mcVx
Microwave IF Transceiver

(**m**ighty **c**heap **V**HF e**x**citer)

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Microwave Transverter IF

- Typical IF frequency: 2 meter ham band
  - 144 ⇔ 5760, 10368, 24192, etc
  - A couple of MHz tuning range will do
  - Only need/want ~1 mW of Tx drive
    - Often use a QRP (<5W rig) with 30-40 dB power atten
  - Rx NF not super critical
- All mode (CW, SSB, FM, digital) transceiver
  - Low 12V power consumption
  - Portable, small, self contained
  - (Very) “nice to haves”:
    - A good selection of IF and AF Rx filters (various SSB, CW, FM, digimode)
    - Digital mode interface
    - Built in CW keyer

Classic Solution

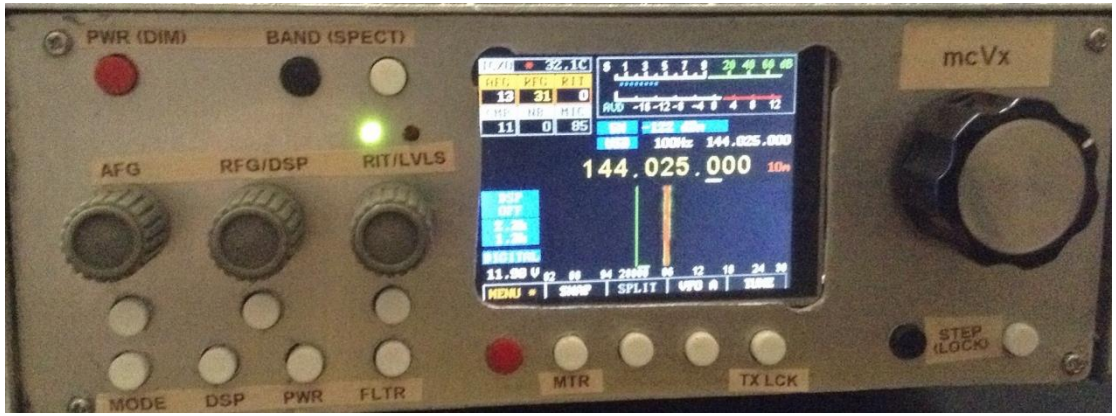
(off the shelf)

- **FT-817** does the job ($780 assembled)
  - 160M-70cm all mode QRP (5W)
    - Need to attenuate tx out by 30-40 dB
  - 2.4 kHz Rx filter (300 or 500 Hz CW for +$$$)
  - NB, but no NR or AF peaking filter (no DSP)
  - Serial CAT for rig control
  - Mono mic/phones analog audio I/O
    - Need to add something like a Rigblaster for digital modes
  - ~ 1.5”, 3 line, 12 char LCD display (i.e., no panadaptor)
    - NB: Can hack a basic panadaptor using dongle & mobile device, extra $$$

Modern Solution

(off the shelf)

- (**KX3+2M**) + **PX3** ($1875 kit , $2055 assembled)
  - **KX3:** 160-6M all mode QRP (10W)
  - **+ 2M** option module (3W) inside KX3
    - Need to attenuate tx out by 30-40 dB
  - DSP IF filters (wide selection) & PBT
  - DSP NB, NR, AF peaking
  - Serial or USB CAT for rig control
  - Analog line i/o for digimodes (mono & IQ, Rigblaster, lotsa wires)
  - ~5” monocolor LCD display for control
  - **PX3:** Panadaptor (second box, more wires)
    - ~ 5” color TFT spectrum/waterfall display
    - 450 point resolution; span = 200 kHz max, 2 kHz min



Homebrew Solution

(some assembly required ☺)

- **mcVx** = **mcHF + miniverter** (~$350 kits/homebrew)
  - mcHF: 80-10M all mode QRP (5W)
  - DSP IF filters (wide selection) several PB center options
  - DSP NB, NR, AF peaking; Tx audio compression
  - USB CAT for rig control, and same cable has …
  - USB ‘built-in soundcard’ audio for digimodes (mono & IQ)
    - also analog line IO (mono & IQ, if you insist on having lotsa wires)
  - 2.8” color TFT LCD (shared control & panadaptor)
    - Touch screen
    - Larger (3.2”.. 5”) display options
  - Panadaptor (extra box, ~2x total size, more wires)
    - TFT spectrum/waterfall display uses about 40% of TFT LCD
    - 256 point resolution; span = 48 kHz max, 1.5 kHz min

- **W1GHZ Miniverter-F** (2M ⇔ 10M, ~ 5mW)

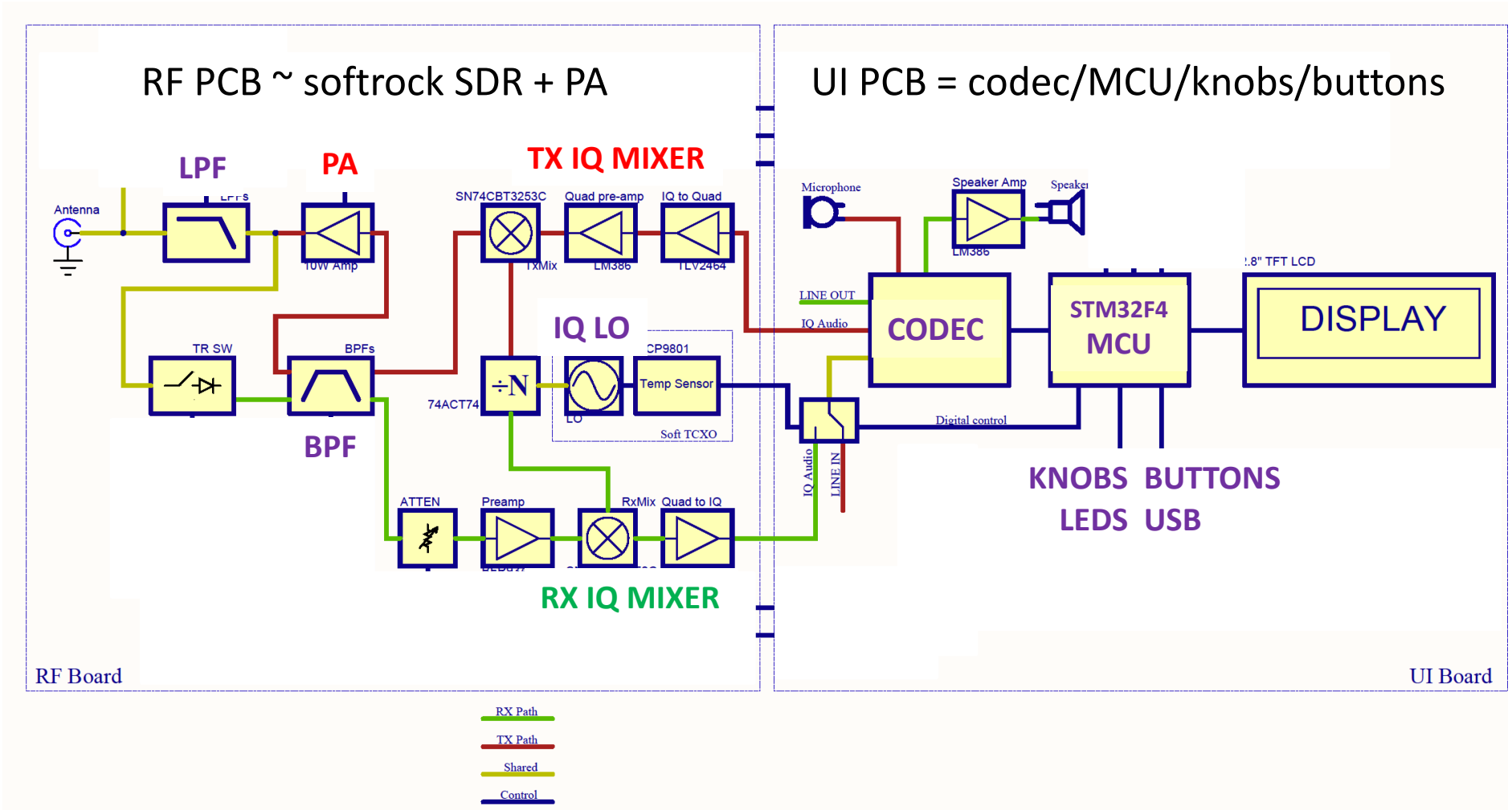
mcHF Project

(mighty cheap HF transceiver)

- Google “mcHF sdr” ---> www.m0nka.co.uk
- Standalone QRP HF SDR kit
- Chris, M0NKA; started project circa 2012
- Inspirations/sources:
  - Softrock40 QRP Direct Conversion SDR (“PC soundcard”)
  - STM32F4 ARM MCU & Wolfram CODEC replace the PC
  - KX3 like form factor (thru rev 0.6)

- Design blog & downloads, HW order @ www.m0nka.co.uk
- M0NKA mcHF Yahoo Group formed in 2014:
  - Builder/user community
  - Discuss, enhance, “how to”, cries for help, photos, mods …

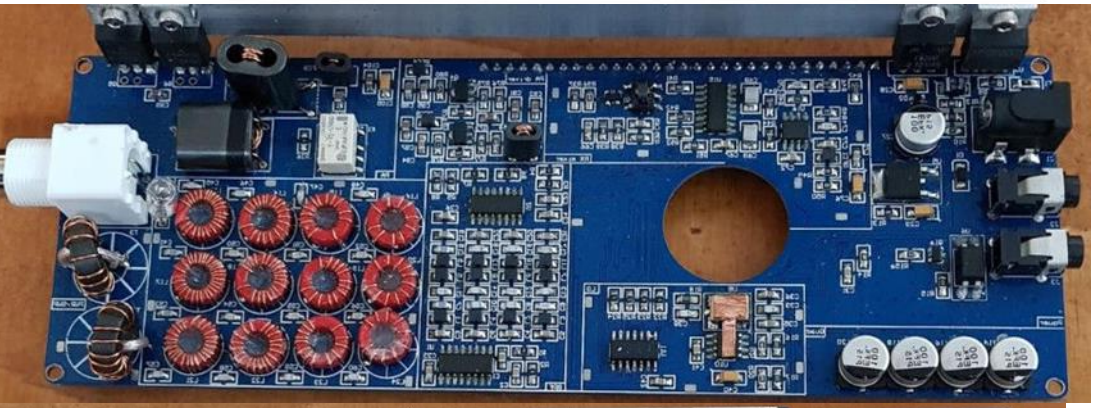
mcHF Block Diagram



Quadrature Switching Detector Dir Conv / Low IF SDR (KX3 architecture is very similar)

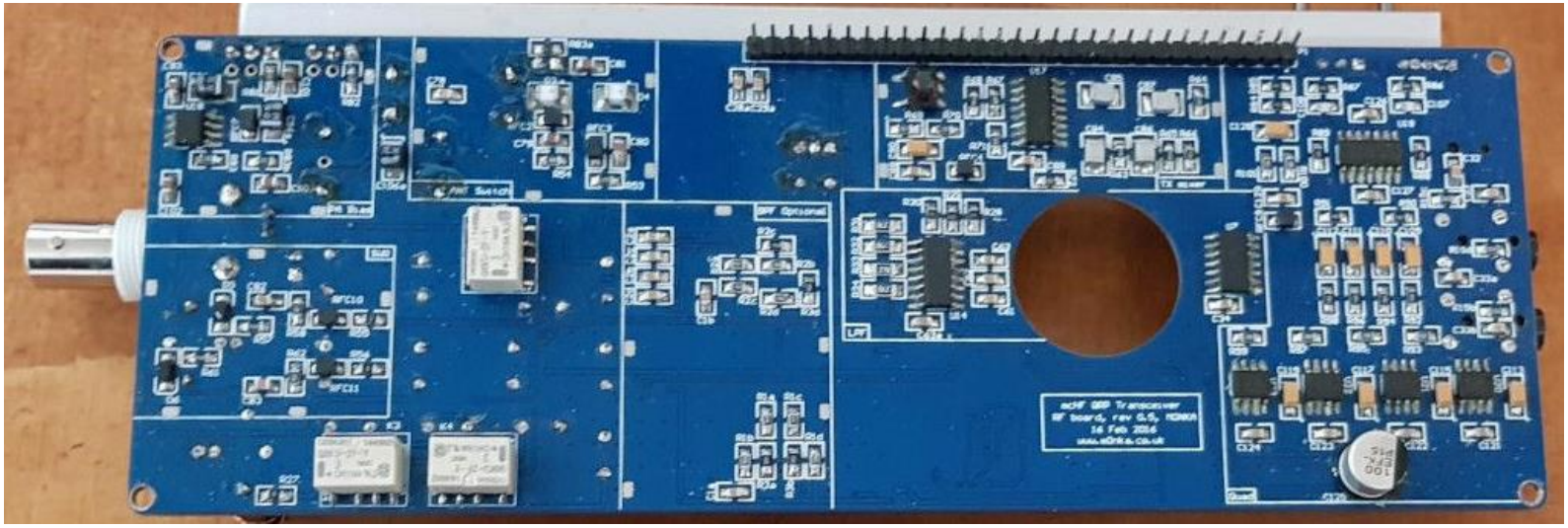
mcHF Hardware

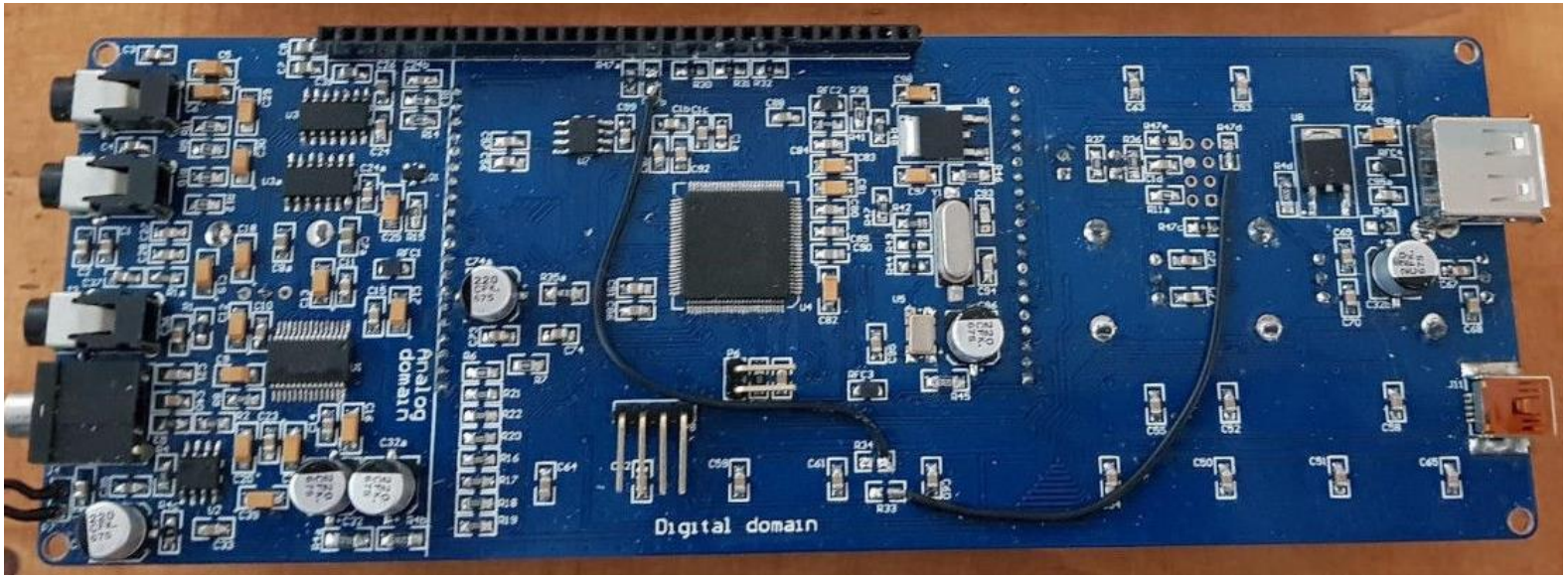
eBay enclosure
(Poland, China, etc)



RF PCB
Si570 LO, Power Supplies
Rx QSD Mixer, Preamp
Tx QSE Mixer, PA
4 BPFs, 4 LPFs

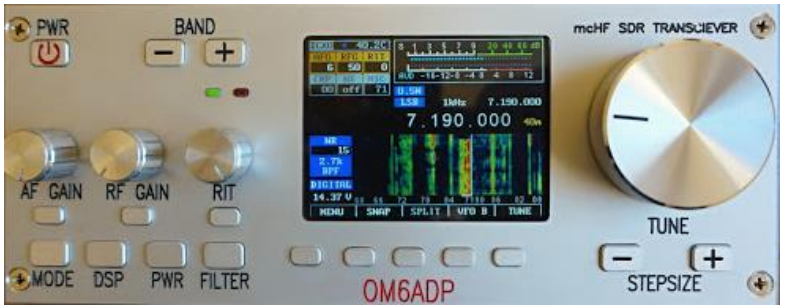
UI PCB
4 Rotary Encoders, 17 Buttons, 2 LEDs
STM32F407 ARM MCU (FP, DSP)
WM8731 Audio Codec, 2 USB
Line In/Out, Mic, Phones/Speaker




Analog domain
Digital domain

mcHF Hardware Versions

- Original two board “KX3” form factor:
  - 2.8” TFT w/touch screen
  - Rev 0.3-0.4 were reworked with fixes, etc (sold as bare boards)
  - Rev 0.5 (late 2015) incorporated all rework (sold as bare PCB or SMD assembled PCB)
  - Rev 0.6 (late 2016) moved Tx preamps (sold as PCB or SMD assembled PCB, now parts kit)
- Rev 0.6 & earlier mcHF enclosure:
  - M0NKA files to 3D print your own enclosure
  - Several metal enclosure eBay vendors
  - Bend and cut your own



- New three board “Sangean/Sony” form factor:
  - Rev 0.7 (early 2018), new FF, 3.2” TFT (sold as bare PCB or SMD assembled PCB, sold out?)
  - Rev 0.8 (next year?), blog teasers: 5” TFT
  - M0NKA selling an enclosure, some knobs on side

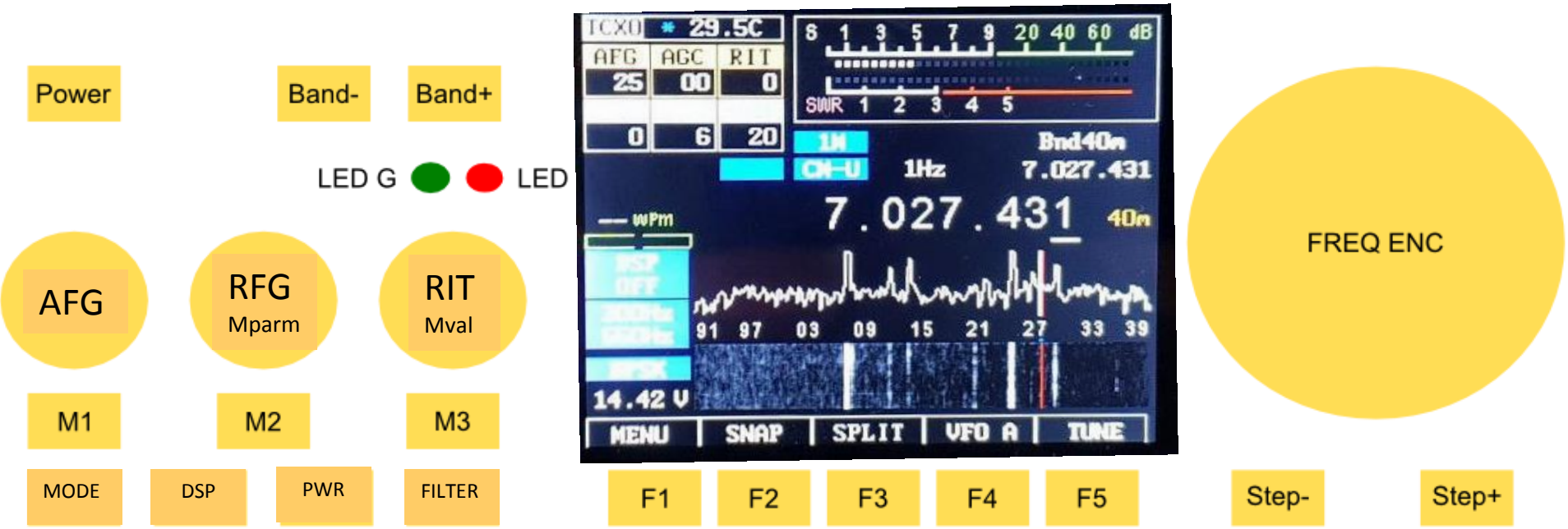
- 0.5, 0.6, 0.7 release packages & change notes

  on Downloads page @ www.m0nka.co.uk

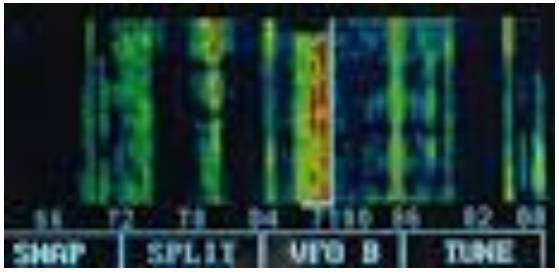
Software…the Soul of mcHF

- 1st Gen: Chris, M0NKA
- 2nd Gen: Cliff, KA8OEI
  - Added waterfall display, FM, user manual
  - src, bin, user man @ m0nka.co.uk (0.219.26.4, last rel)
- 3rd Gen: Andreas, DF8OE, et al
  - Google “UHSDR Wiki” (doc) and “UHSDR github” (code)
  - Many (sometimes daily) releases (now 2.8.0); I’m using 1.2.0, Aug 2016
  - More filters, spectrum zoom, touch screen, better NB/NR, USB CAT/audio
  - More modes: FreeDV, CW keyer/decoder, PSK, RTTY
- All run on 0.5-0.7 mcHF HW and also on reworked 0.3-0.4
- 3rd gen also runs on several other platforms (OVI40, etc)
- Source code available for custom mods and enhancements

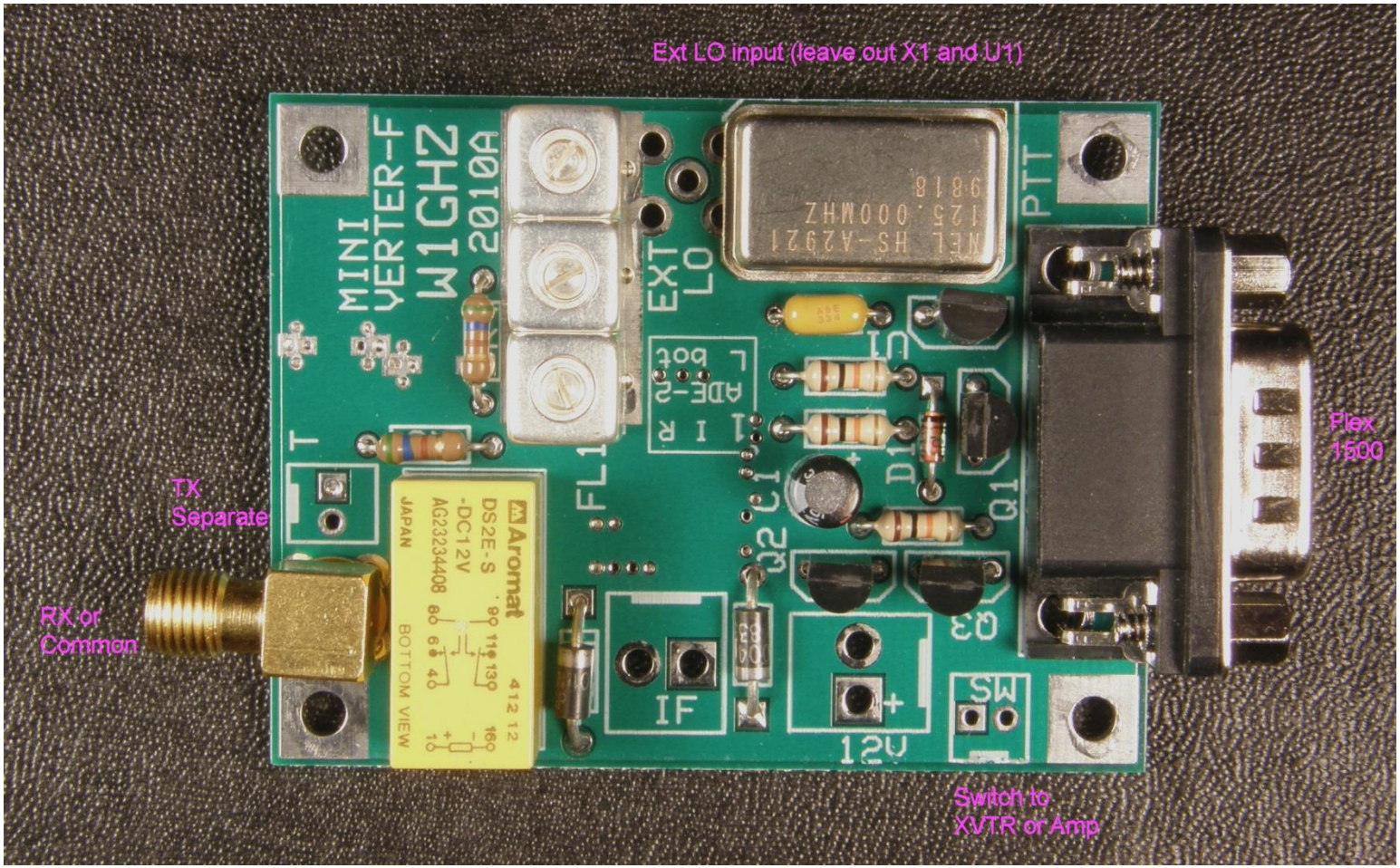
mcHF User Interface



SPECTRUM SCOPE
AND/OR
WATERFALL DISPLAY



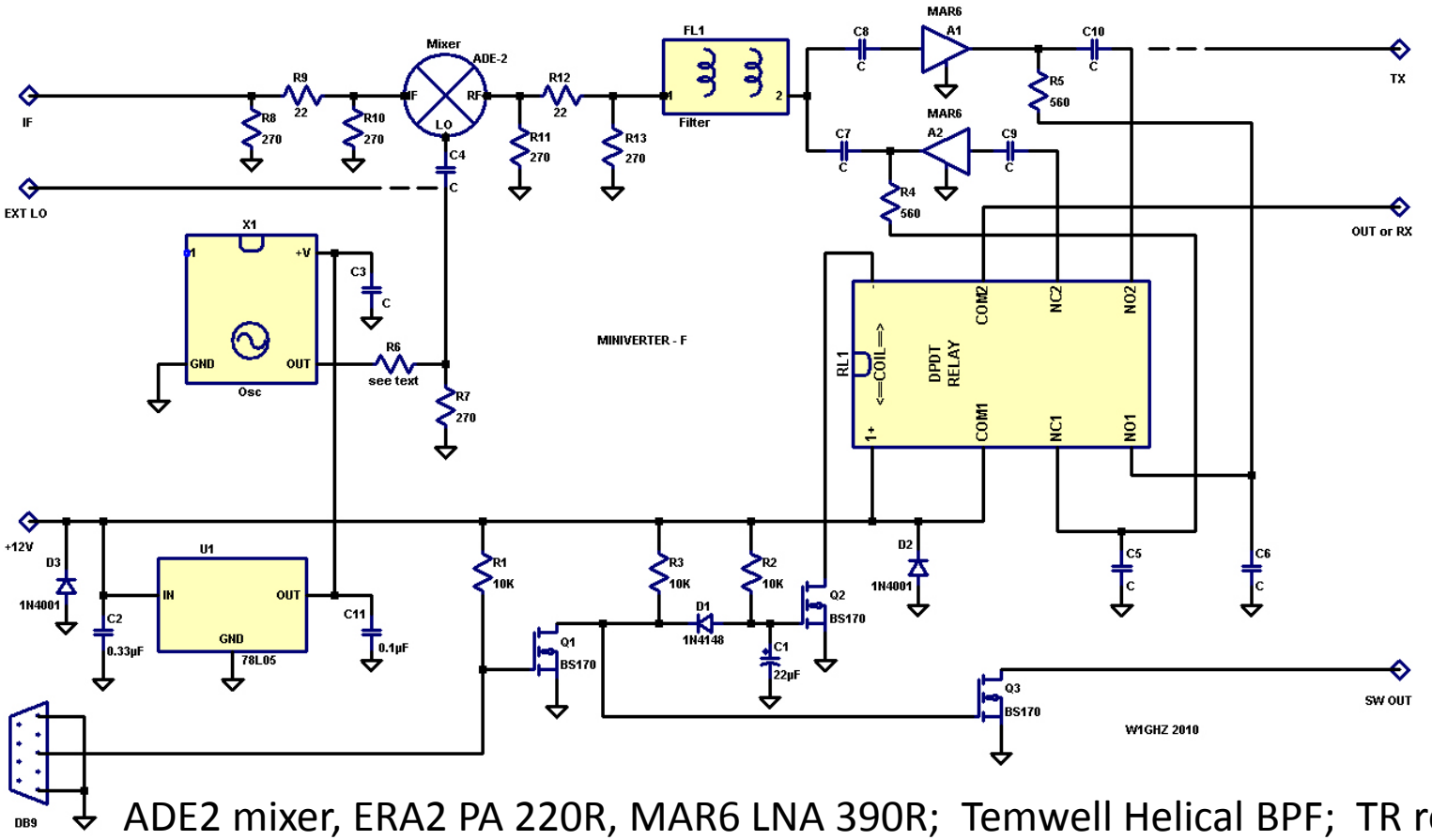
W1GHZ Miniverter-F



Bare PCB from W1GHZ; Writeup on his Small Projects website

W1GHZ Miniverter-F

28 MHz <-> 144 MHz

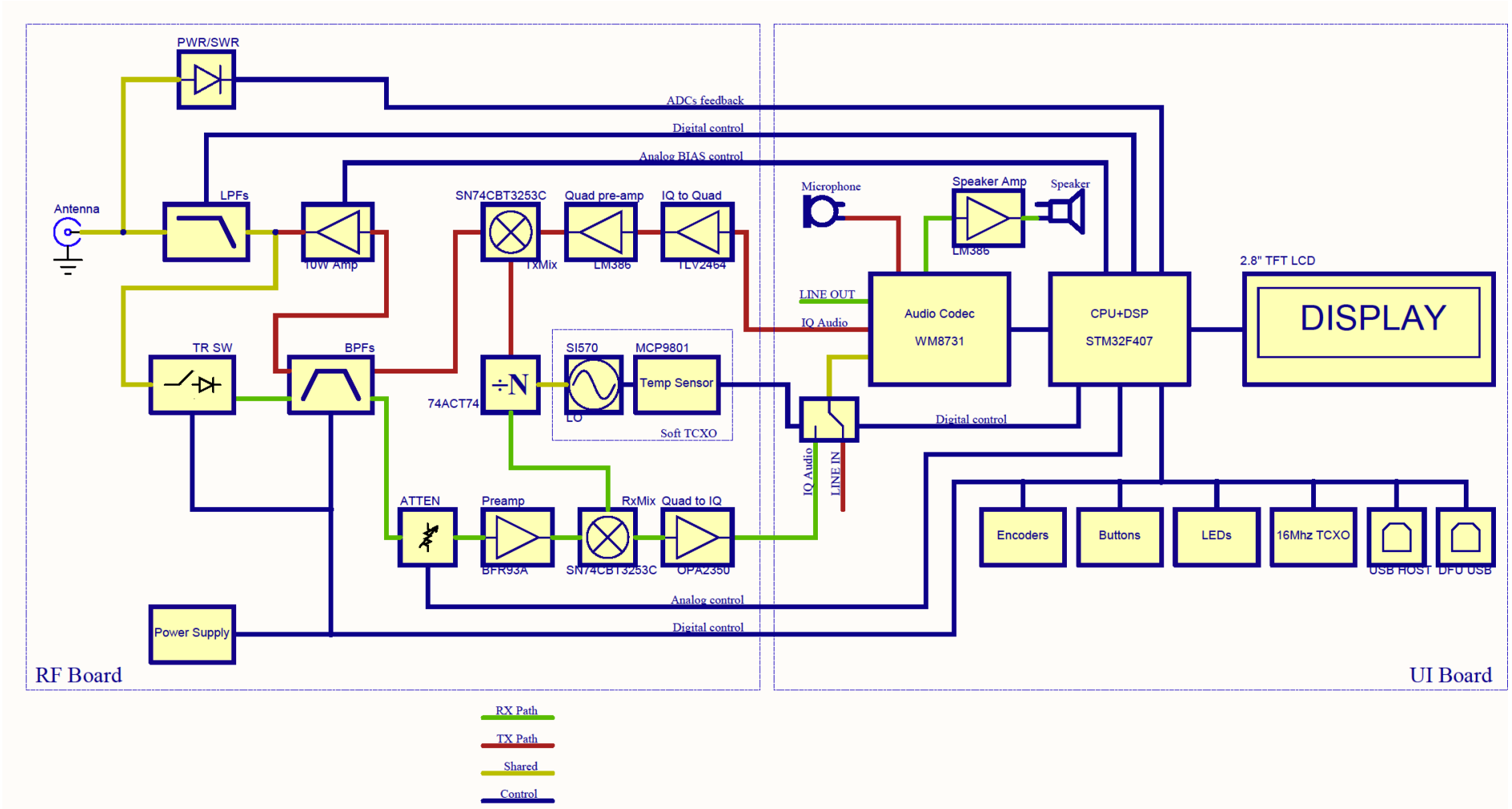


ADE2 mixer, ERA2 PA 220R, MAR6 LNA 390R; Temwell Helical BPF; TR relay

Conversion gain ~0/7 dB Rx/Tx P1dB ~10 dBm Rx NF ~2.3 dB, -7 IIP3

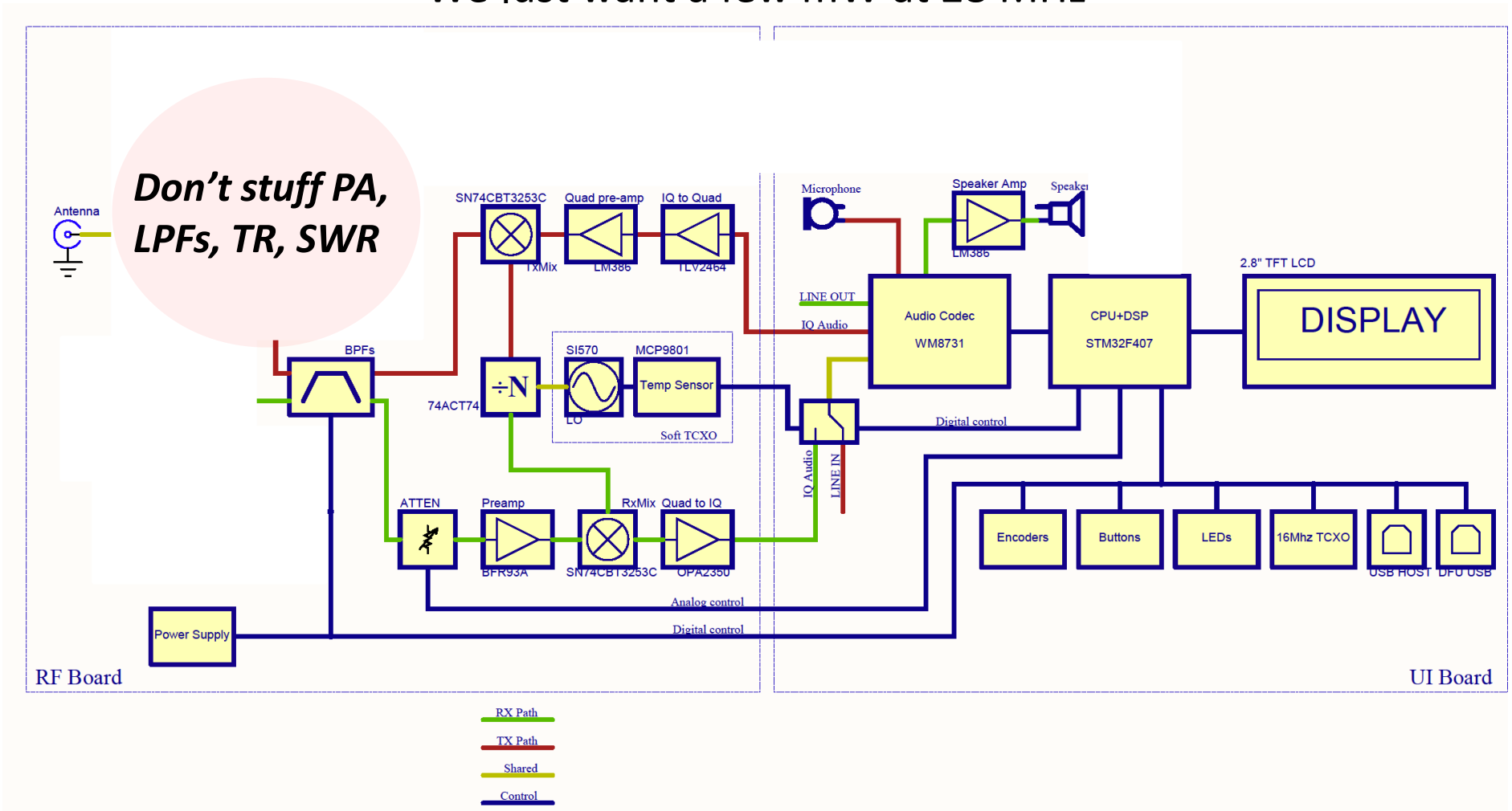
I modified PTT logic for T/R sequencing so that mcHF PTT out keys uwave xvtr, then uwave xvtr TxInhibit (817 style) activates miniverter TR relay Tx

mcVx = mcHF …


PWR/SWR
ADCs feedback
Digital control
Analog BIAS control
Antenna
LPFs
10W Amp
SN74CBT3253C
TXMix
Quad pre-amp
LM386
IQ to Quad
TLV2464
Microphone
Speaker Amp
LM386
Speaker
2.8" TFT LCD
DISPLAY
LINE OUT
IQ Audio
Audio Codec
WM8731
CPU+DSP
STM32F407
TR SW
BPFs
74ACT74
÷N
SI570
LO
MCP9801
Temp Sensor
Soft TCXO
Digital control
IQ Audio
LINE IN
ATTEN
Preamp
BFR93A
RxMix
SN74CBT3253C
Quad to IQ
OPA2350
Encoders
Buttons
LEDs
16Mhz TCXO
USB HOST
DFU USB
Analog control
Digital control
Power Supply
RF Board
UI Board
RX Path
TX Path
Shared
Control

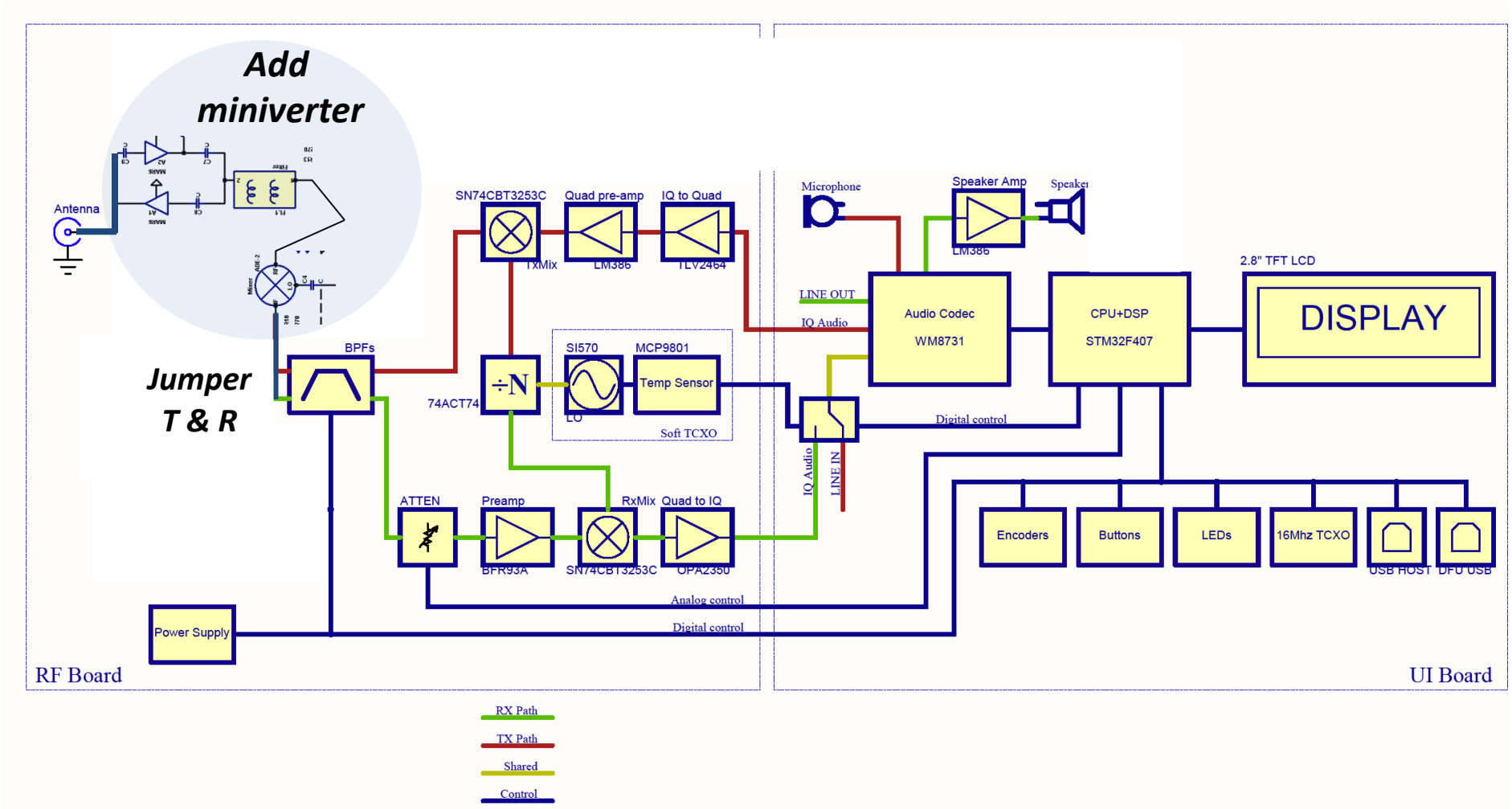
mcVx = mcHF – PA …

We iust want a few mW at 28 MHz



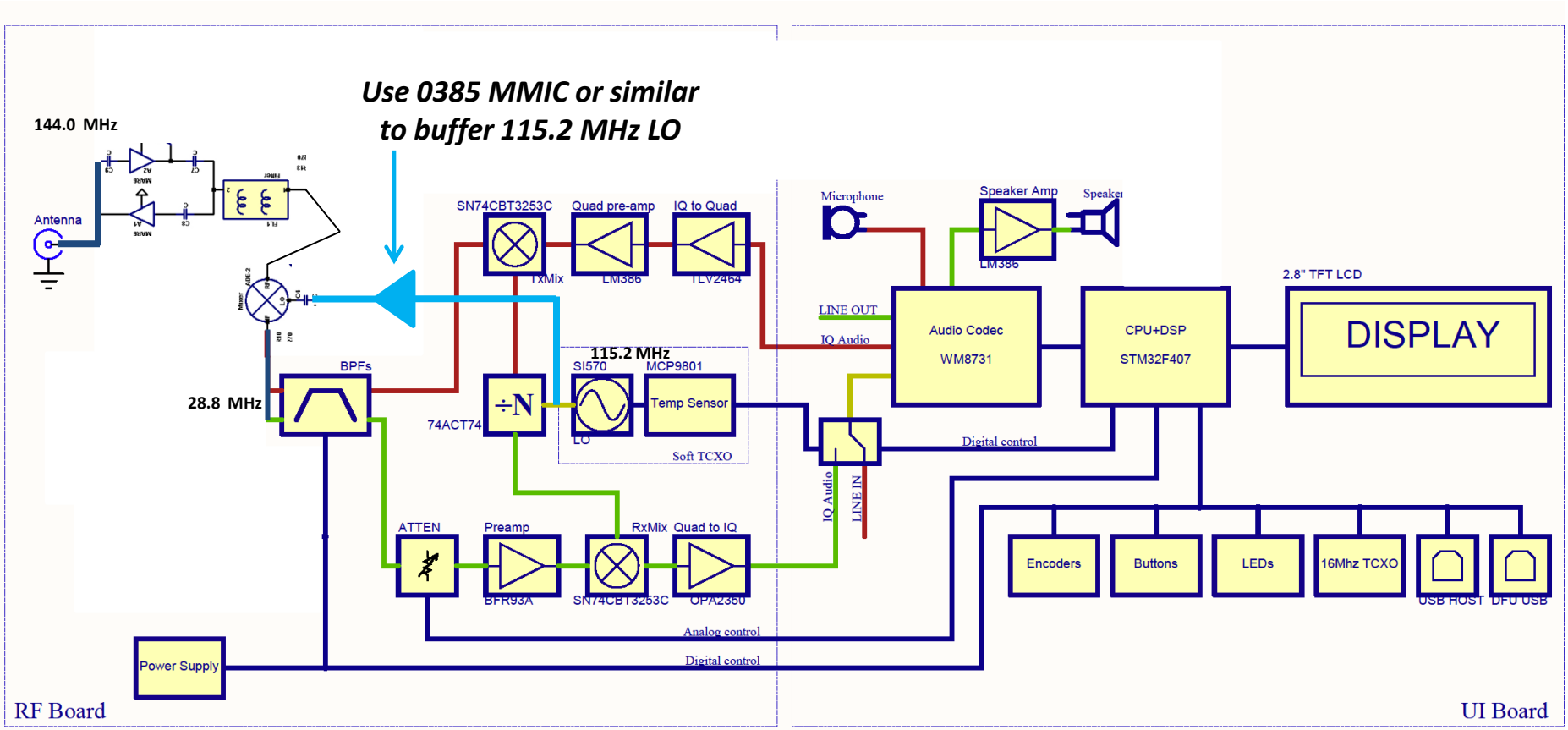
mcVx = mcHF – PA + miniverter …

We just want a few mW and fair NF at 144 MHz



mcVx = mcHF – PA + miniverter + LO buffer

Buffer a copy of the mcHF LO; it runs at 4x our IF freq (quadrature LO for mixers)



115.2 MHz LO div by 4	= 28.8 MHz IF	(1x IF)
Buffered LO	= 115.2 MHz LO	(4x IF)
2 Meter RF signal	= 144.0 MHz	(5x IF)

One way to get the LO

- I buffered & shared the existing mcHF LO

  LO varies with IF (4x IF) 115.2 .. 117.6 MHz
  IF is 28.8 .. 29.4 MHz
  2M xvtr tunes to 5xIF 144.0 .. 147.0 MHz (Temwell BPF)

  – mcHF LO is already temperature compensated by software

  – mcHF software calls this 5x transverter mode

  – mcHF works better with 6 (or 12) KHz low IF in software
  – So, we add a 24 (48) kHz LO offset to correct for the low IF (x4)

- *Because of limited number of mcHF codec outputs, CW Tx (only) uses ZIF…*
- *so there is a shift of 24 (48) kHz on CW Tx freq in 5x xvtr mode …*
- *until I can fix the SW, I use a Tx split freq (up 24)*

Another way to get the LO

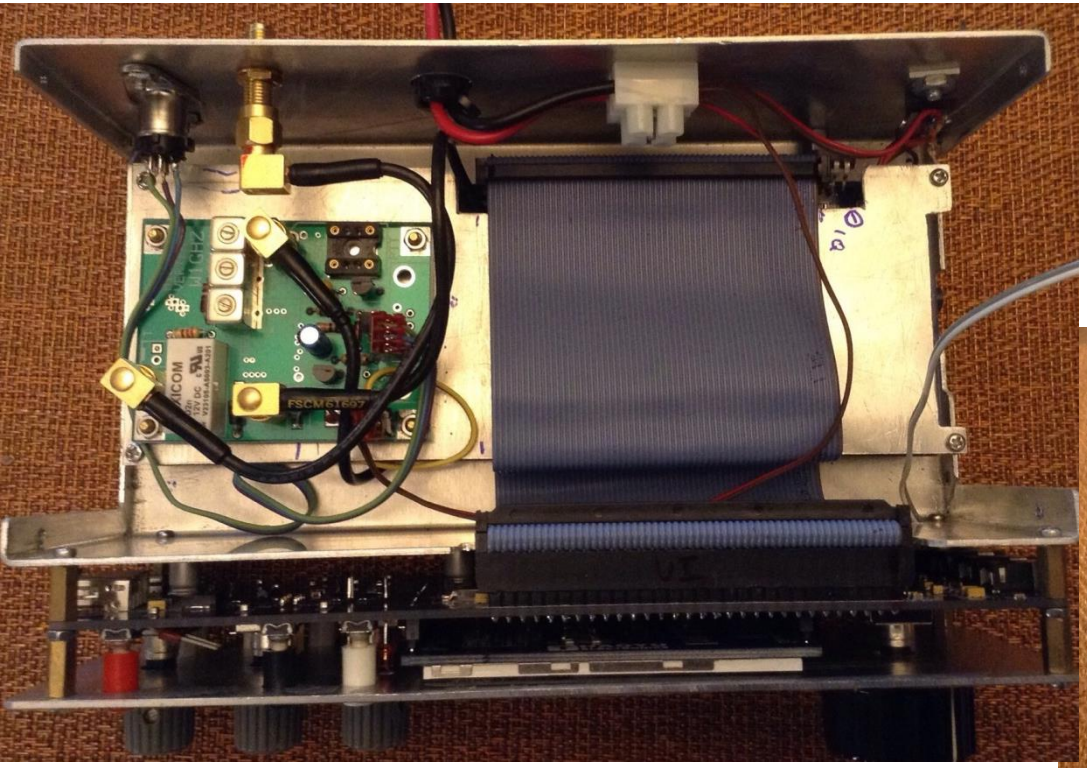
- Add a separate 116.0 MHz oscillator

LO fixed at 116.0	116.0 .. 116.0 MHz
IF is	28.0 .. 29.7 MHz
2M xvtr tunes IF+116	144.0 .. 145.7 MHz

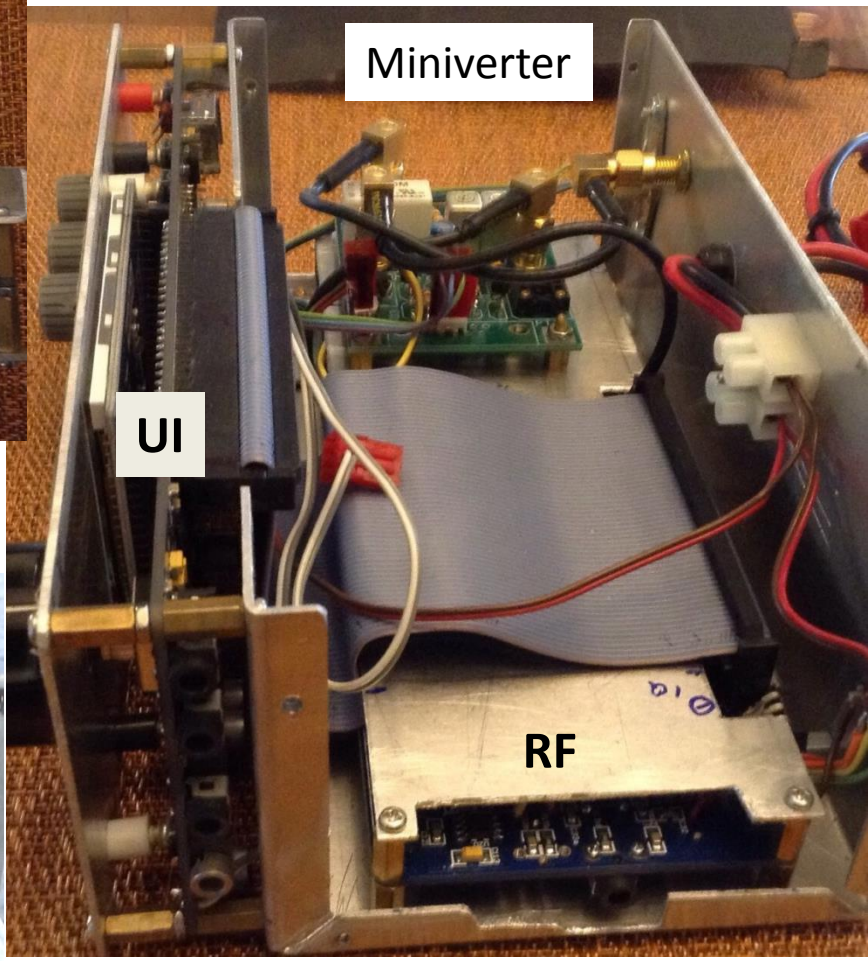
mcHF software calls this 1x xvtr with 116 MHz offset

- *No CW Tx shift bug with this approach*
- *But need a second stable LO @ 116.0*
- *…and Tx range limited to 1.7 Mhz by mcHF SW (10M band)*

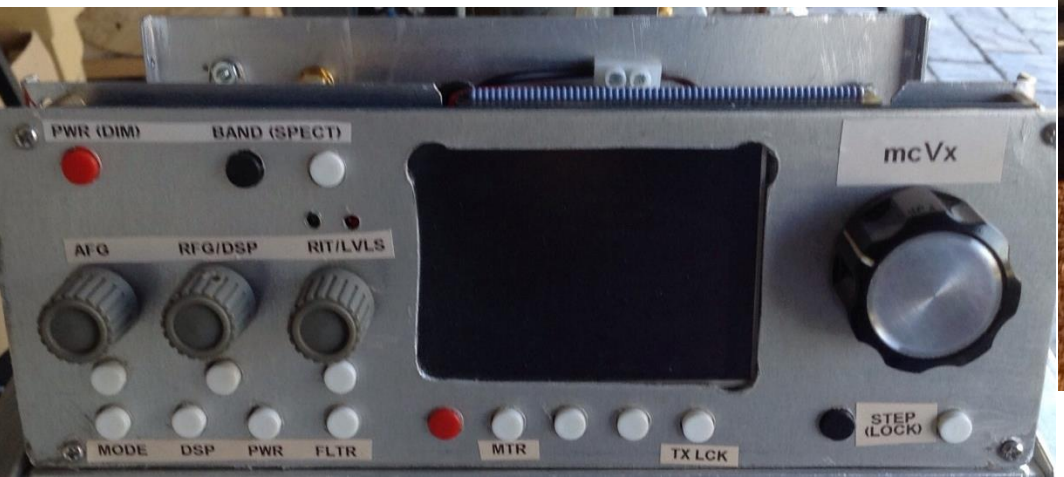
Rear: power, antenna, “817” ACC (PTT out, TxInhibit in)



mcVx Enclosure



Shield RF board & miniverter from UI board’s digital noise



Side panel: mic, ear, line i/o, key

Results

- Works well as a microwave IF
  - Small, standalone, cheap, low power consumption
  - Sensitive rx, good selection of filters & modes
  - Panadaptor is very sensitive and very handy
  - Tx spurs (carrier and image) are OK for uwaves
  - Bonus: Can use as selective RF voltmeter
    - With AGC off, linear over 40-50 dB (3 dB RFG or 5 dB AFG steps)

- Some Nits
  - Like most LCDs, has some glare & sun issues (hood)
  - CW Tx shift bug (split workaround, or fix HW or SW)
  - “Twin Peaks” codec bug; manual/auto reset in SW
  - Barely enough gain for dyn mic (turn it up to 11), designed for electret mic
  - HW & SW are moving targets

Similar kits *& possible spinoff projects*

- **UHSDR software supports:**
  - **OVI40 German version of mcHF in the works**
  - **One or two Polish mcHF versions/clones**
  - **One or more Chinese clones (RS-918) on eBay (caveat emptor)**
- *ST Micro makes a nice $55 "Discovery" eval board for STM32F749*
  - *Has a 5" higher res color touch screen and similar audio codec*
  - *Add some encoders and buttons to make a UI board replacement*
  - *Add a RF board (see below)*
  - *Would require a port of UHSDR code (or new code) to Discovery board*
- **Some alternative ways to transvert to 2M:**
  - **DEMI 2M xvtrs**
  - **Ukrainian 2M xvtrs**
  - *Lay out a 2M RF board (RF(one band)-PA+miniverter) to use with mcHF UI or Discovery*

Extra mcHF Stuff, too detailed for the talk

- Many folks install a socket (two SIP pin strips) for the LCD, as they have been know to fail occasionally
  - The socket makes the LCD a bit high for some cases; see the Yahoo use group for comments on which cases fit which arrangements; YMMV.
  - I built my own case to avoid that issue… but that mean I needed taller pushbutton switches and longer encoder shafts; I have the Mouser part numbers if needed (I got them from Yahoo group)
  - My buttons have round caps instead of the square 3D printed caps, easy to drill panel holes
- I mentioned that spur suppression may not up to latest FCC HF standards (but more than OK for microwave use)… there are three reasons this may happen (most don't affect mcVx):
  - 17M band 2nd harmonic is not well filtered by the 17-10M BPF/LPF… really should have one more filter bank (this is one thing KX3 did better)… not an issue fror the mcVx single band (10M) application, but maybe for you if you are building an HF rig; similarly, if building an HF rig, be sure to selected a matched pair of PA FETs (matched gate thresholds and IDDq) to minimize even harmonics of push pull PA. None of this matters for mcVx.
  - The undesired QSE mixer sideband (about 12 or 24 kHz away from desired, depending on which offset (6 or 12) is used) is suppressed by careful balancing of I and Q amplitude and phase in software. See the setup menu IQ balancing options. Be sure to do this adjustment (see the Configuration Menu). The balance gets worse as the frequency increases from 80 to 10 meters; in the older software, there was a single balance adjustment (per mode). This meant that the balance should be adjusted for 10M in the mcVx application, for best results. Later versions of the software added two balance frequencies (80M and 10M) and interpolated the balance for intermediate bands, not important for mcVx, but probably helpful for mcHF applications. Latest versions of the software added an 'automatic' IQ balance algorithm (for Rx only). This 'improvement' may be helpful for mcHF. Again, doesn't matter for the single band mcVx application. Just be sure to balance IQ at 10M.
  - Finally, the Tx carrier suppression gets poorer as the frequency increases. At 10M, the carrier was between 30 and 40 dB down, so OK for microwaves, but not quite FCC HF spec… YMMV. This is because the quadrature swicting mixer performance is sensitive to the div by 4 Johnson counter (74AC74, U11 on RF board) speed and edge specs. What some folks do to improve the higher band mixer performace is to substitute a faster '74 part for U11 made by Potato Semiconductor (sold on eBay). This part uses a different power supply voltage, so a wire jumper is needed, too. I haven't tried this mod, but it sounds good… lots of discussion on the Yahoo group, UHSDR wiki, etc. This is (of course) referred to as the "Potato Chip" mod ☺. Again, not important for the mcVx application, but you might consider for HF application.
- Several folks have reported problems with the mcHF polyfuse (F1) not behaving well. I jumpered out F1, replaced with a 3AG in line fuse on the power cord (that also fuses the miniverter).

Extra mcVx Stuff, too detailed for the talk

- Expanding on the brief notes I wrote under the miniverter schematic:
  - I used a different MMIC (ERA2) for the tx amp, to get a bit more gain and max power out
  - I rewired the PTT circuitry … I took the PTT out from the mcVx to an FT817-style "accessory jack" (same DIN conn, same pinout, PTT and Tx Inhibit signals).
  - The PTT out keys the microwave transverter, which holds the Tx Inhibit signal to mcVx active during Rx and in the beginning of Tx, until all stages of the microwave transverter have settled into the Tx state (PA drain supply, antenna relay, etc). Once the microwave transverter is ready to Tx, it releases the Tx Inhibit signal.
  - The Tx inhibit signal goes to D1 (and Q1) of the miniverter, which switches the miniverter relay to Tx state (allowing Tx RF to reach the microwave transverter) only AFTER the microwave transverter has gone to Tx. That's my sequencer.
- There are various pinouts for the Temwell filters
  - make sure that yours matches the W1GHZ PCB layout
- mcHF rev 0.5 RF board mods for common IF connection to miniverter:
  - DON'T wind/install L13-24 (LPF), K1-K4(LPF), T2-T3, T5-T7 (PA and SWR), C81, PA FETs
  - Remove RFC5, RFC6 (PA driver power supply) and U18 (PA bias) to cut PA power supplies
  - DO install T1 (RX mixer) and T4 (Tx mixer)… IIRC these are the only "nonSMT" parts that I had to install on the RF board (that came with only SMT parts already assembled)
  - Jumper PA_TXIN (pin 6, T5) & RX_ANT (C81)… the common 28 MHz IF to the miniverter.

Extra mcVx Stuff, too detailed for the talk

- I buffered the mcHF's Si570 LO (U8 on RF board) to provide the correct LO drive level (+10 dBm) to the miniverter's ADE-2 mixer
  - For my board, using parts from my junk box, that meant a blocking cap connected to pin 4 of U8, followed by a 220 ohm series level set resistor to an old MSA0385 MMIC mounted on one of WA5VJB's MMIC amp PCBs. I used two 51 ohm resistors in series for the drain bias, then some bypass caps, then a 100 ohm dropping resistor, this whole mess drew ~35mA from +12 volts tapped off of the RF board.
  - Also note, several short ground paths from the MMIC board to LO (C38, C36, R49) and a short RF tap from LO pin 4 (R18)