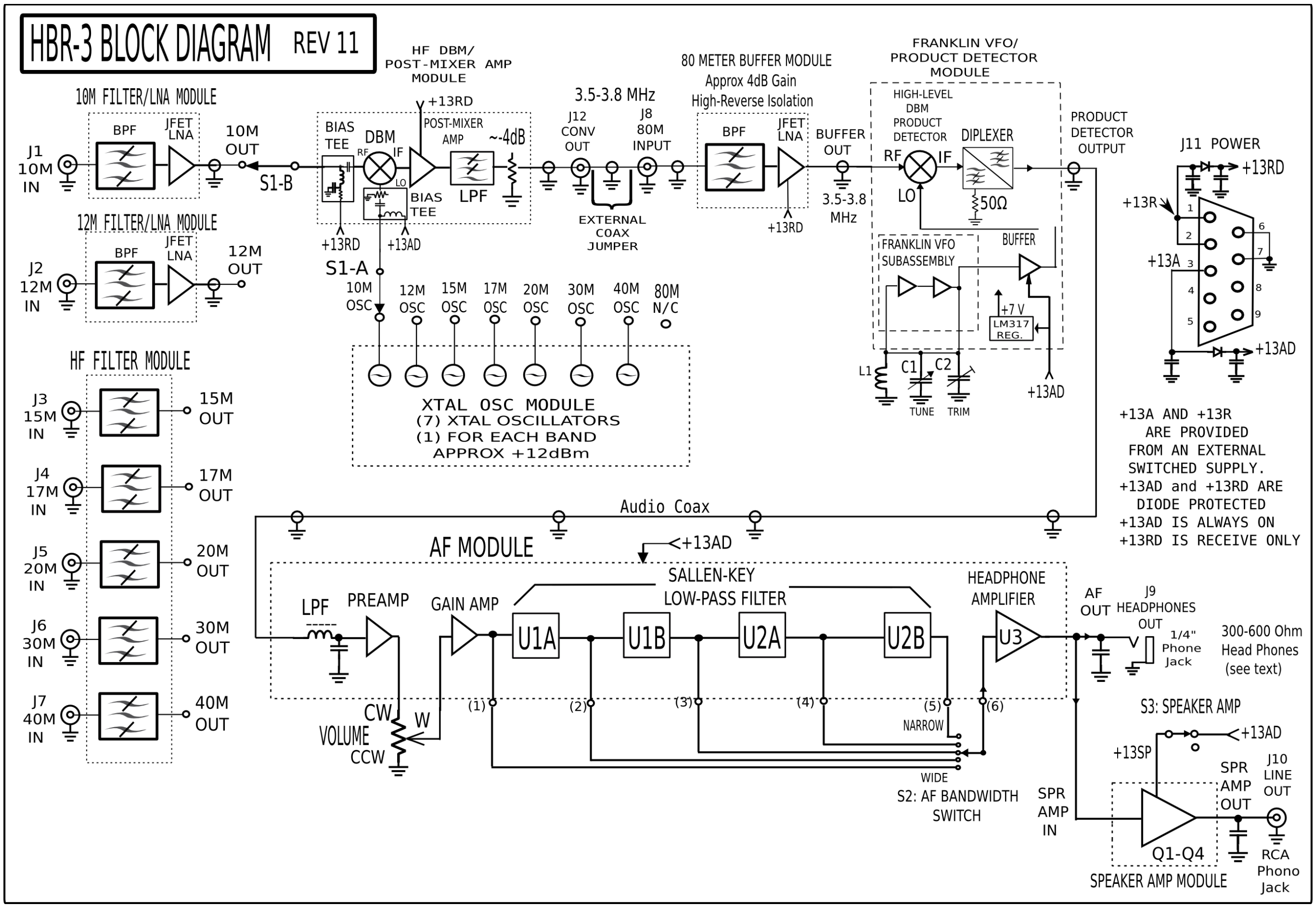
The HBR-3 Amateur HF Receiver for 80-10 Meters

Doc's: HBR-3_Rev11.odt. / HBR-3_Rev11.pdf January 2024

HBR-3 Block Diagram and Schematics. Tables of Part Lists/Component Specifications:

Document Outline:

1.0 BLOCK DIAGRAM:



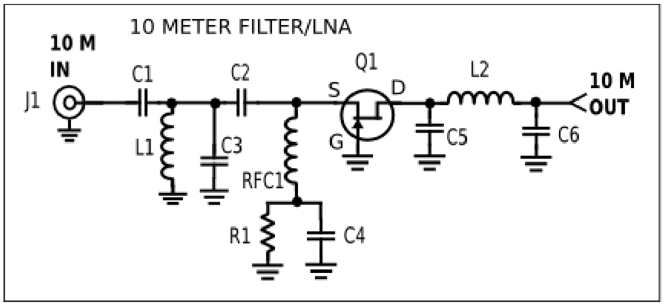
HBR-3 Receiver architecture is superheterodyne for 40-10 meters, using down-conversion in front of a buffered 80 meter Direct-Conversion receiver. The 80 meter frequency range is 3500-3800 KHz which covers CW and digital modes. This band works well for the Down Converters, which in this case down-convert signals in the 7.0-7.3 MHz, 10.0-10.3 MHz, 14.0-14.3 MHz, 18.0-18.3 MHz; 21.0-21.3 MHz, 24.8-25.1 MHz[1] and 28.0-28.3 MHz bands. With this receiver, no objectionable spurious have been noticed, and out-of-band rejection of strong SWBC signals is good throughout. The Dynamic Range and the Audio Bandwidth are improved over my previous efforts. The band-switching arraignment is improved, both in performance and for operating purposes. The HBR-3 was preceded by the HBR-2, which is slightly smaller and no provision for 12 meters in that unit.

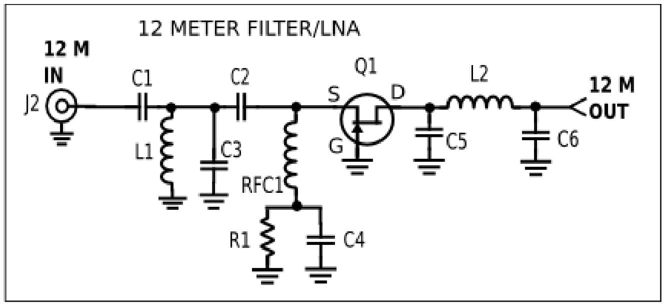
Each amateur band is individually Band Pass Filtered, and for 10 and 12 meters equipped with an JFET LNA. A Double-Balanced Mixer (DBM) using a Schottky Diode Ring down-converts to 80 Meters. A post-mixer MOSFET amplifier is used after the DBM to preserve Noise Figure and supply some gain. The product detector is preceded by a low-gain grounded-gate JFET amp, its purpose is high reverse isolation. This is necessary to reduce the product detector’s LO signal from leaking to the antenna on 80 meters. See Appendix A, section E for details on this matter. Somewhat unusual is the use of individual Crystal Oscillators for the HF Down-Converter. With a previous design that used a common oscillator that only switched crystals, the problem was greatly varying LO injection levels, band to band, with only around 0-3 dBm or less and poor harmonic rejection. The DBM needs approximately +7 to +10 dBm, with good harmonic rejection. This design solves those problems and others as well. Some more notes and “Additional Thoughts” follow in the Appendixes.

[1] With exception of 12 Meters, all bands listed above were built/tested, for which there is provision.

2.0 HBR-3 MODULES:

A. 10/12 Meter Filter LNA Modules and Parts List.





REF DES	10 meter FILTER/LNA	12 meter FILTER/LNA	NOTES
C1	10 pF	TBD	
C2	5pF	TBD	
C3	50 pF	TBD	
C4	0.1 uF X7R or X5R Ceramic Chip	TBD	
C5	5.6 pF NPO Ceramic Chip	TBD	
C6	180 pF NPO Ceramic Chip	TBD	
L1	T50-6; 487nH; 10~11T	T50-6; TBD value and turns	
L2	T50-6; 4.1uH; ~32T	T50-6; TBD value and turns	
RFC1	100uH RFC, API Delevan 1025-68K	100uH RFC, API Delevan 1025-68K	
Q1	2N5486,2N4416A or MMBF4416A	2N5486,2N4416A or MMBF4416A	Many Substitutes possible.
R1	100 ohms Chip Resistor	100 ohms Chip Resistor	

Unless otherwise noted, All Capacitors are NPO Chip or Leaded (short leads) ceramic.
J1,J2 : RCA Phono Jacks, Switchcraft 3501FPX, MPJA 35354 PL, or equiv.

B. HF Filter Module and Parts List.

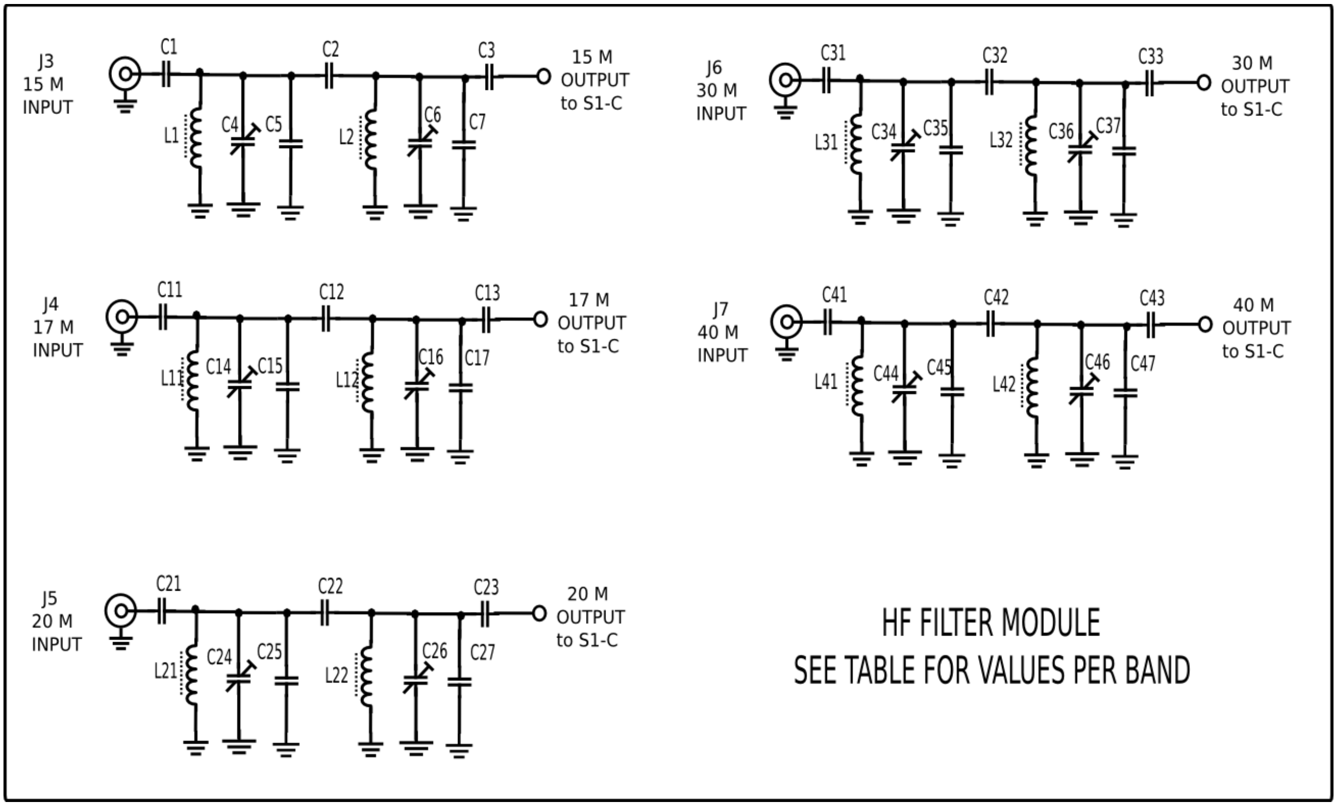


Table 2. HF Filters 15/17/20/30/40 Meters PCB. For all Bands L1 and L2 are wound on T50-6 Toroids; AWG#26 unless otherwise noted.

15 Meters	17 Meters	20 Meters	30 Meters	40 Meters
C1,C3: 10 pF	C11,C13: 20 pF	C21,C23: 24 pF (2x12pF)	C31,C33: 15pF	C41,C43: 39 pF
C2: 0.5 pF	C12: 3pF	C22: 3pF	C32: 1pF	C42: 4pF
C4,C6: 3-18pF Trimmers	C14,C16: 5-60pF Trimmers	C24,C26: 5-30pF Trimmers	C34,C36: 5-30pF Trimmers	DNI
C5,C7: 39pF	C15,C17: 12pF	C25,C27: 50pF	C35,C37: (22+39pF)=61 pF	C45,C47: 330pF
L1,L2: ~1000nH 12T	L11,L12:~950nH 13T	L21,L22:~1311nH 14T	L31,L32:~2304nH 24T AWG#24	L41,L42:~2695nH 23T

NOTES:
[1]All Fixed Capacitors Silver Mica or NP0 Ceramic Chip or Leaded.
[2] J3-J7: RCA Phono Jack, Switchcraft 3501FPX, MPJA 35354 PL, or equiv.
[3] Some adjustment of the inductors may be necessary to obtain correct passband. Compressing turn spacing to increase inductance or expanding turn spacing to decrease inductance is normal.

C. HF Crystal Oscillator Module and Parts List.

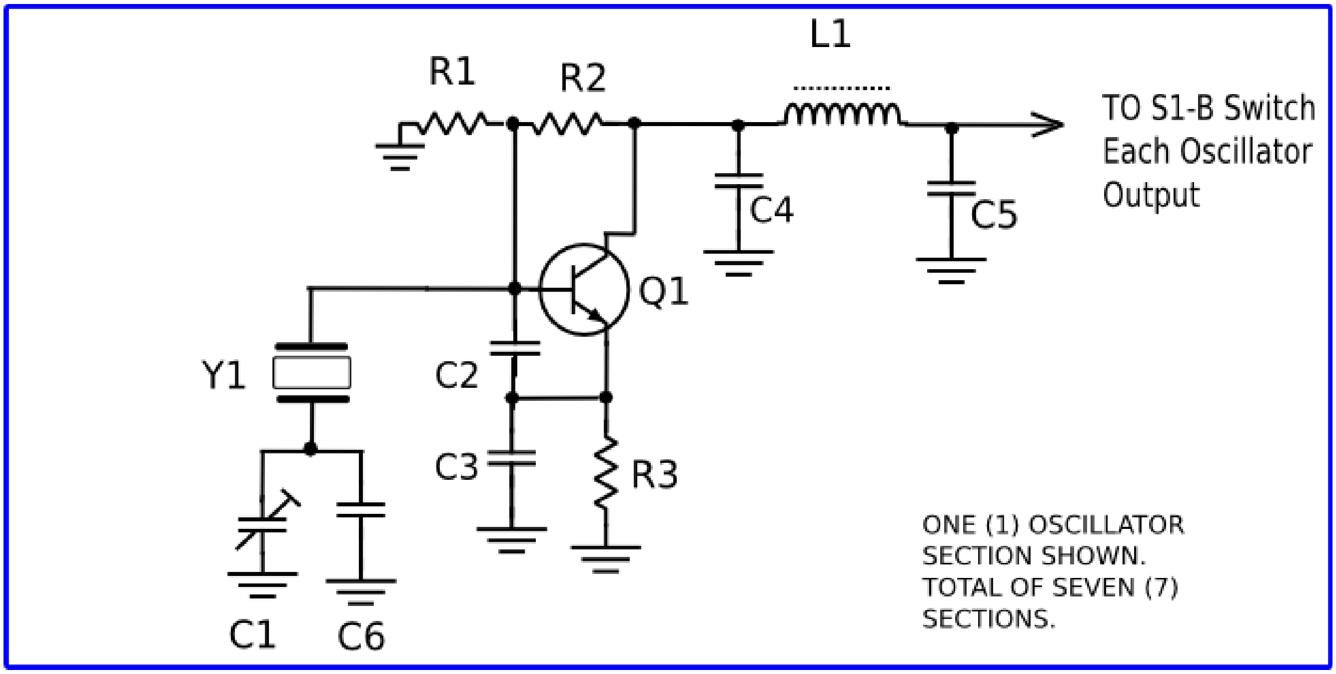


TABLE 3: HF Crystal Oscillators :

REF DES	10M	12M	15M	17M	20M	30M	40M
C6	DNI	TBD	15 pF	15 pF	15 pF	15 pF	30pF
C3	100pF,	TBD	100 pF	100 pF	150 pF	150 pF	150 pF
C4	~39pF	TBD	~58pF (47+9pF)	~66pF	~94pF (2x47pF)	~150pF	~94pF (2x47pF)
C5	~147pF (47+100pF)	TBD	~220pF (100+120pF)	~250pF (2x100+50pF)	~352pF (330+22pF)	~560pF	~352pF (330+22pF)
L1*	15T ~1uH	TBD	18T ~1.4uH	21T ~1.83uH	25T ~2.51uH	32T ~4.1uH	25T ~2.51uH
Y1	24.500 MHz	TBD	17.500 MHz	14.500 MHz	10.500MHz	6.500MHz	10.700MHz

Common Component Values to each band: All Capacitors NPO Chip ceramic unless otherwise noted.
C1: Trimmer SMD 5-30pF
C2: 47 pF NPO Chip
Q1: MMBT2222A or 2N2222A
R1,R2: 20 K SMD or Leaded Resistor
R3: 690 ohms (220+470 ohms chips in series)
*L1: All L1's for the HF Crystal Oscillators are wound on Micrometals T50-6 cores

See Appendix A, Section C for discussion on HF Crystal Oscillator Modules
Also, If finding crystals of the appropriate frequencies listed in Table 3 becomes an issue, one might consider switching a bank of Programmed Oscillators instead. This requires redesign of the HF Crystal Oscillator Module, but this is feasible. These Programmed Oscillators are reasonably priced.

D. HF-DBM Converter / Post-Mixer LNA Module and Parts List.

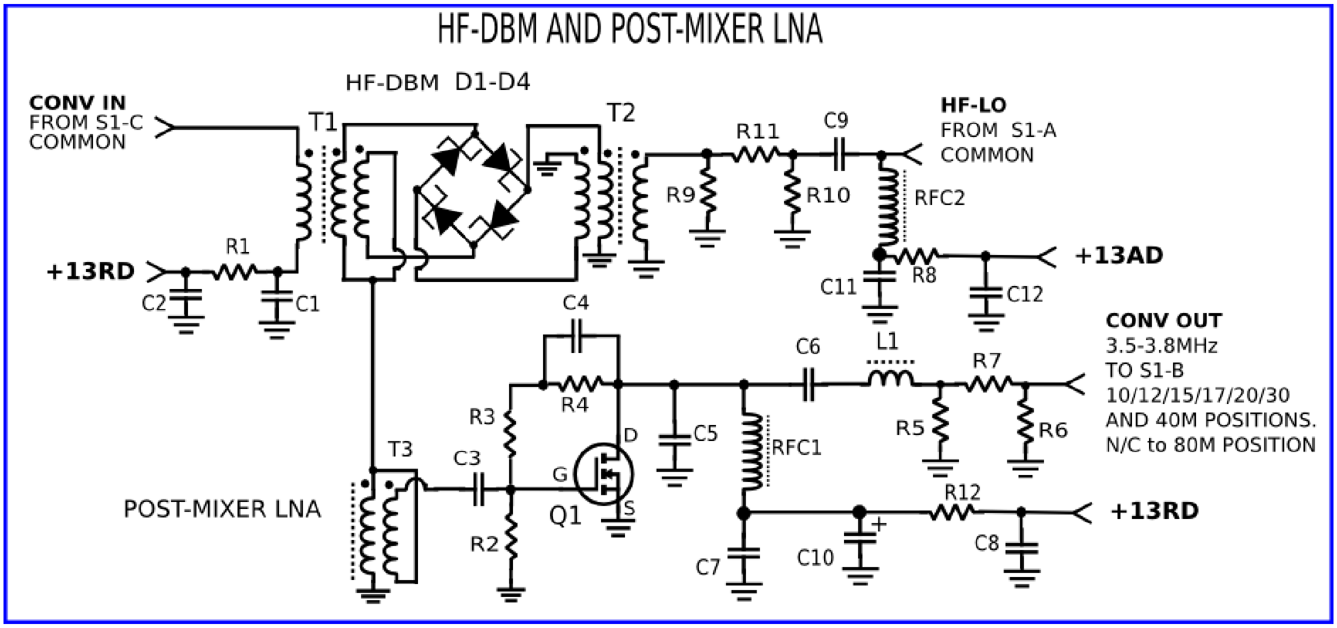
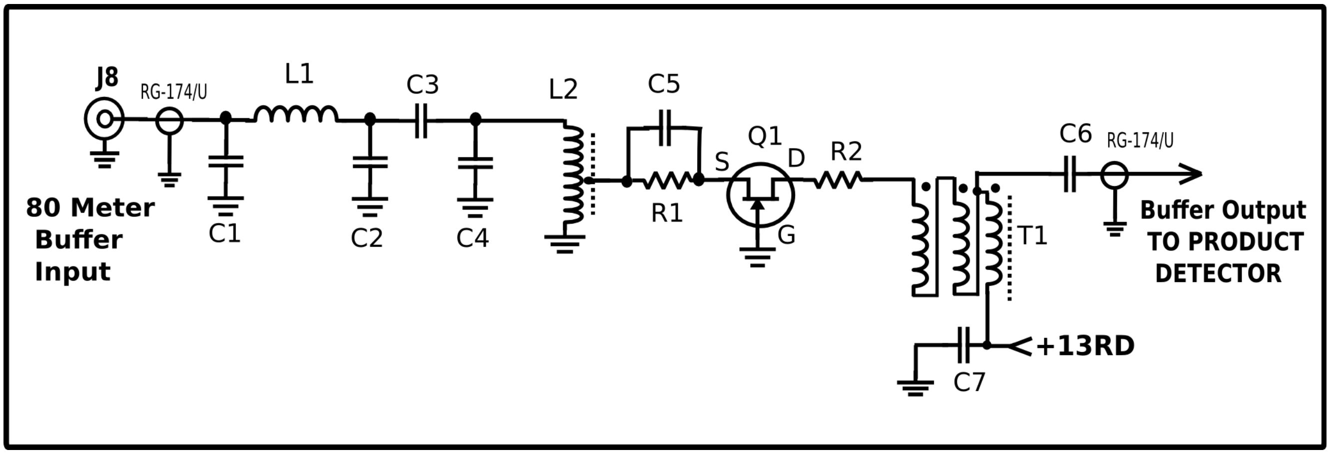


TABLE 4.

REF DES:	DESCRIPTION
C1-C3,C6-C9,C11,C12	0.1uF, X7R, 50 V, Chip Cap 1206 size
C4	0.01 uF, X7R, 50 V leaded capacitor
C5	270 pF, NPO, Chip Capacitor
C10	22uF 16 V, electrolytic
D1,D2,D3,D4	Schottky Diodes, Matched to 2mV, ZC5800E or equiv. See Text.
L1	Micrometals T50-6, 27 Turns, ~ 2.92 uH
Q1	N-Channel MOSFET, 2N7000. See text for discussion.
R1,R7,R8	27 ohms SMD or Leaded
R2	10K SMD or Leaded
R3	4.7 K SMD or Leaded
R4	22K SMD or Leaded.
R5,R6	220 Ohms SMD or Leaded
R12	150 ohms SMD or Leaded
R9,R10	430 ohms SMD or Leaded
R11	16 ohms SMD or Leaded
RFC1,RFC2	100uH RFC, API Delevan 1025-68K or equiv.
T1,T2	Trifiliar Transformer, 7 Turns AWG#30 on 0.5” FT50-43 u~850 or FairRite P/N 5943000301 or equal
T3	Bifiliar Transformer, 9 Turns AWG#28 on 0.37” FT37-43 u~850. Alternate: 7 Turns AWG#28 on 0.5” FT50-43 u~850.

E. 80 Meter Buffer Module and Parts List.

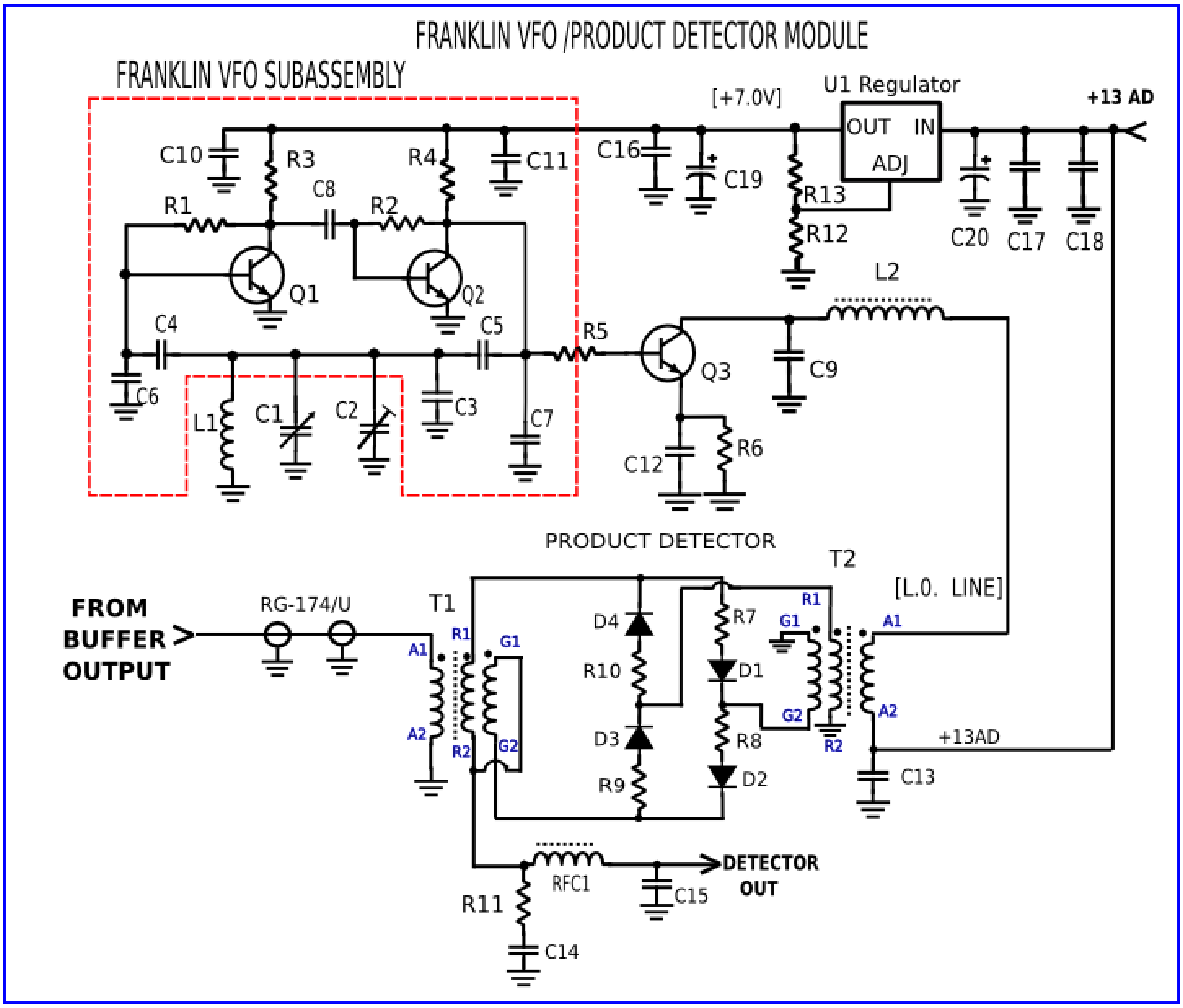


REF DES	DESCRIPTION/ PART NUMBER
C1	2200 pF NPO SMD or Leaded
C2	470 pF NPO SMD or Leaded
C3	56 pF NPO SMD or Leaded
C4	150 pF SMD or Leaded
C5,C6,C7	0.1uF X5R or X7R 50V Chip Capacitor
J8	RCA Phono Jack, Switchcraft 3501FPX, MPJA 35354 PL, or equiv.
L1	4350 nH 33T, T50-6 Toroid
L2	9600 nH, 49T, Tap at 13 T from ground end. T50-6 Toroid
Q1	U310, J310, or MMBFJ310
R1	100 ohms SMD or Leaded
R2	50 ohms SMD or Leaded
T1	9:1 Z Ratio Transmission Line Transformer. 7 Trifilar Turns AWG#28 on u~850 Fair-Rite P/N 5943000301 or equal

Unless otherwise noted, All Capacitors are NPO Chip or Leaded (short leads) ceramic.

The 80 Meter Buffer Module is to be installed as far as possible from the Franklin VFO/Product Detector Module components, especially the VFO Module’s L1. Shield the 80 Meter Buffer Module if possible to reduce LO Leakage and potential for tunable hum. See Appendix A, Design Discussion.

F. Franklin VFO/Product Detector Module and Parts List.
See Parts List and Notes after this schematic.



The Franklin VFO/Product Detector *Module* is a Double-Sided PCB (DSB) mounted directly on the housing floor, for mechanical stability and good grounding. The Franklin VFO *SubAssembly* is a Single-Sided PCB, right-angle mounted to the housing floor. R5 is attached between the SubAssembly and the Module, connecting Q2-C with Q3-B. Direct connections are made between the SubAssembly and C1,C2 and L1 with stiff tin-plated wire.
Optionally, a separate subassembly consisting of VFO components U1, R12,R13 and C16-C20 inclusive can lessen the slight heating of frequency-determining elements. This is optional, not required.

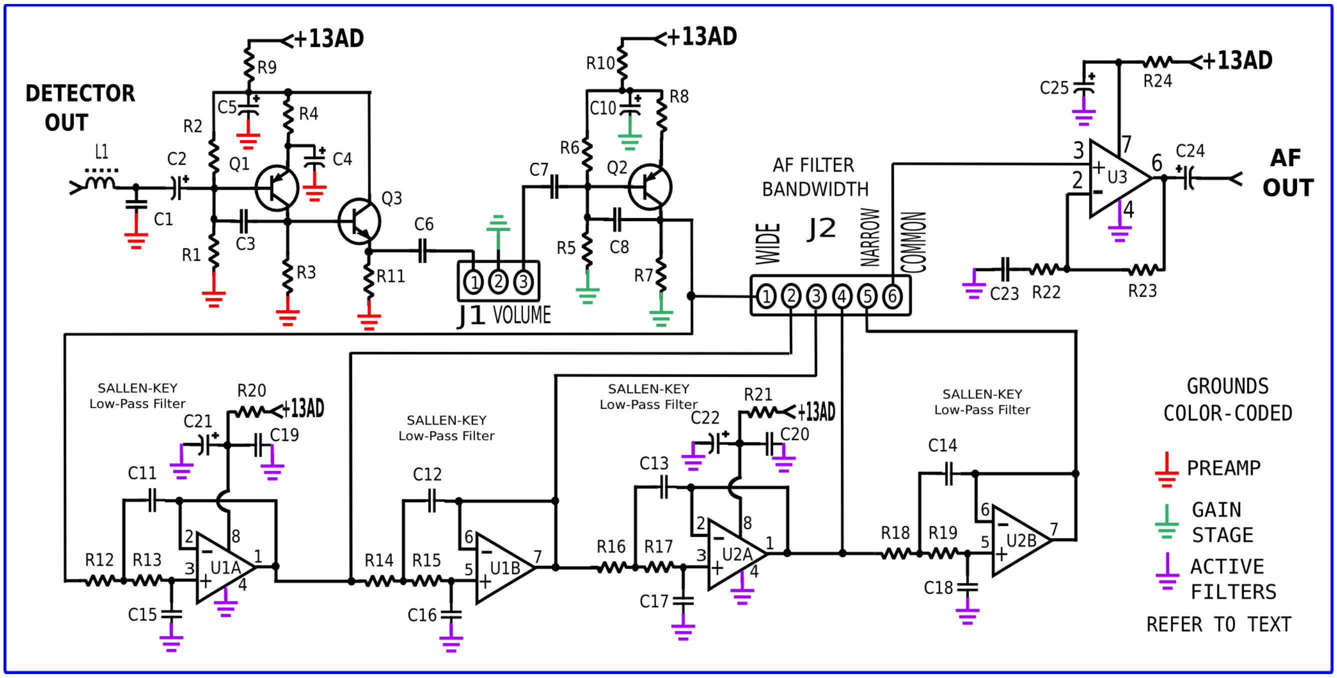
See Appendix F for more detail on the Franklin VFO SubAssembly.

F. Franklin VFO/Product Detector Module and Parts List.(Continued)

REF DES	DESCRIPTION/ PART NUMBER	REF DES	DESCRIPTION/ PART NUMBER
C1	Air Variable Tuning Capacitor, 5 to 43 pF. The capacitor used is supported both front and back.	R1	100K SMD or Leaded Resistor
C2	Air Trimmer Capacitor ~ 5-25pF	R2	180K SMD or Leaded Resistor
C3	~208.2pF NPO SMD Capacitor. Made from 2x100pF + 8.2 pF NPO chip	R3,R12	1K, SMD or Leaded Resistor
C4,C5	3pF NPO SMD Capacitor.	R4	1.8K, SMD or Leaded Resistor
C6,C7	50pF NPO SMD Capacitor.	R5	2.2K Leaded Resistor. Attach between SubAssembly and Module
C8	330 pF NPO SMD Capacitor.	R6,R13	220 ohms, SMD or Leaded Resistor
C9	(3x100)+47=347 pF. NPO SMD or Leaded Capacitors.	R7-R10	33 ohms +/- 1% or better, SMD or Leaded.
C10-C18	0.1uF 50 V X5R or X7R SMD Capacitor	R11	51 ohms, SMD or Leaded Resistor
C19,C20	6.8uF, 35 WVDC Tantalum	RFC1	100uH RFC, API Delevan 1025-68K
D1-D4	1N4148. Match to within 2mV Vforward	T1,T2	11 T Trifiliar on FT50-43 or Ferronics 11-250-J #36. A_L=509nH/T^2 . Amber center wire is for LO drive on T1 and RF for T2.
L1	7.16uH AIR CORE, Ceramic or Cardboard form 0.375"dia. Approx 41Turns AWG#26 close-spaced. Staked with Epoxy, Allow full cure, then re-trim C16 for correct frequency coverage.	U1	LM317T TO-220 Package.
L2	33 Turns on T50-6, ~4400 nH		
Q1,Q2,Q3	2N2222A, MMBT2222A		
Vernier Dial	Lafayette YN-7 or equivalent. Drives C1. Can be found on surplus market.		

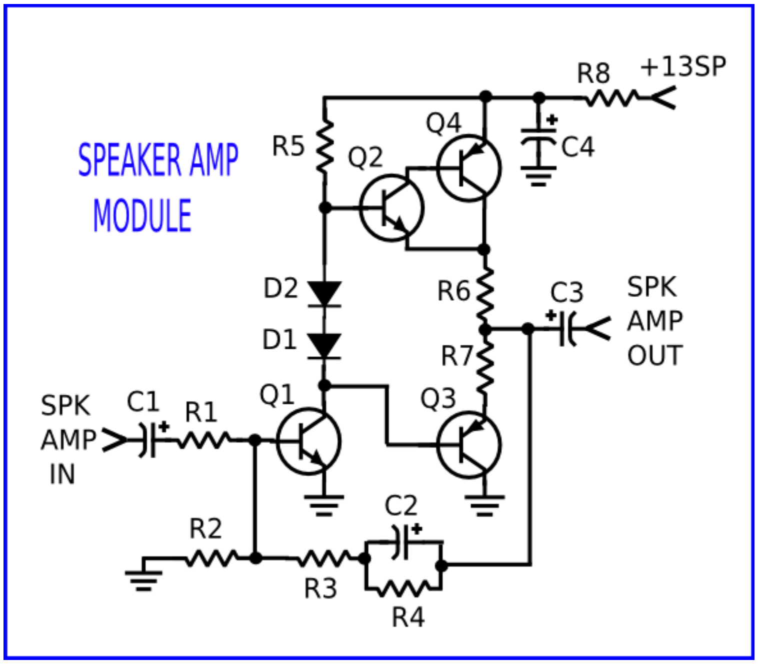
Notes:
1) Unless otherwise noted, All Capacitors are NPO Chip or Leaded (short leads) ceramic.
2) PCB Information:
a) Main Franklin VFO/Product Detector Module uses FR-4, 0.062" thick Double-Sided Copper
b) Franklin VFO/Product Detector SubAssembly uses FR-4 0.031" or 0.062" thick Single-Sided Copper. This is important for temperature stability.

G. AF Module Schematic and Parts List.



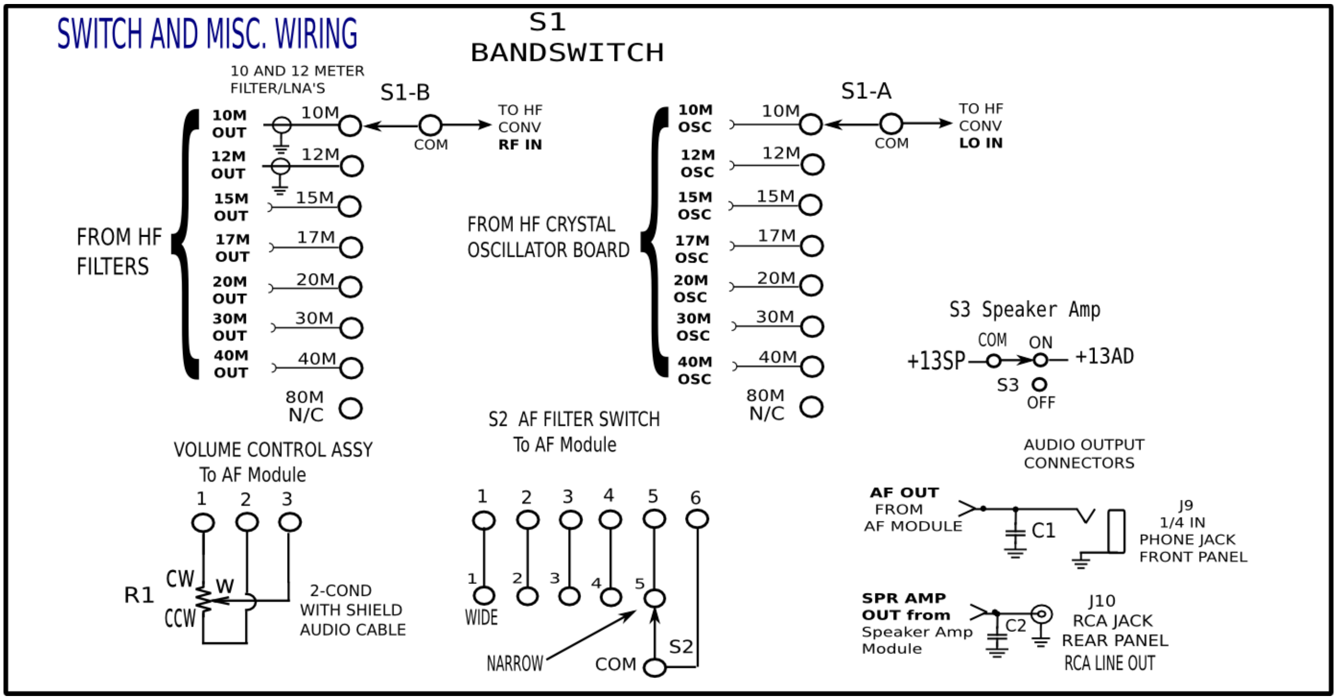
REF DES	DESCRIPTION/ PART NUMBER	REF DES	DESCRIPTION/ PART NUMBER
C1	0.39 uF, 100 V Film Capacitor	Q3	2N3415,2N3904 or equiv. NPN
C2,C4	6.8 uF, 35 WVDC Tantalum Capacitor	R1,R5	100K SMD or Leaded
C3,C8	100pF NPO, 50V, SMD	R2,R6	10 K SMD or Leaded
		R3,R7	15K SMD or Leaded
C6,C7,C19,C20,C23	0.1uF X5R or X7R SMD	R4,R8,R11	1000 ohm SMD or Leaded
C5,C10,C21,C22, C25	Capacitor, Electrolytic SMD, 330uF, 25WVDC	R9	430 Ohm SMD or Leaded
C11-C14, inclusive	0.022 uF Film Capacitor Example: Kemet P/N R82DC3220Z360J or equiv.	R10	2700 Ohm SMD or Leaded
C15-C18,inclusive	1500 pF Ceramic Chip, NPO,50V Murata P/N GRM1885C1H152JA01J or equiv.	R12-R19	39K Chip Resistors. Any size 0402 to 1206.
C24	10 uF 25 WVDC Tantalum Capacitor	R20,R21,R24	100 Ohm SMD or Leaded
J1,J4	3 pin socket made from Mill-Max 310 series 0.1” spacing SIP Socket with Long Pin	R22	3300 Ohm SMD or Leaded
J2	6 pin socket made from Mill-Max 310 series 0.1” spacing SIP Socket with Long Pin	R23	56K Ohm SMD or Leaded (54K Ohm used)
J3	1 pin socket made from Mill-Max 310 series 0.1” spacing SIP Socket with Long Pin		
L1	Approx 44~88 mH Toroid Inductor. Western Electric 88mH Toroid used here.	U1-U2	Dual Op Amp, MC1458, LM1458 or equiv.
Q1,Q2	2N2907A or MMBT2907A PNP	U3	Op amp, LM741C or equiv.

H. Speaker Amplifier Module Schematic and Parts List.



REF DES	DESCRIPTION/ PART NUMBER	REF DES	DESCRIPTION/ PART NUMBER
C1,C2	1.5 uF, 25 V Tantalum Capacitor	R3	22 K SMD or Leaded
C3,C4	Capacitor, Electrolytic SMD, 330uF, 25WVDC	R4	100 K SMD or Leaded
D1,D2	1N914,1N4148, MMBD914 or equiv.	R5	4700 Ω SMD or Leaded
Q1,Q2	2N2222, 2N3415, 2N3904 or equiv. NPN	R6,R7	3.3 Ohm SMD or Leaded
Q3,Q4	2N2907, 2N3906 or equiv. PNP	R8	18 Ohm SMD or Leaded
R1	6800 Ω SMD or Leaded		
R2	15 K SMD SMD or Leaded		

I. Switch and Miscellaneous Wiring:



SWITCH S1 BANDSWITCH :

REF DES	DESCRIPTION/ PART NUMBER
S1	Open-Frame Wafer Rotary Switch. Electroswitch P/N D4G0211N (2P11T) used here. Others (2P8T) may be less expensive. Epoxy-glass, phenolic or ceramic wafers preferred.
RF Coax RG-174/U (as Required)	

VOLUME CONTROL ASSY:

REF DES	DESCRIPTION/ PART NUMBER
R1	Volume Control, 10 K~100K

S2 AF FILTER SWITCH:

REF DES	DESCRIPTION/ PART NUMBER
S2	Rotary Switch SP5T or equiv. Example(SP7T) P/N Jameco RSL25-1-1-7-19R
6-Conductor Ribbon cable with 6 pin socket made from Mill-Max 310 series 0.1” spacing SIP Socket, Long Pin. Epoxy Staked.	

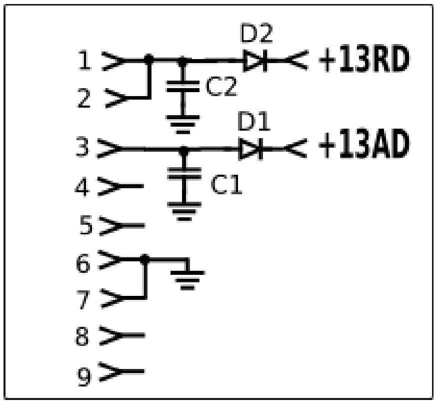
SPEAKER AMP SWITCH:

REF DES	DESCRIPTION/ PART NUMBER
S3	Toggle Switch SPST , Example P/N TE Connectivity A101SDCQ04

AUDIO OUTPUT CONNECTORS:

REF DES	DESCRIPTION/ PART NUMBER
C1,C2	0.1 uF X5R or X7R Capacitor Leaded
S3	Toggle Switch SPST , Example P/N TE Connectivity A101SDCQ04
J9	¼” (6.35 mm) Phone Jack .Example P/N Switchcraft P/N 11
J10	RCA Phono Jack, Switchcraft 3501FPX, MPJA 35354 PL, or equiv.

I. Switch and Miscellaneous Wiring (Continued):   Power Connector J11:



There are two supply lines used, +13AD and +13RD. Both are reverse-bias diode protected. The +13AD line is always powered. The +13RD line is powered only during receive, and is not powered during transmit. This allows the receiver to reduce gain and allows the operator to *monitor their CW signal as it is being transmitted*, with adequate audio volume. It mutes the receiver just enough for this purpose, and for my uses, it is preferred to using a side-tone.

REF DES	DESCRIPTION/ PART NUMBER
C1,C2	0.1 uF X5R or X7R Capacitor Leaded
D1,D2	1N4001,1N5804 or equiv.
J11	D-SUB, Male, 9 Pin Solder Cup (ex: Cinch 40-9709M or equiv)

Appendix A. Design Discussion

A. 10/12 Meter Filter/LNA Modules

Used on the top two HF bands, mainly to maintain Noise Figure. Simple Grounded-Gate JFET LNA's that are stable, typically, providing good NF consistent with moderate (but not high gain). DC Power is routed from the RF output connection via S1-C. These are powered by +13RD, and are not powered during transmit.

B. HF Filter Modules

The HF Filters employed on 40-15 meters inclusive, are simple top-coupled symmetrical tank circuits that are easy to tune. Ample image rejection is provided especially from 30-15 meters inclusive due to the LO low-side injection to the HF DBM, and the excellent low side rejection from these filters. Their insertion loss is low enough not to require any LNA or preamp on the 40~15 meter bands.

C. HF Crystal Oscillator Modules

In a change from the previous receivers I have built, this receiver uses individual HF Crystal Oscillators, not just a switched crystal/ trimming capacitor combination along with a “minimal parts-count” oscillator and buffer. Instead, Colpitts oscillators and an output filters are switched by S1-A and the results are greatly improved. The previous arrangement only yielded 2-3dBm for 40 and 30 meters, dropping to -13dBm for 10 meters. The harmonic rejection was -12dBm, and only slightly better on the higher bands, not adequate. These HBR-3 HF Crystal Oscillators yielded +12~+13 dBm consistently, and with -33 to -38dBc Harmonic rejection. This helped greatly in removing spurious responses to the strong 31-meter SWBC band when tuning 30 Meters Amateur. The old 2x 6.5 MHz LO produced 13 MHz mixed with ~9.4 MHz to produce ~3.6 MHz. Either filter out the 9.4 MHz -or- just clean up your LO harmonic. Took the latter route- much better!

D. HF-DBM Converter/Post-Mixer LNA Module

The HF-DBM receive its LO input from the HF Crystal Oscillators mentioned in section 'C'. The DC power for the HF Crystal Oscillators is provided via a 100 uH RFC in a Bias-Tee configuration. Some attenuation ~2dB, is provided before LO Injection into the Schottky diode DBM providing about +10dBm. This appears as clean sine wave on a scope, and a good spectrum seen on a spectrum analyzer. The same DBM receives the RF input in a similar way, except without additional attenuation. This keeps NF at a low, but the DC bias used only for the 10 and 12 meter Filter/LNA's. All RF inputs to the DBM are routed through S1-B.

The IF output of the DBM is sent through an inexpensive MOSFET IF Amplifier. It has been used in the past and was characterized with a NF ~2dB and an output P1dB of about +22dBm. This stage's output is attenuated by ~4 dB and routed to the 80 Meter Buffer via an external coax jumper connected from J12 to J8 when operating all bands other than 80 meters. 80 meters operation does not use the HF modules (sections A through D) and the antenna is directly connected to the 80 meter Buffer.

The Schottky diodes used in the DBM are inexpensive discretes, with good RF performance at HF. They did perform noticeably better than switching type 1N4148's above 20 MHz, with better conversion gain, lower NF. A better and more available alternate to the ZC5800E could be the On-Semi MBD330 or MBD770, amongst others.

E. 80 Meter Buffer Module

The 80 Meter Buffer's primary purpose is to supply high reverse isolation to block the product detector's LO signal from leaking into the antenna during 80 meter operation, possibly causing re-radiation. This manifests itself as a persistent “tunable hum” on 80 meters, often seen with certain antennas. This leakage is minimized so it does not become coupled into AC line rectifiers, usually found in low-cost consumer electronics. The re-radiation can be difficult to deal with. Approx 7dB of forward gain is provided in this circuit, just to preserve noise figure of the receiver in its different configurations. The high-dynamic range of the U310/J310 JFET series used in a grounded-gate configuration with output match designed for low-broadband gain and high reverse isolation. Measurements made with my direct-conversion receivers showed that an LO leakage less than -70dBm was both desirable and attainable. The HBR-3 and HBR-2 both measured -73 to -77dBm at 3.5-3.8MHz. I recall “tunable hum” with LO leakage at only -50dBm (0.01 microwatts!) in some past measurements. It is recommended to install this module apart from the VFO/Product Detector Module, with a shield if possible.

F. VFO/Product Detector Module

The VFO is a Franklin oscillator circuit, with an air-core staked inductor, NPO ceramic and air variable capacitors for minimum overall temperature variation, lightly coupled to the active elements. The VFO active elements are two BJT’s Q1 and Q2, with a third BJT Q3, used as a buffer to minimize oscillator loading. Q1 and Q2 and associated components are attached to a single-sided PCB. This reduces the effect of the PCB dielectric on the VFO Temperature Coefficient. Buffer Q3, regulator LM317T and associated components are installed on a double-sided PCB. All paths need to be as short and mechanically stable for both subassembly and the module. The buffer stage provides clean +12.5 dBm LO level to the Double-Balanced Product Detector. A regulator, the LM317T holds the supply voltage for Q1 and Q2 much tighter than the Zener diode regulator previously used. This DBM is a High-Level Class 2, Type 2, with V_F matched diodes and matched series resistors, to increase the back-bias of the “off” diodes during the driven diodes “on” cycle. This improves the Product Detector's intermodulation performance. One could give use Schottky diodes in this 80 Meter Product Detector in place of the switching type 1N4148's, but I have not seen any advantage at this frequency. Also, my junkbox produced many 1N4148's that I could use, but I didn't have many Schottky's available. The 1N4148's are reasonably robust to RF burn-out. Transformers T1 and T2 were wound with 3-color trifilar wire, taking care to connecting their leads correctly.

G. AF Module Schematic.

A more or less conventional approach is used through the AF chain. This is where most of the receiver gain and selectivity is found, and where gain stability needs to be maintained. To do this, multiple gain stages are used, with individual grounds (see color-coded grounds in the schematic) for the PCB pattern to keep ground currents from coupling unwanted feedback between stages. Each of these individual grounds are returned to the chassis ground via metal standoffs and hardware There are 3 sections in the AF Module: Preamp, Gain Stage and Active Filters. There are (6) metal standoffs used, (2) for each section. Verify that no two grounds *between* sections are shorted before installing the AF Module. From the Product Detector’s output, a single-section passive low-pass filter is used to roll-off high frequency audio, providing the benefit of matching the Product Detector’s low output impedance to the AF Module’s higher input impedance (at the first stage). This also prevents high frequency overload from strong stations near our operating frequency from affecting the AF module. A 44~88mH toroid goes a long way for this purpose. If L1 is omitted, with a short in its place, the receiver still functions, but without the aforementioned benefits.

There are two low-noise AF preamps with gain control between these stages. Each has a high-pass characteristic to roll off low-frequency noise and hum, followed by up to four sections of Sallen-Key low-pass filters, designed for low-Q, minimal ringing and excellent roll-off. All stages used very commonly available parts, and all these are very inexpensive, and substitutions are feasible. Like most of my projects, it was based on what I had available, but your junkbox might have available a different mix of goodies. The 2N2907A (MMBT2907A) is low in noise, but other PNP BJT's may do better. The discrete preamp stages provide sufficent gain to over-ride the noise of the following filter stages, but if you have RC4558 or NE5532 op amps instead of the MC1458's used here, try them, because they may be lower in noise. A single Quad 741 op amp, LM348 has also worked well. Previously, I used MFB Bandpass Filters were used, but as it was important for me to be able to accurately zero-beat to other stations against my Transmitter VFO, I returned to the Sallen-Key low-pass. It also seems to ring less. There is some peaking around 700 Hz, and some roll-off of the lower frequencies, but the greater attenuation of the higher frequencies allows for good rejection of the off-frequency stations. It sounds good for a CW filter.

The DC voltage, as measured at J2, pin 1 is important. With +13.8 Volts DC applied to the receiver (at J9 pin 3), the DC voltage at J2, pin1 on the AF module should be +6 ± 1 volt. This DC voltage sets the bias voltage for U1, U2 and U3 in this module. If it is less than +5 volts, then decrease R8 from its nominal 1000 ohm value to 910 ohms, if necessary. Likewise if it is greater than +7 volts, then increase R8 to 1100 ohms. Repeat this process, if necessary to center the DC bias voltage at J2, pin 1 at +6 ±1 volt. Once done, no further adjustment should be necessary for the DC bias.

The AF Module is designed to drive ~300- 600 ohm high-impedance headphones typical of the Telex 610 or certain Califone models. Used Telex 610's can be inexpensive on e-bay. They are rugged and with a ~300 or 600 ohm impedance easy for a general-purpose op amp to drive. The AF module has a LM741C to drive headphones (with a ¼ inch phone connector) and also supply a line through an RCA phono connector for an external amplifier/ speaker. With so much audio gain as was needed for this receiver, it was found best to keep the AF Module separate from the Speaker Amp Module, thereby making stability much easier to achieve.

H. Speaker Amp Module.

This optional module allows a small speaker to be driven. Approx 400mW is available to 8 Ω load. The circuit is typical class AB with a quiescent current of approx 15~20mA. This module should be separate from the AF Module, so as to improve stability.

I. Band-Switch S1, Volume Control AF Bandwidth and Audio Output Wiring:

The Band-Switch S1 is probably the most expensive part in the receiver. Unless your junkbox already has it in stock. At about $35 new from Allied, maybe less somewhere else. Go with a good open-frame wafer rotary switch with individual sections, either epoxy-glass, phenolic or ceramic. This gives you good RF isolation between sections, something the cheaper ones can't provide. The Electroswitch D4G series has been around and is still available. Notice, in this receiver I did not try to use a 4 pole switch and eliminate all the individual RCA phono connectors from the antenna inputs in this receiver. I did try that in an earlier home-brew version. One could easily degrade the HF filter performance with all the coupling between switch sections, unless we specially modify the rotary switch with a shielding partition, but it was decided not to go through all of this. Running individual input lines from the RCA phono jacks (J1-J8) to the Filter/LNA's and the HF Filter inputs, followed by running their respective outputs to S1-C, proved to be a much better layout option and minimized any electrical performance compromise, especially in RF isolation. So what if there was a minor inconvenience of moving the antenna line in-sync with S1's Bandswitch Selection? Not a problem. If you want to have it easier, redesign the front-end with solid-state CMOS, low-IMD RF switches, to replace S1. That will involve more circuitry, but is feasible.

J. Power Connector J11:
A Standard 9-Pin D-Sub Connector is used in my station for all power and keying. In the case of the Equipment side, the Male 9-Pin D-Sub Connector is installed and the Female is on the Power Cable side. RF Decoupling is provided locally by C1 and C2. The reverse bias protection is provided by D1 and D2. Then "+13AD" is always at approximately +13 Volts DC with diode protection. The line "+13RD" is at approximately +13 Volts DC when you are on receive mode. It can be grounded or left open during transmit, when it will reduce the HBR-3 receiver gain. This was done so that during your CW Transmit, the HBR-3 Receiver monitors your sending.

J11 power 9-pin Connector pin-out:

PIN(s)	FUNCTION/ Description	PIN(s)	FUNCTION/ Description
1,2	+13.8R (Receive) . This is +13.8 A via a T/R relay contact during receive [1].	6,7	Ground
3	+13.8A (Always)	8	Key Line. Not used for this receiver.
4,5	+24 T. Not used for this receiver.	9	T/R Relay control. Not used for this receiver.

Note: [1] The transmitter has a corresponding +13.8T on pins 1 and 2. This is connected to the same T/R relay, different contact.

Appendix B. Specifications and Design Analysis: Gain/NF/Dynamic Range.

Frequencies	RF Frequency Ranges: 80 M 3.5-3.8 MHz 40M 30M 10.0-10.3 MHz 20M 14.0-14.3 MHz 17M 18.0-18.3 MHz 15M 21.0-21.3 MHz 12M TBD 10M 28.0-28.2 MHz	HF Crystal Frequencies: 80 M Not Used 40M 10.7MHz 30M 6.5 MHz 20M 10.5 MHz 17M 14.5 MHz 15M 21.0-21.3 MHz 12M TBD 10M 28.0-28.2 MHz
AF Bandwidth	Refer to Appendix D for QucsStudio Simulation Note: Receiver BW is approx 2x AF Bandwidth due to double-sideband reception.	
NF (estimated)	80M: ~8-9 dB; 40-15M: ~11.5 dB; 12-10M: ~5 dB	
MDS (estimated)	80M: -136/-127 dBm; 40-15M: -138/-129 dBm; 12-10M: -143/-135 dBm	
IIP3 (estimated)	80M: 12 dBm; 40-15M: 4.5dBm; 12-10M: -9.5 dBm	
DC Power	13.8VDC @ 82 mA approximately with J9-3 and J9-9 DC powered.	
Audio Output Power:	Headphone Jack: 8 Vpk-pk into 300 ohms, or approx 25 mW RCA Line Out: approx. 10 K output Z. Suitable for feeding audio amplifier with speaker.	

Appendix C. Additional Thoughts......

Architecture and Circuit Details...
Originally I was open to different approaches from the HBR-2, a Direct-Conversion receiver with HF Down-Converters in front. I looked at and/or also build up modules for doing this with completely different methods, including DSP, but my junkbox was full of analog goodies.

In the end, for my type of operating CW, in the 10-25 watt range, looking for casual QSO's, not so much contests or "pile-ups", and also portable operation. Packing the receiver, along with the other items needed for portable operating, including a dipole antenna is easy. QSO's were had from Northern New York, Rhode Island and Cape Cod. I really wanted full 80-10 Meters complete, with better dynamic-range, cleaner audio, free of ringing, and audio filters with better selectivity, and that removing the unwanted sideband never amounted to a big priority. It rarely caused me to even move to the opposite side of the other guy's transmitted frequency, let alone see it as an inherent 3 dB additional noise source. I estimated it would be more straightforward to tighten up the audio filter for these concerns, but simultaneously make it better behaved than the old HBR-2 in other ways. There were other deficiencies within the old HBR-2 that I was not aware of until I was building and testing HBR-3. The result is a receiver that is a pleasure to use!

In this revision, the Franklin 80 Meter VFO is used with excellent results. Two BJT's are used for the Franklin VFO and one BJT for the Buffer. This generated ample drive for the Product Detector, which is Class 2/Type 2 High Level. This is an improvement in drive level, measured at +12.5dBm. A LM317 regulator, was used, preferable to a Zener diode, with better stability as the result.
The Audio Module Filter is an Active Sallen-Key Low-Pass. I had been considering other types of audio filters. SCAF, DSP filters and even some all-passive designs. I estimated that by the time I had put in the effort for the alias filtering and post-filtering both SCAF and DSP, I already would have built a moderately decent Active Filter, anyway. So, I just proceeded to do just that. The key here is multiple sections, of Low-Q ~1.8-1.9. Don't be aggressive with the Q, you may pay with excessive group delay and ringing. This design has a mild amount of low-frequency roll-off to help with hum and low frequency noise, but not so much as to inhibit the effective use of "zero-beating", which I use with my homebrew CW transmitters. Being able to accurately zero-beat another station when answering CQ's has proven to be a plus for getting replies.

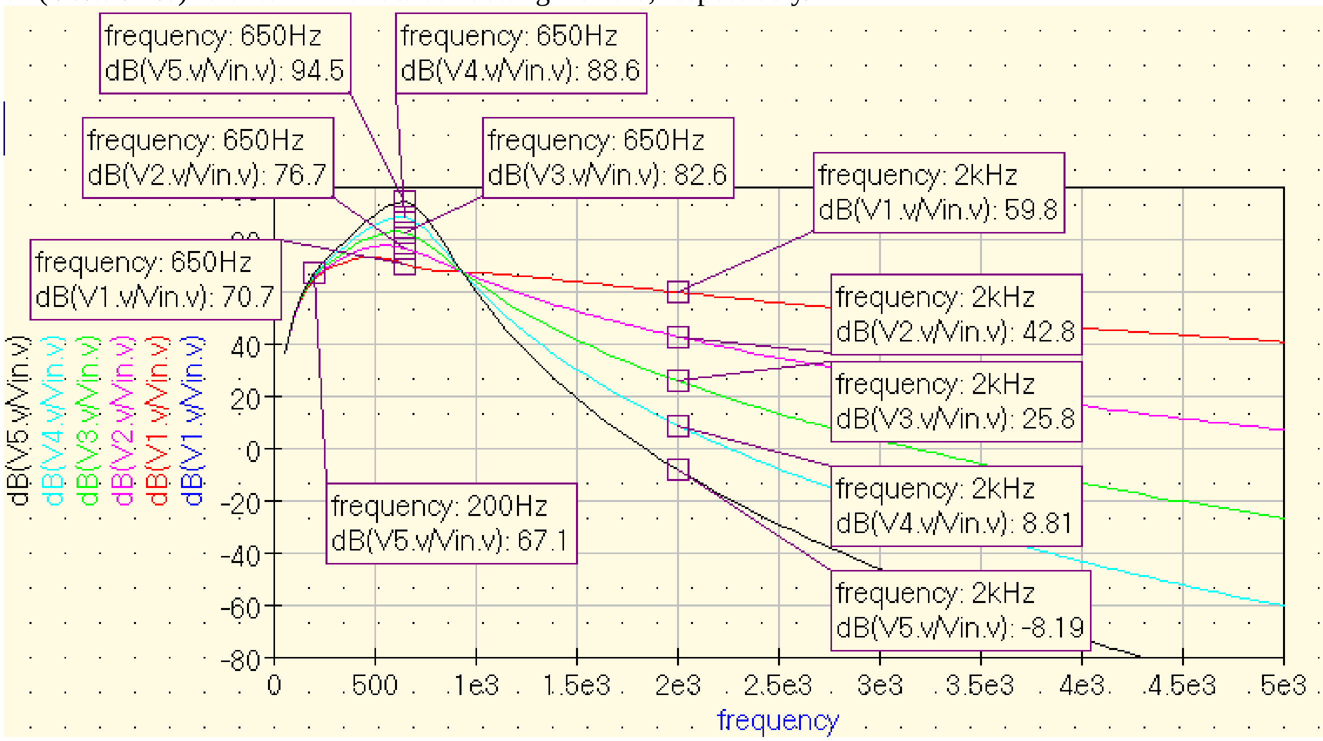
Component Availability….

I completely built these receivers from what I had on hand, with very few additions. The Bill of Material reflects this. Your situation may be different. This was not in any way meant to be a construction article, just a documentation for my HBR-3 Receiver, and to maybe spawn a few of your own ideas and concepts, using other components as available to you.

Since building the HBR-3 to this revision, it was decided to apply all revisions to the HBR-2. Results were a "carbon-copy" of the HBR-3. The HBR-2 is the same now as the HBR-3, except that it is smaller due to the available enclosure and that there is no provision for 12 Meters in the HBR-2.

If finding crystals of the appropriate frequencies listed in Table 3 becomes an issue, one might consider switching a bank of Programmed Oscillators instead. This requires redesign of the HF Crystal Oscillator Module, but this is feasible. These Programmed Oscillators are reasonably priced.

Appendix D. QucsStudio AF Module Frequency Response (Simulation). The labels dB(V1.v/Vin.v) thru dB(V5.v/Vin.v) refer to AF Bandwidth Setting 1 thru 5, respectively.



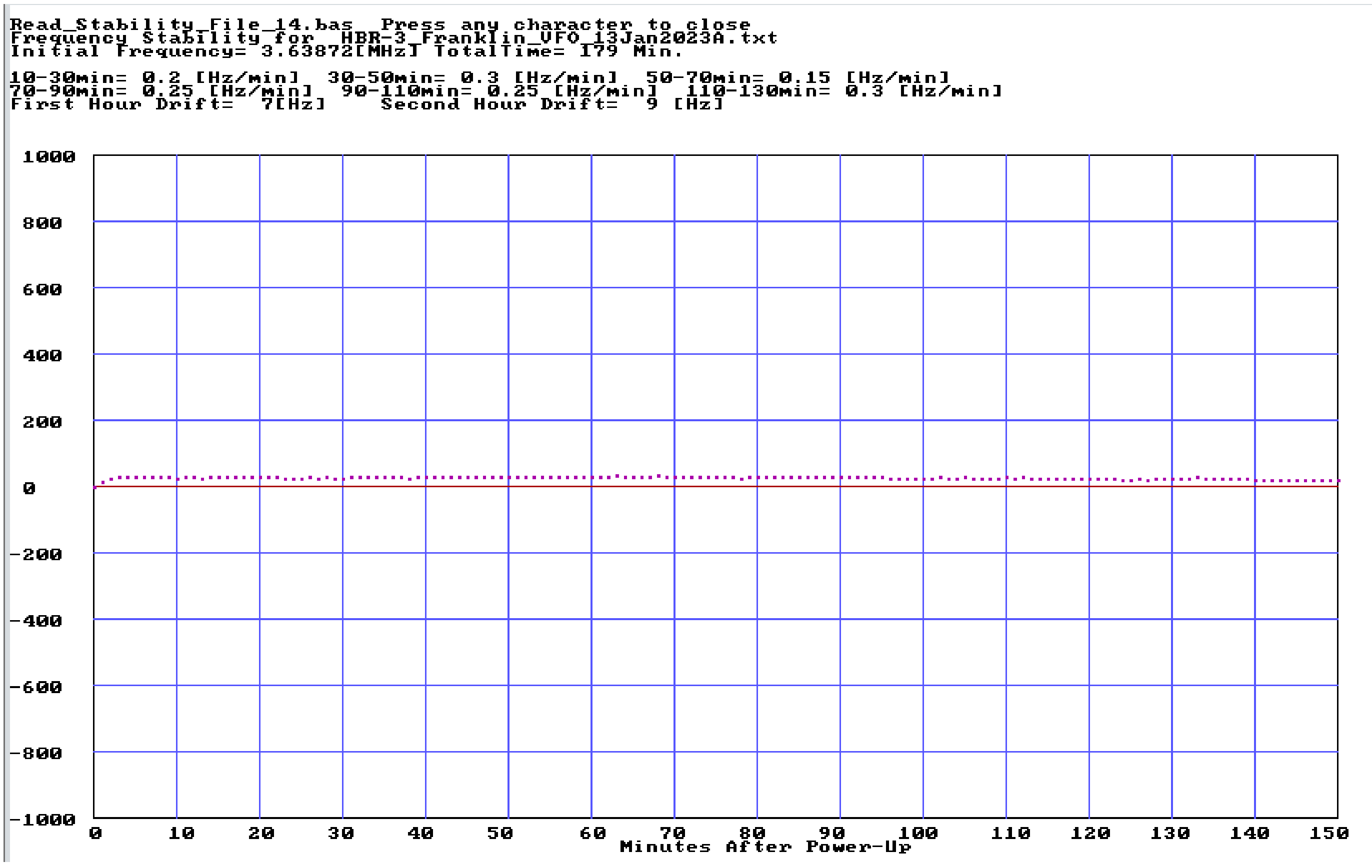
There is some low-frequency roll-off as noted before. This is desirable to reduce LF noise, but not so much to prevent effective use of zero-beating with my own transmitter. This helps when answering someone's CQ call.

Filter peak response is approx ~650 Hz for all settings. From the graph in Appendix D, the filter rejection with respect to the peak response at 2000 Hz is:

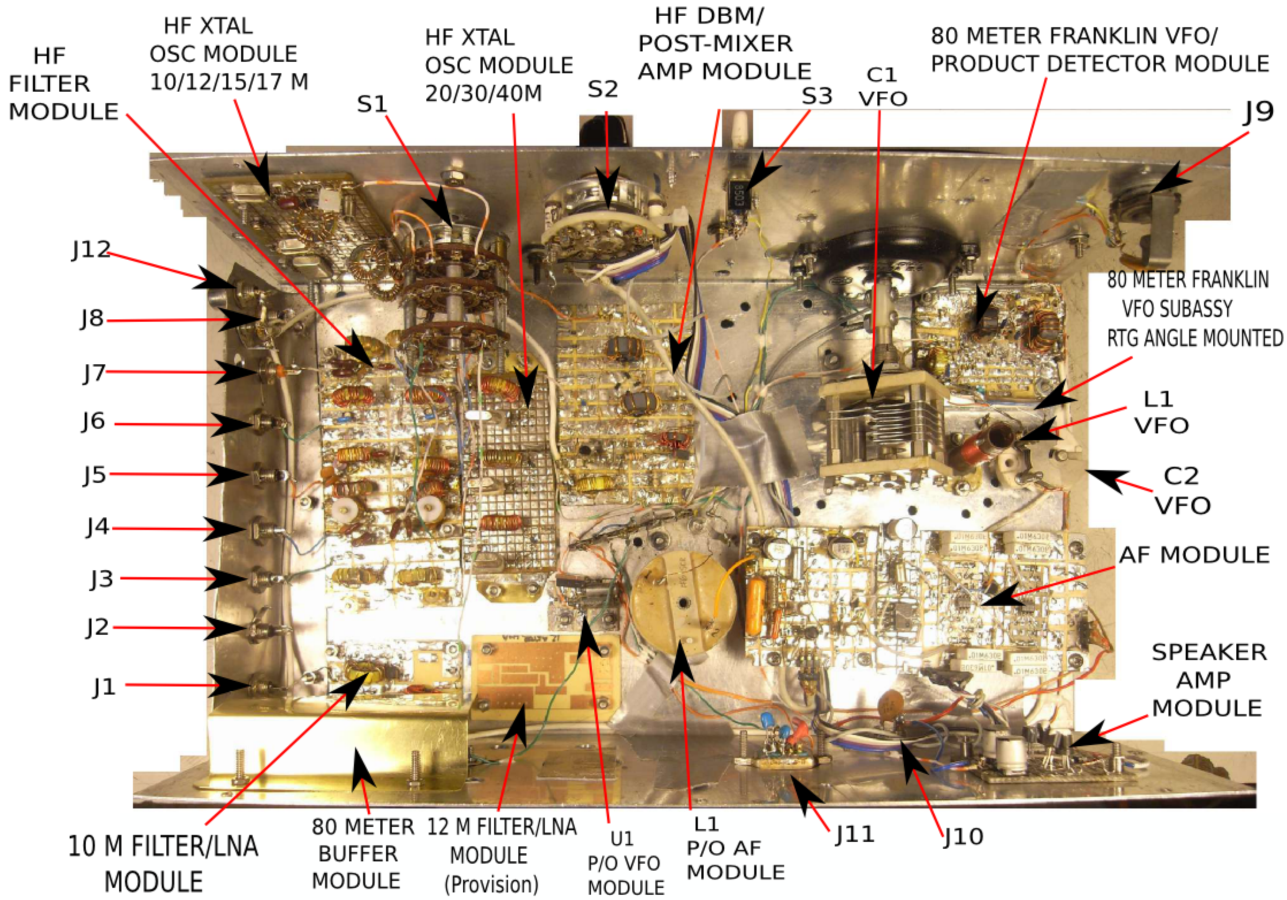
AF FILTER SWITCH POSITION	Approx Filter Rejection with respect to peak response at 2000 Hz:
1	-10.9 dB
2	-33.9 dB
3	-56.8 dB
4	-79.8 dB
5	-102 dB

Appendix E. Franklin VFO Frequency Stability (Measured over 2 ½ hours) .
This graph is measured using a Homebrew Frequency Counter. A homebrew ATE setup uses the counter, serial interface to Arduino UNO R3 which provides USB connection to a laptop running a Freebasic logging program.

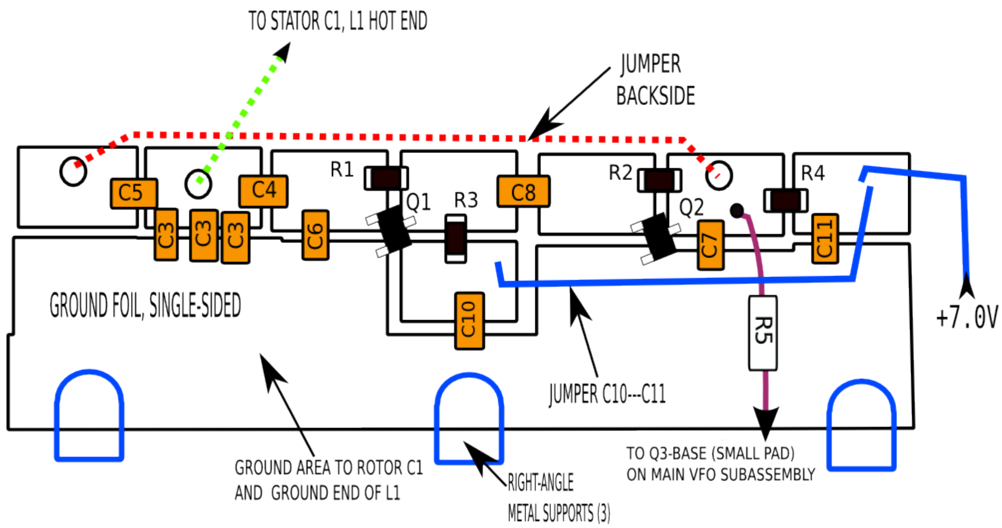
Note: Your results may vary from mine, depending upon component stability and VFO construction.



Appendix F. Internal Photos (Refer to notes below)



Franklin VFO Subassembly Detail. This is right-angle mounted to housing floor.



Notes:

[1] The 80 meter Buffer Module is located as far from the L1 of the Franklin VFO, so as to minimize coupling. Shielding is optional between L1 plus Franklin VFO Subassembly, and everything else. See Appendix A for discussion.

[2] Optionally, a separate subassembly consisting of VFO components U1, R12,R13 and C16-C20 inclusive can lessen the slight heating of frequency-determining elements. This is also optional, not required.

Appendix G. References: This is by no means an exhaustive list. My comments *italicized*.

1) "Direct-Conversion, A Neglected Technique", Wes Haywood W7ZOI and Dick Bingham, W7WKR. QST, November 1968.
This is the paper that launched direct-conversion in the amateur community. The HBR-2 and HBR-3, amongst many others, have their origins in this work. Direct-conversion was neglected for decades until this.

2) Oscillation Circuit, U.S. Patent # 2,028,596 Filed May 19,1930. Charles S. Franklin and Bertram J. Witt.
While I am not saying that this LC oscillator type is inherently more stable than another type, the Franklin seems to enable better stability by employing reduced coupling with the active devices. However, the need for stable frequency-determining components is just as real as for any type. For all parameters such as stability, power output, phase noise, etc still require design attention to obtain the desired performance.

3) "Mixers: Part 2 Theory and Technology" Bert Henderson, Watkins-Johnson RF Signal Processing Components, 1985.
This paper defines Classes and Types of Diode Mixers, and more. There are several other mixer-related papers authored by Bert Henderson.

4) Electronic Filter Analysis and Synthesis, Michael G. Ellis, Sr. 1994. Artech House.
All the math you need for writing your own filter design programs. Good for understanding VCVS type filters such as Sallen-Key and other filter topologies.

5) Active-Filter Cookbook, Don Lancaster, 1975, Howard W. Sams & Co.
Also a great reference on the topic, less theory but more directed toward applications.

6a) RF Applications, Catalog 3, Issue E, Micrometals Inc
Practical RF Data on wound toroids. Get to know how to best use their toroids and the limitations.
6b) Q Curves For Iron Powder Cores, A Supplement to Catalog 3, Micrometals Inc.
Practical RF Q Data for same.

7) Solid-State Design for the Radio Amateur, Wes Haywood W7ZOI, Doug Demaw, W1FB 1977, ARRL.
Along with ARRL's EMRFD and Introduction to Radio Frequency Design, a most valuable trio of texts.

8) The ARRL Handbook, ARRL
Still the one.