Challenges of SSB

The development of the QSX All-mode HF transceiver kit

QRP ARCI FDIM seminar

Thursday 16-May-2019

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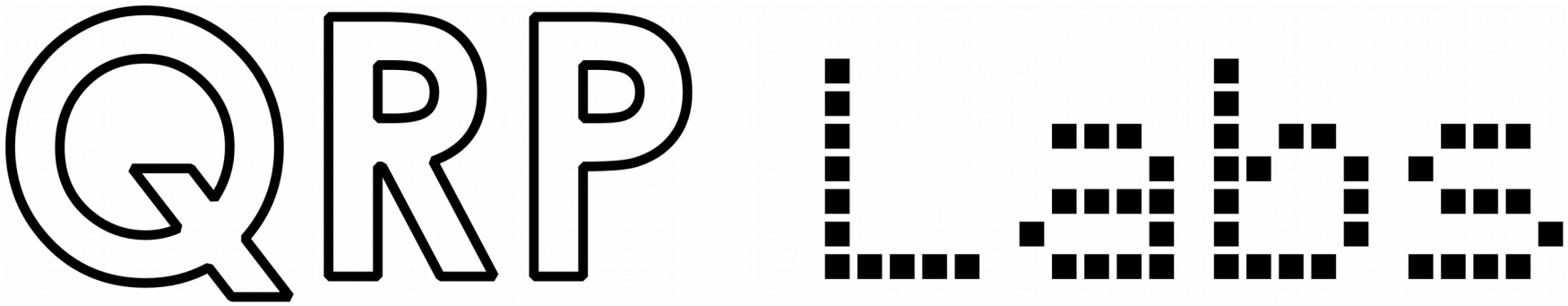


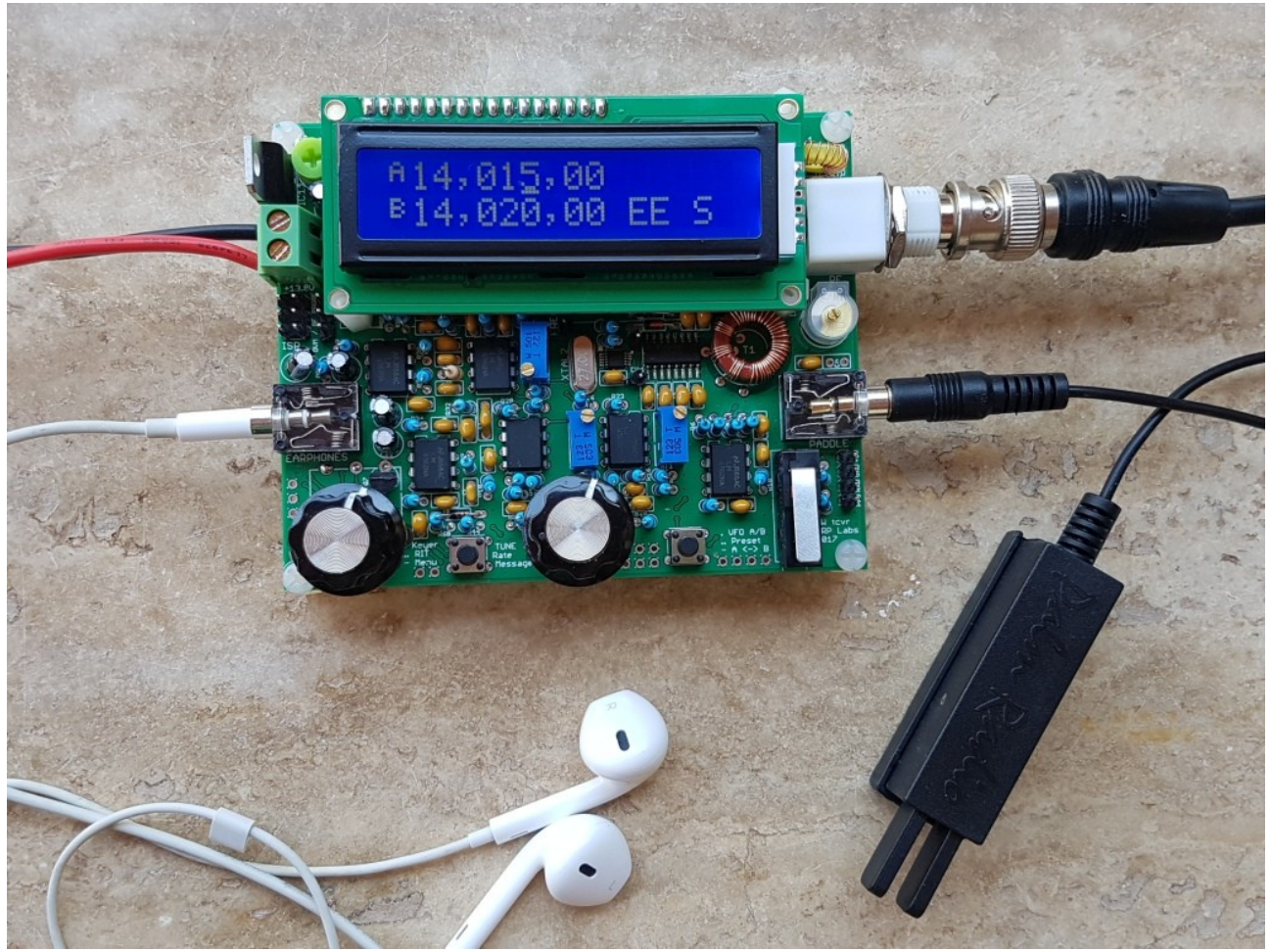
http://qrp-labs.com

QSX transceiver kit

- **Q**RP Labs **S**SB/CW **X**cvr
- Introduced at YOTA 2018 summ buildathon in S.Africa
- Still under development
- AIM:
  - Very high performance HF transceiver
  - 160m to 10m, all-mode, 10W
  - Very low cost
  - Tons of features
  - Easy, fun and education to build and use

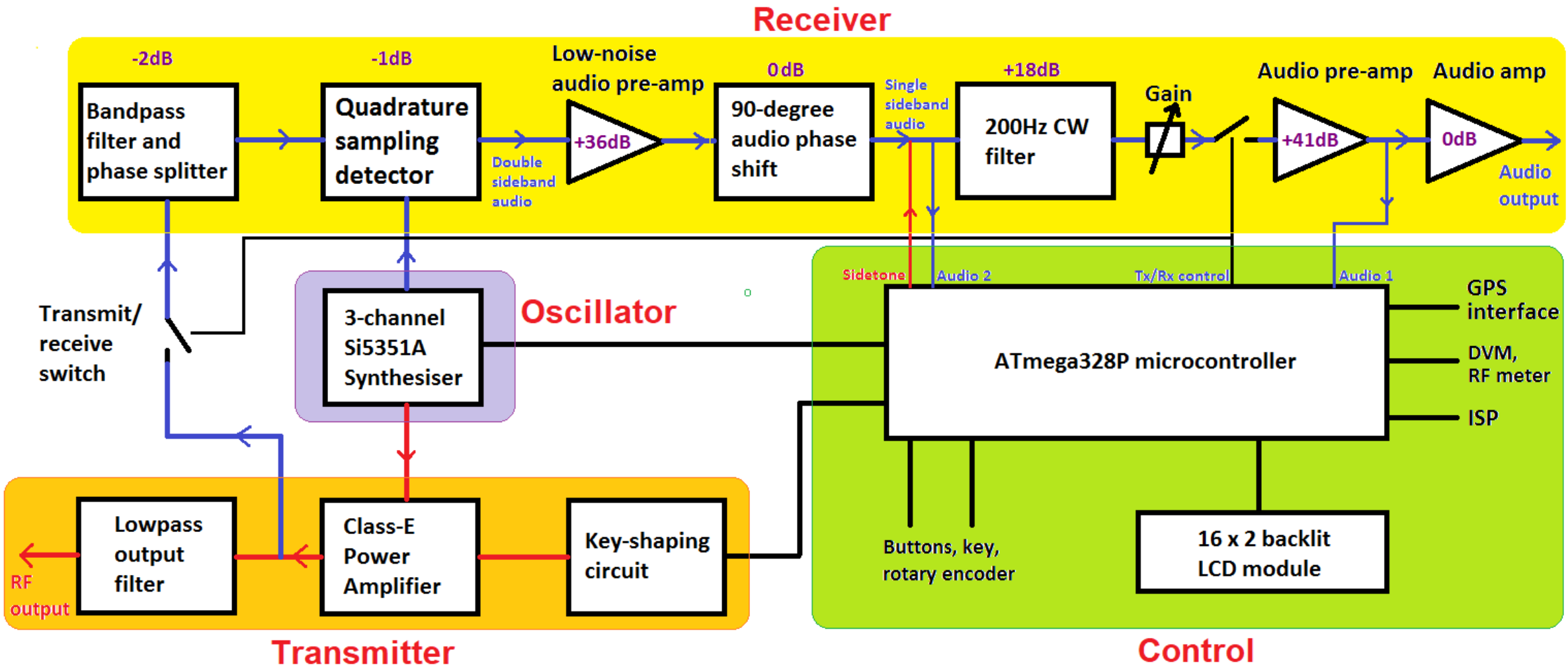
QCX 5W CW transceiver kit

- **Q**RP Labs **C**W **X**cvr
- Introduced at YOTA 2017 summercamp buildathon
- Since 21-Aug-2017, 7,230 kits shipped
- Mono-band CW transceiver with high performance, built-in test equipment, and loads of features



Transceiver architecture

- This is the old QCX 5W CW architecture… a good starting point for SSB?



Problems adapting that for SSB

Receiver:

- Audio phase shift must be wideband and accurate
- We're going to want AGC
- Multiple filters, for SSB and for CW and perhaps different filter widths
- More complex Band Pass Filter because we want it to be multi-band

Transmitter:

- For CW, the PA is easy (Class C, D, E are all Ok)… but for SSB we need a Linear – much more complex
- We need a proper SSB exciter, not just an oscillator feeding an amp
- We're going to want Speech processing
- Must handle CW key-shaping too

Software Defined Radio (SDR) to the rescue

SDR replaces some of the blocks of the radio transceiver with Digital Signal Processing by a computer

- Advantages:
  - Lots of flexibility to implement features
  - Software can be updated to easily add new features
  - Cost savings
- Disadvantages:
  - Requires a computer!
  - Requires high performance conversion between digital and analog
  - Digital Signal Processing sounds scary

SDR: solving the disadvantages

1. Requires a computer

- Use an embedded 32-bit ARM processor!
- STM32 series are popular, easy and low cost
- Plenty of processing power, at 168MHz

2. Requires high performance conversion between digital and analog

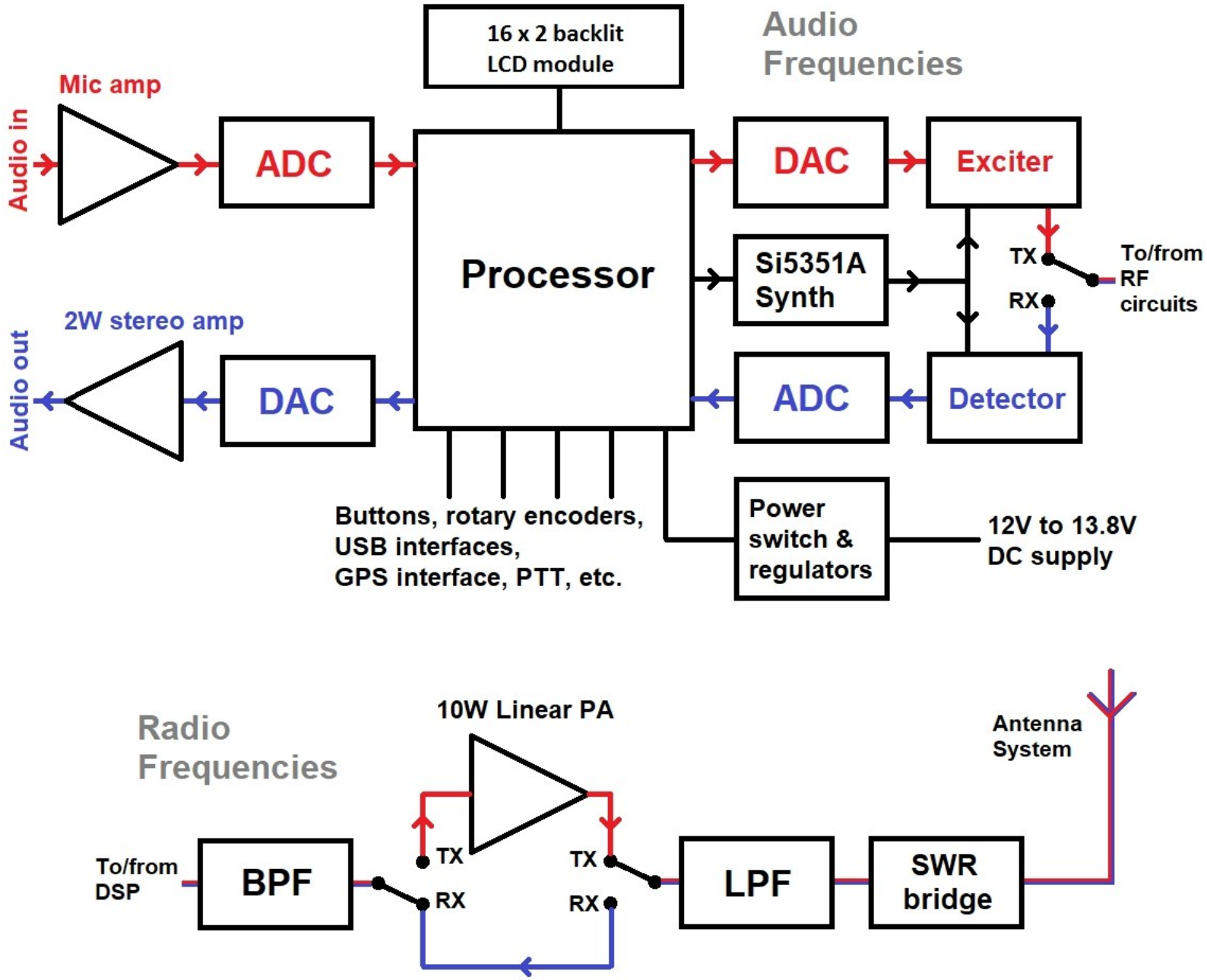
- 24-bit ADC and DAC chips are available
- Cost of Processor an ADC and DAC chip is LESS than the analog circuits they replace
- Some of the conversions can use the built-in 12-bit ADC and DAC in the processor

3. Digital Signal Processing sounds scary

- Lots of examples around the internet!

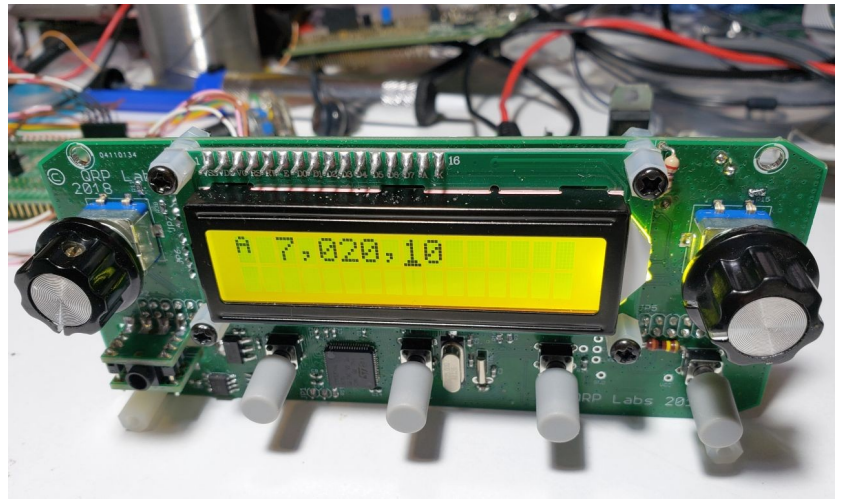
QSX Block diagram

- Key point: the cost of ADC + DAC + Processor is LESS than the analog circuit blocks they replace!



QSX features

- DSP (filters, AGC, Speech compression, noise reduction)
- Built-in test and alignment equipment
- SWR Bridge
- USB A and USB B connectors
- Paddle input for CW (built-in IAMBIC keyer)
- WSPR and QRSS modes beacon mode included



- GPS interface for frequency and time discipline, and beacon modes
- RJ45 connector for Kenwood/Yaesu style microphones
- Realtime clock (CR2032 battery holder)
- 10W power output CW, Digital or SSB

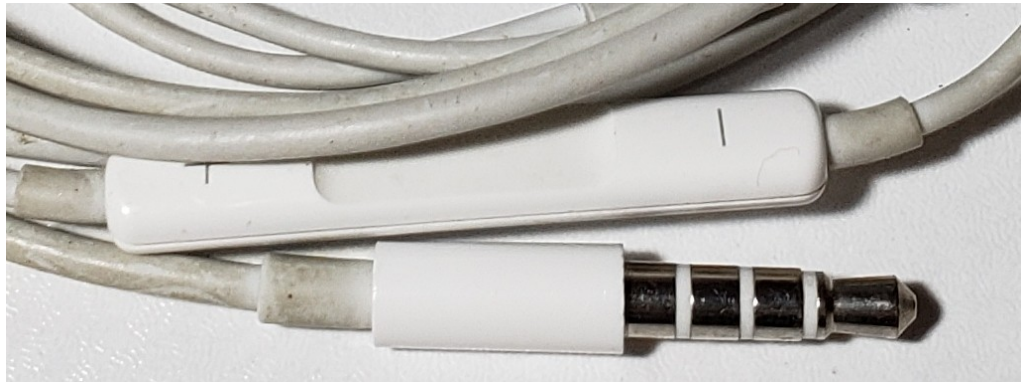
CW and SSB features

CW features

- Full or Semi-breakin (QSK)
- Iambic keyer
- On-screen CW decoder
- Message and frequency memories
- Full 10W Power output
- Raised-cosine envelope shaping
- Variable filter centre frequency and bandwidth

SSB Features

- Automatic Gain Control (AGC)
- Speech processing/compression
- Variable bandwidth filters
- 10W PEP power output
- Dual mic



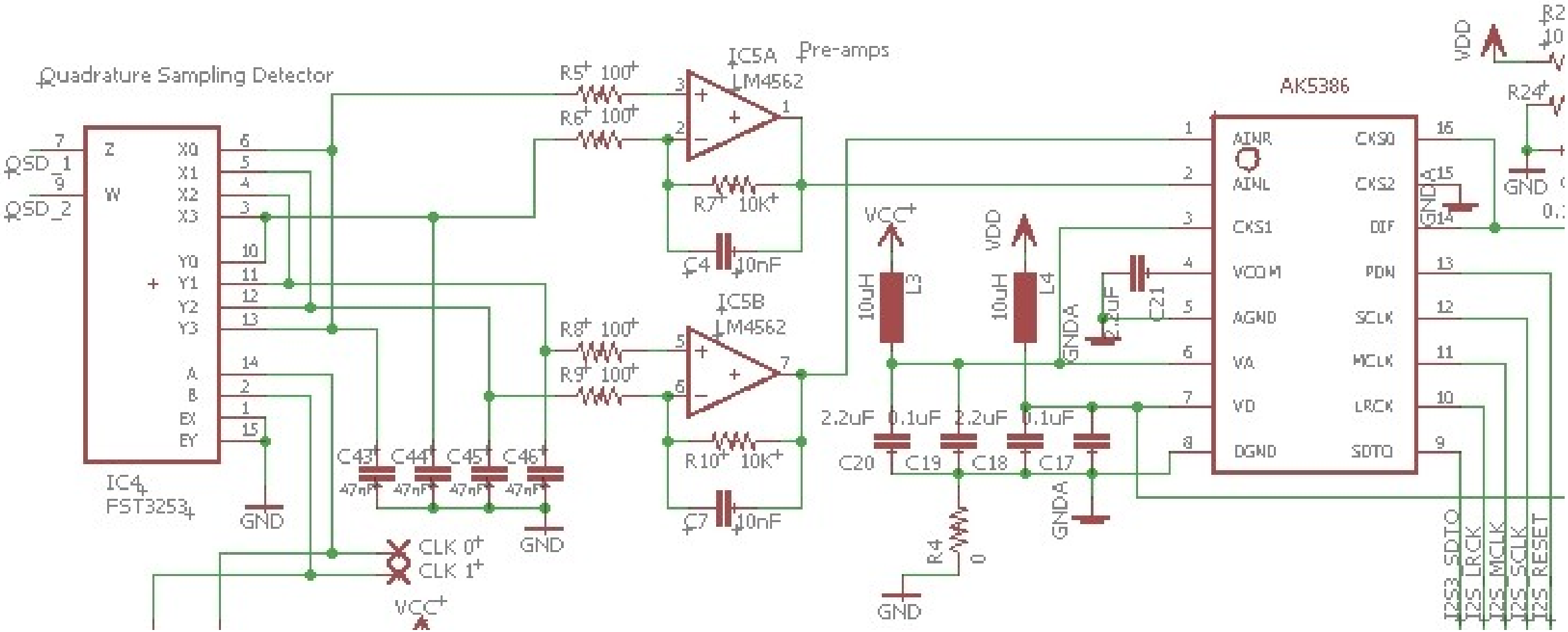
Digital and other modes support

- RTTY and PSK31 supported natively (no PC required)
  - USB keyboard text entry
  - CW to RTTY/PSK31 translator
  - RTTY and PSK31 decoding on-screen
- Connect to a PC with a common USB cable, for:
  - Digital modes: USB 24-bit USB soundcard emulation
  - Virtual Serial COM port, for CAT rig control over the **same** USB cable
- Full 10W Power output continuous key-down (100% duty cycle)
- Also AM, FM modes

Performance

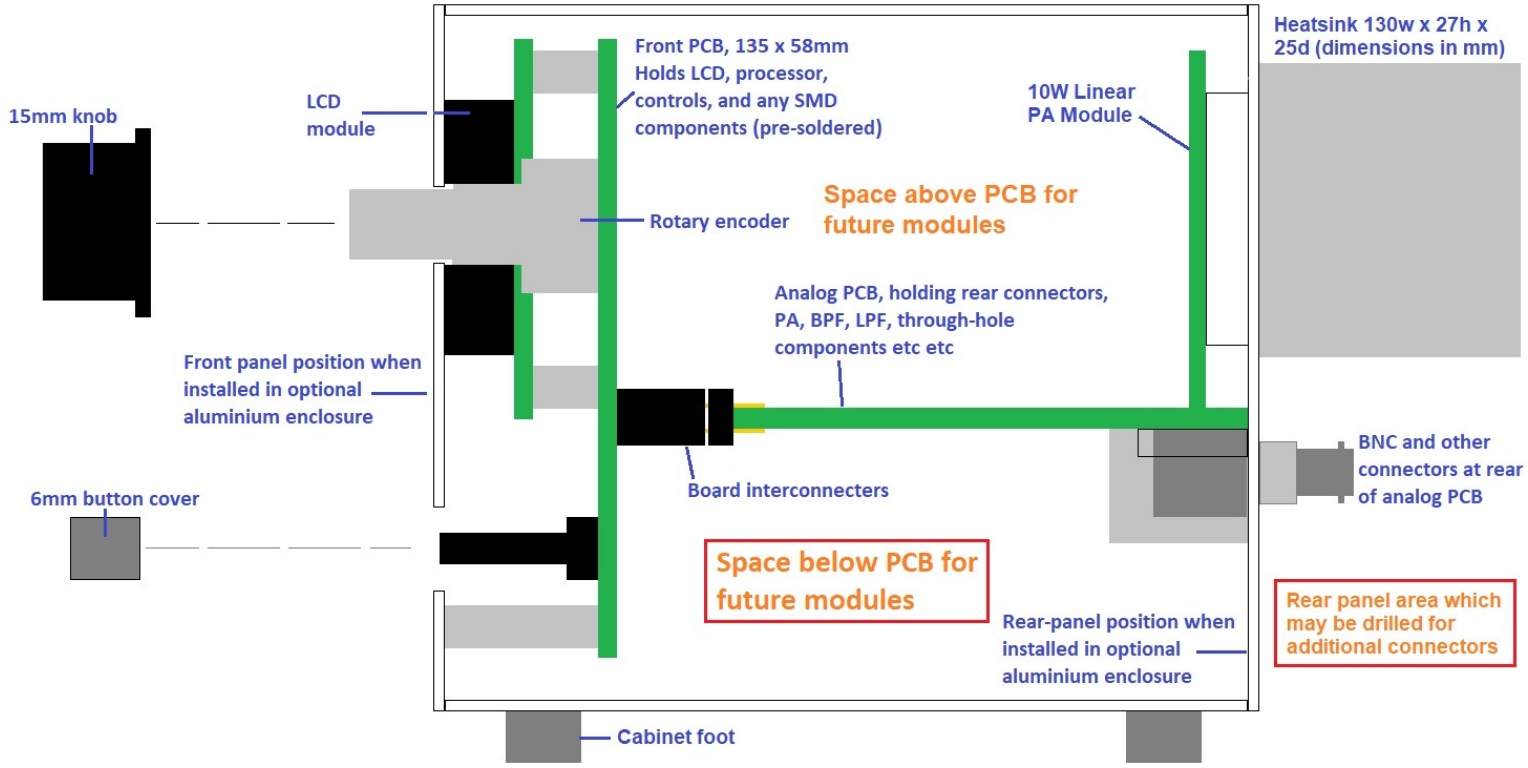
- Around 100dB dynamic range expected
- 24-bit Receiver ADC has 110dB dynamic range
- High IP3 front end mixer (Quadrature Sampling Detector)
- 12kHz IF mode (away from mains hum)
- Narrow Band Pass Filter per band, attenuates out-of-band signals
- Compliant with all regulations on harmonic and spurious output
- Good IMD transmit performance
- Variable transmitter power output 1 to 10W
- DSP features: sharp filters, noise reduction, notch filter etc.

Quadrature Sampling Detector

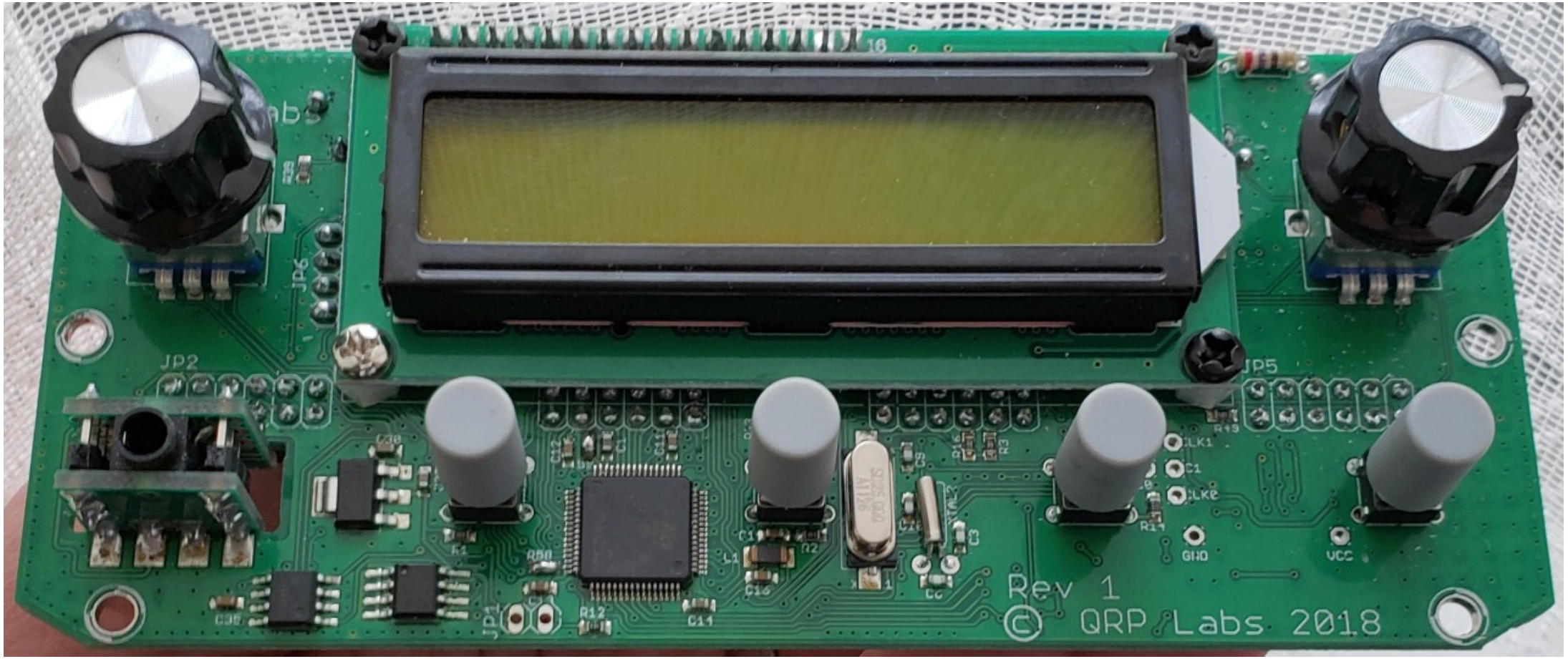


Mechanical design

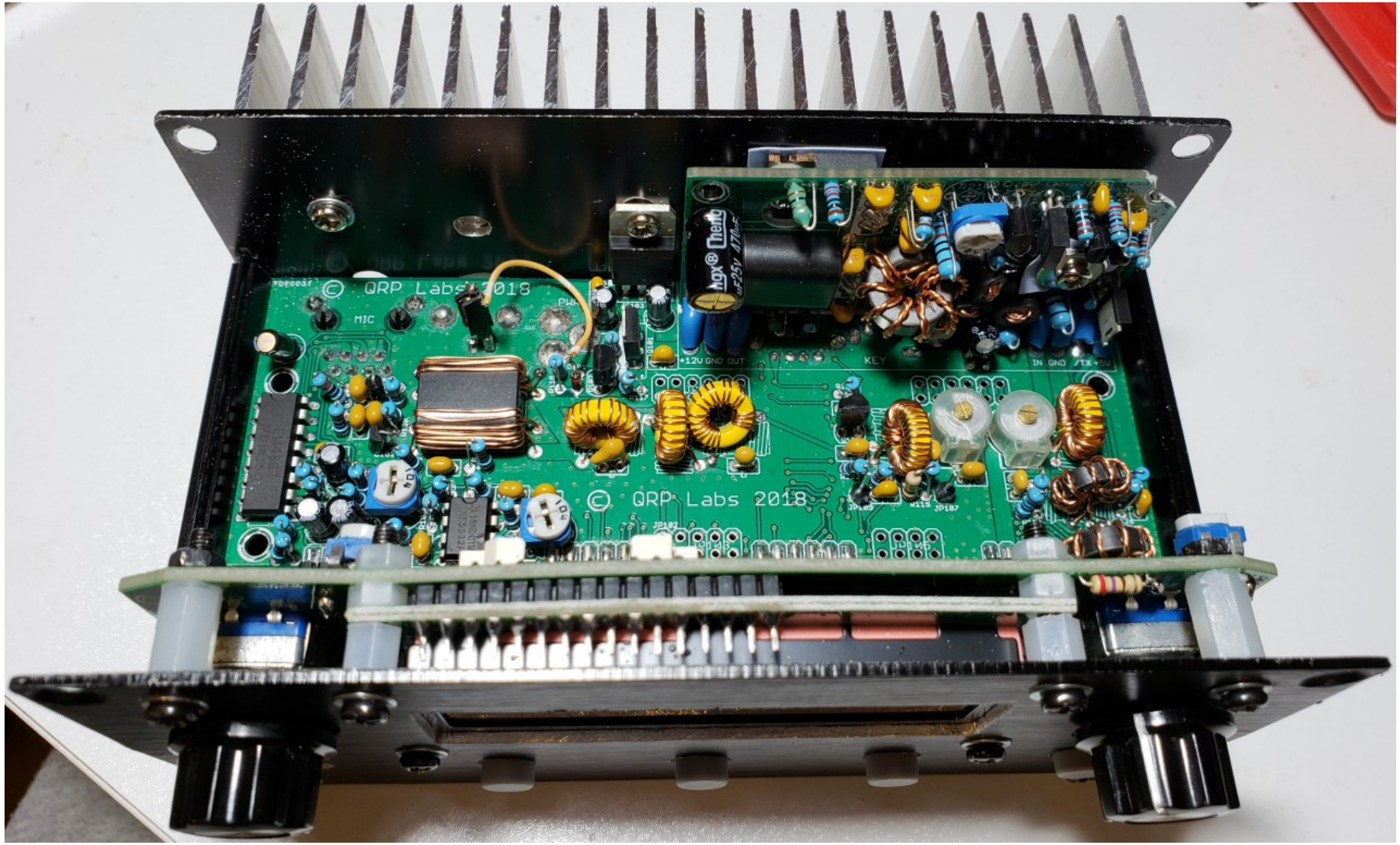
- Think about the enclosure
- Think about manufacturing process
- Controls should all be at the right altitude
- All controls should be board-mounted to remove any wiring



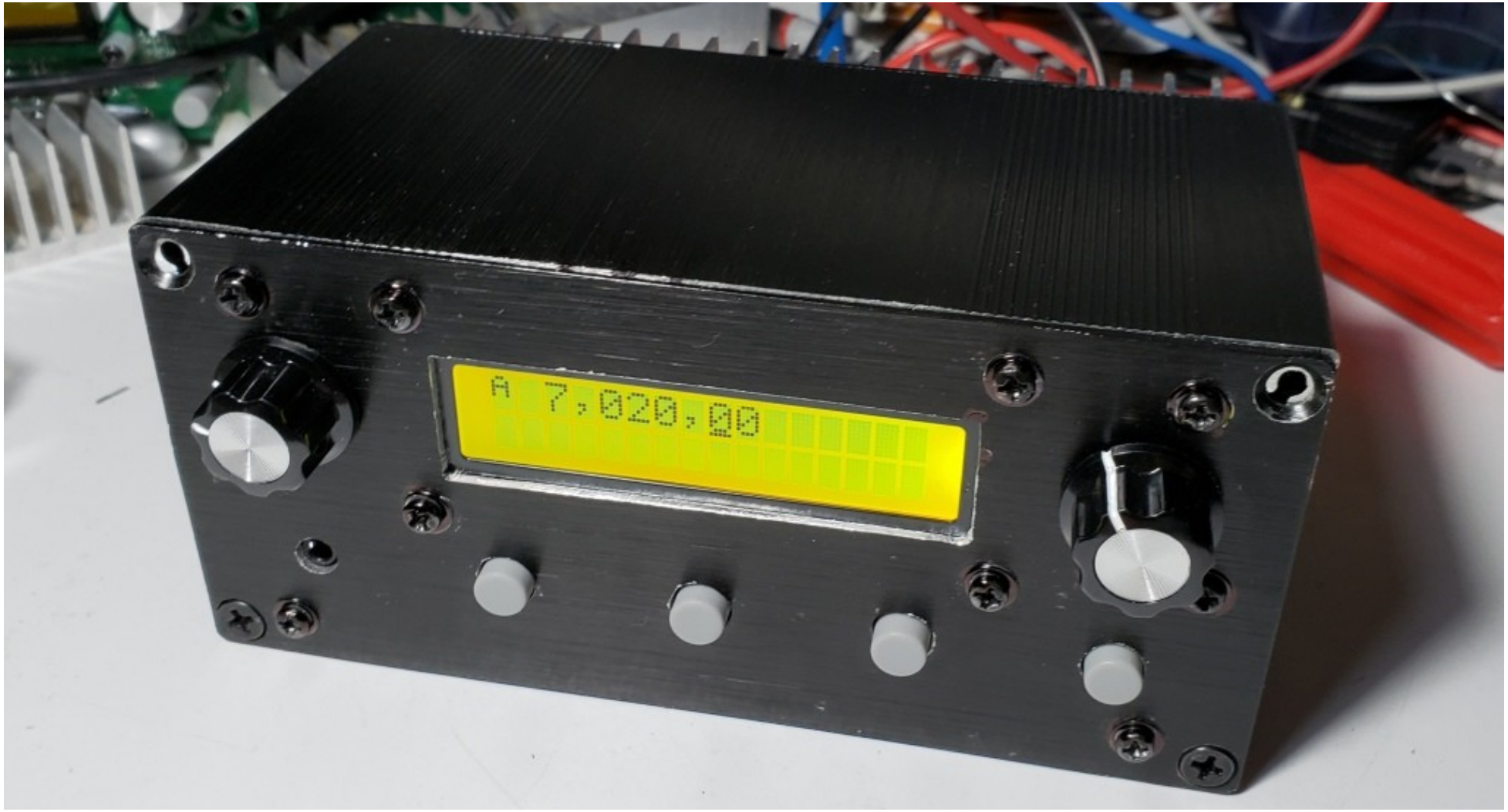
3 boards: Front panel, rear board, and PA board



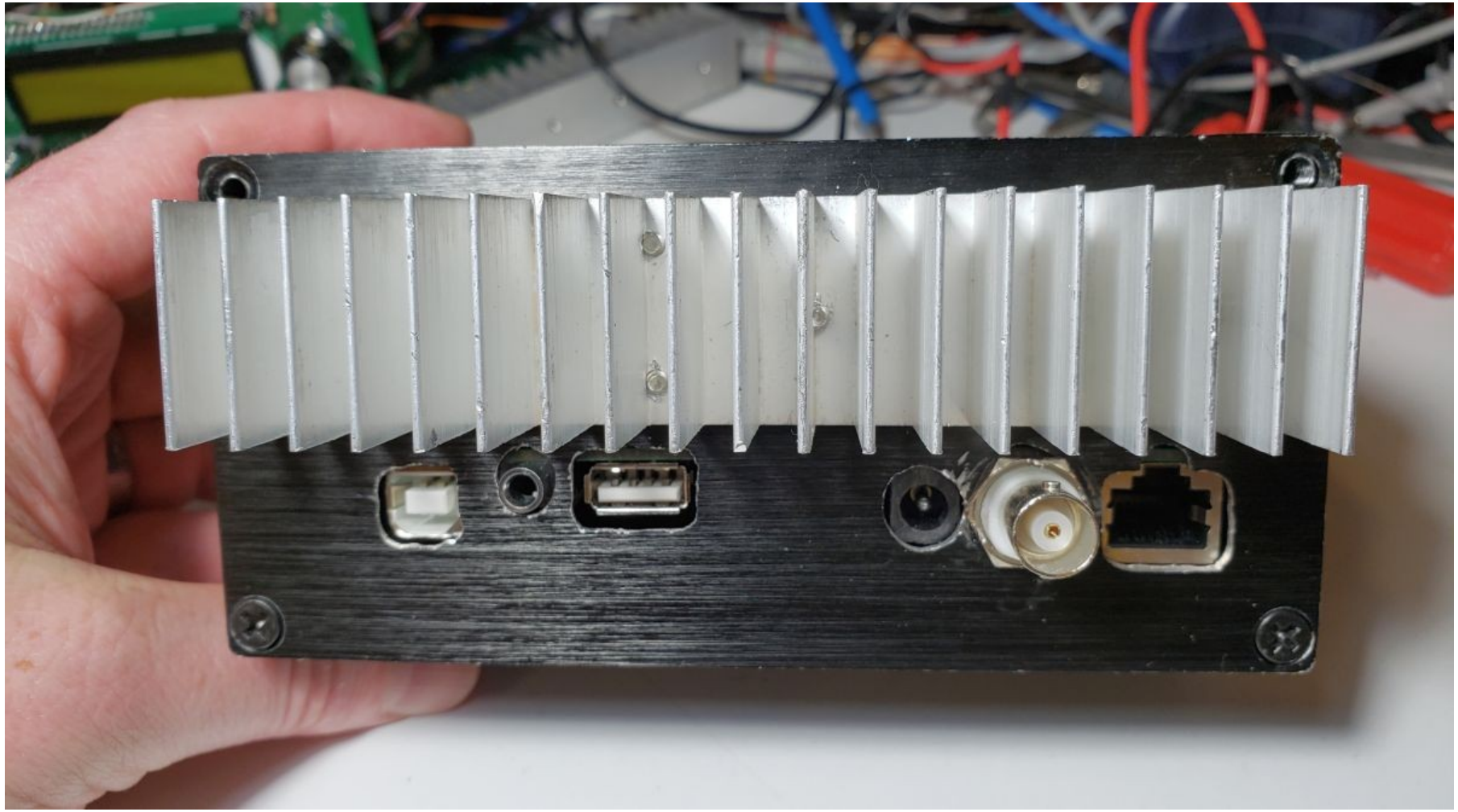
Rear board and PA board



Enclosure

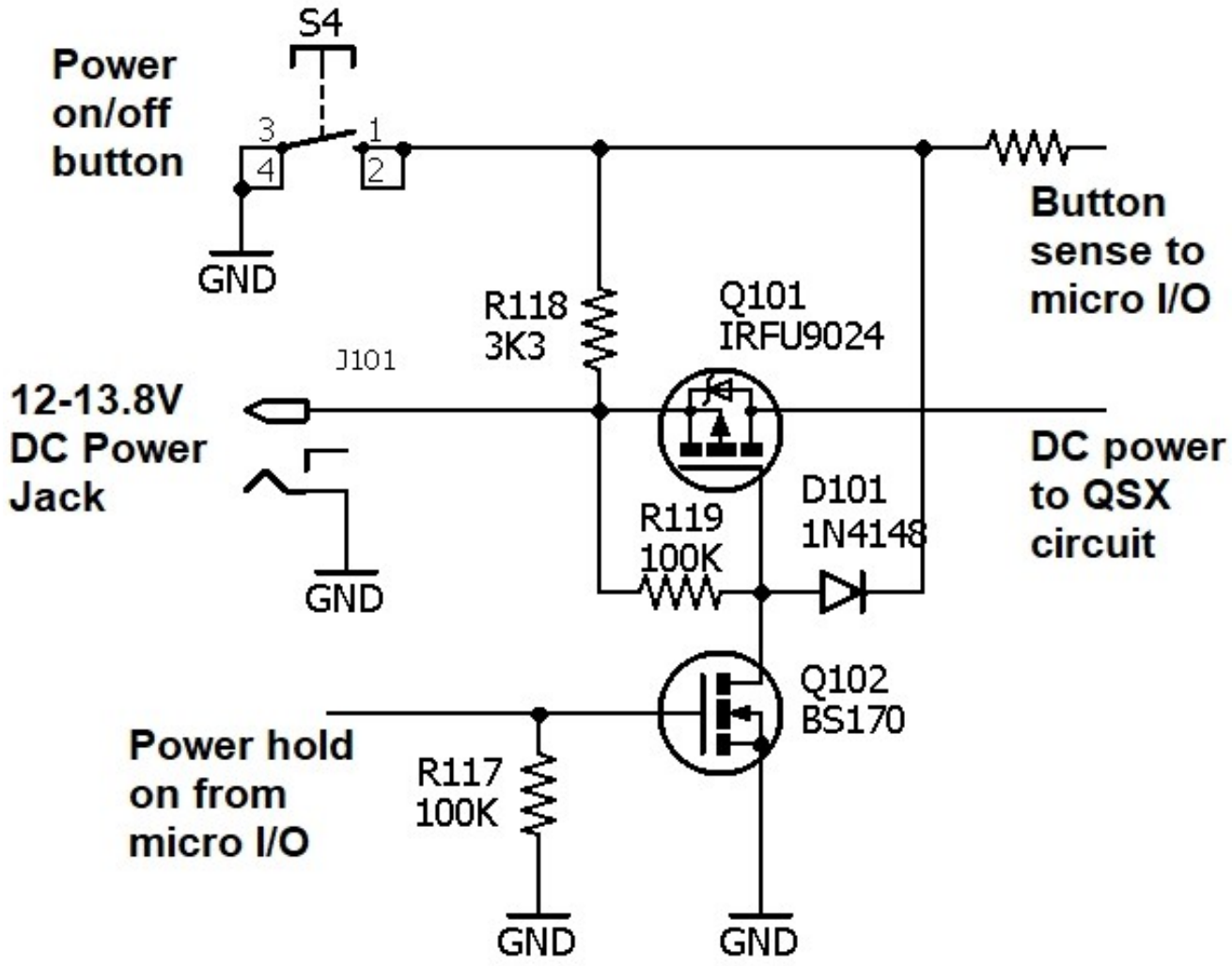


Rear panel connectors



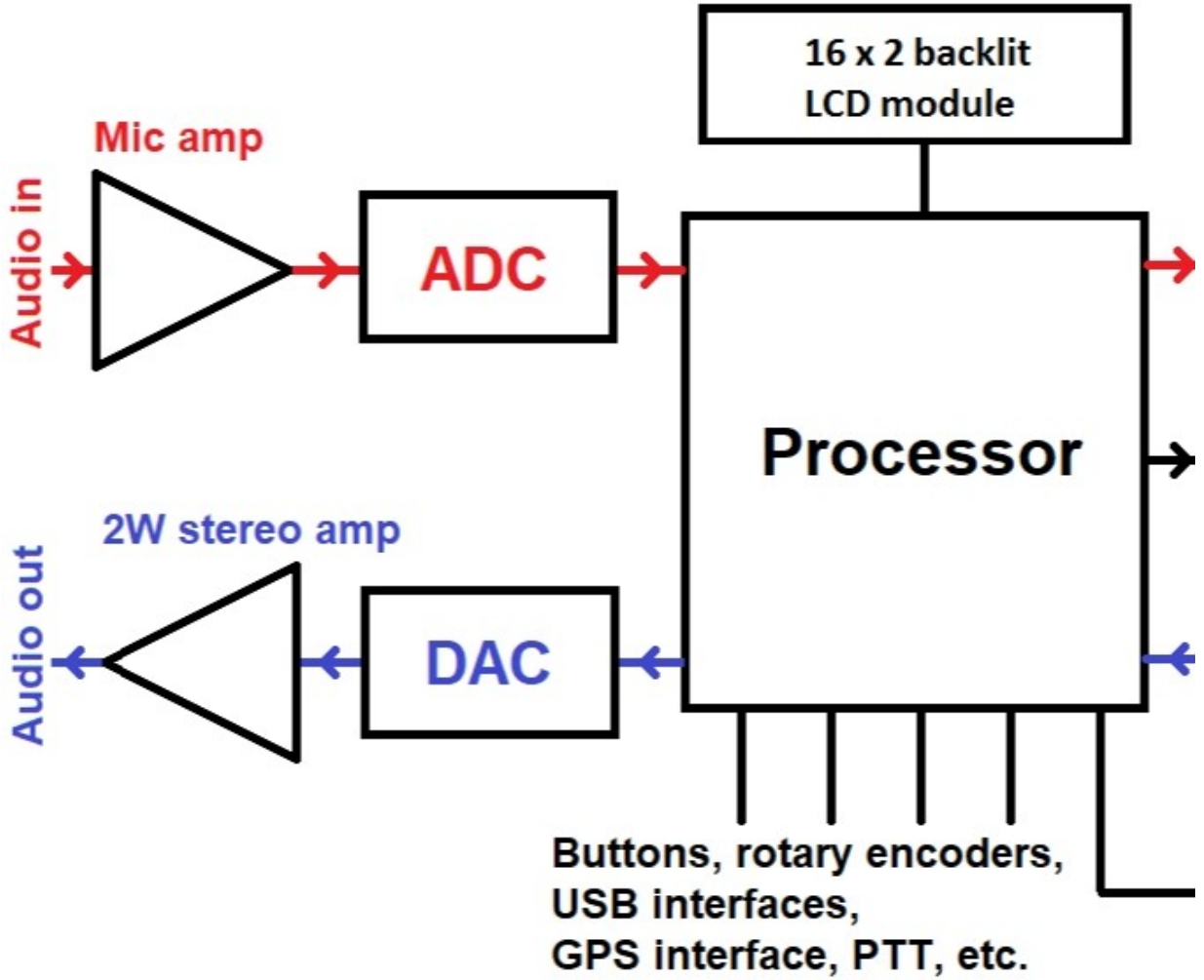
Mechanical and electronic design interact: #1

- Front panel controls “altitude”
- Reverse polarity protection and soft power switch
- Push button on/off
- Allows “graceful” power-down, saving radio state

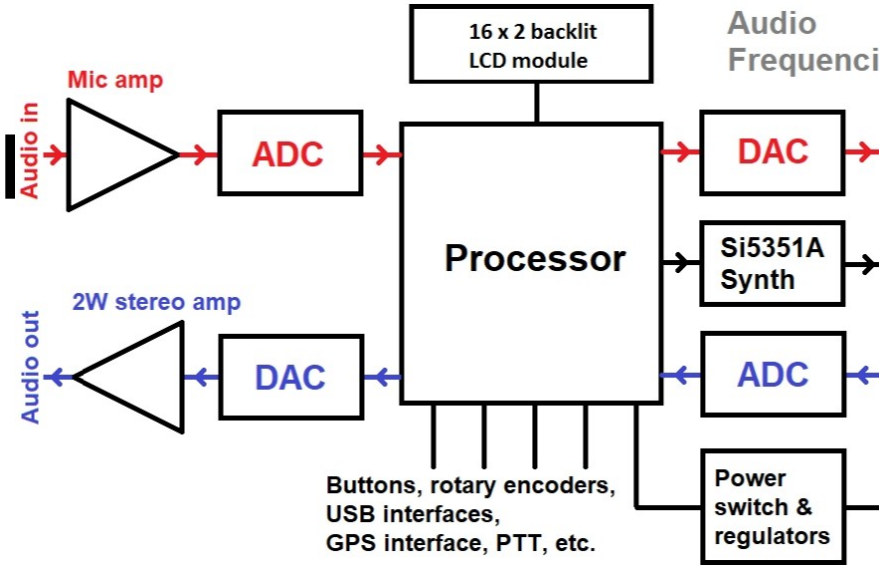


Mechanical and electronic design interact: #2

- No gain control potentiometer!
- Instead: 24-bit DAC, with rotary encoder
- Plenty of dynamic range!
- Allows “stereo” output
  - Binaural reception
  - Second receiver
  - Volume balance adjustment between left and right ears



ADC and DAC performan

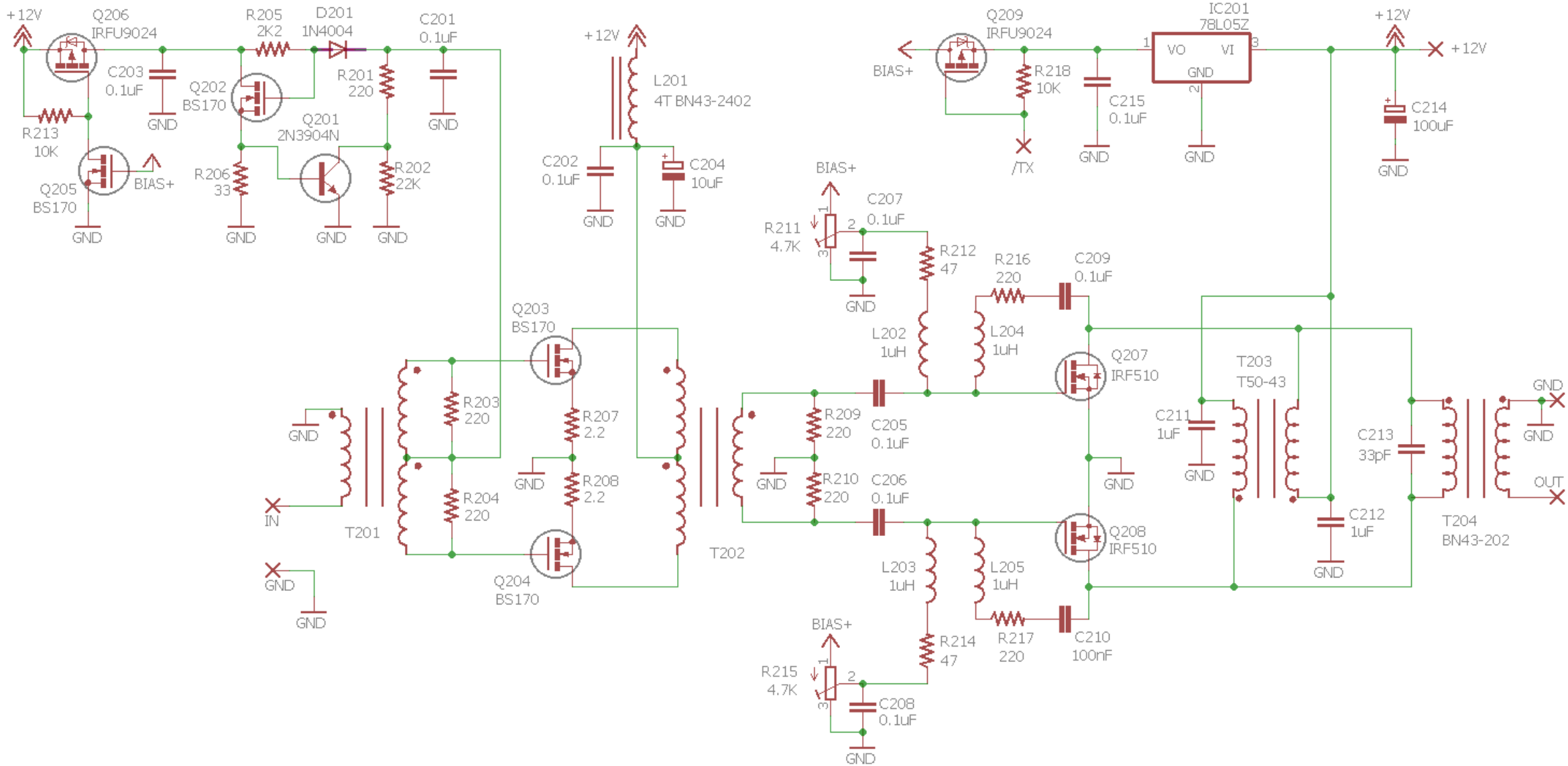


- Four conversions are needed:
  - 12-bit Audio in (microphone)
  - 24-bit Audio out (stereo to earphones)
  - 24-bit ADC input from detector (stereo I & Q channels)
  - 12-bit DAC output to Exciter (stereo I & Q channels)
- 24-bit ADC is critical to performance
  - 6dB per bit theoretical… limited in practice
  - ADC chip has 110dB dynamic range:
- 24-bit audio output DAC, enough dynamic range
- Others can use the internal peripherals of the processor

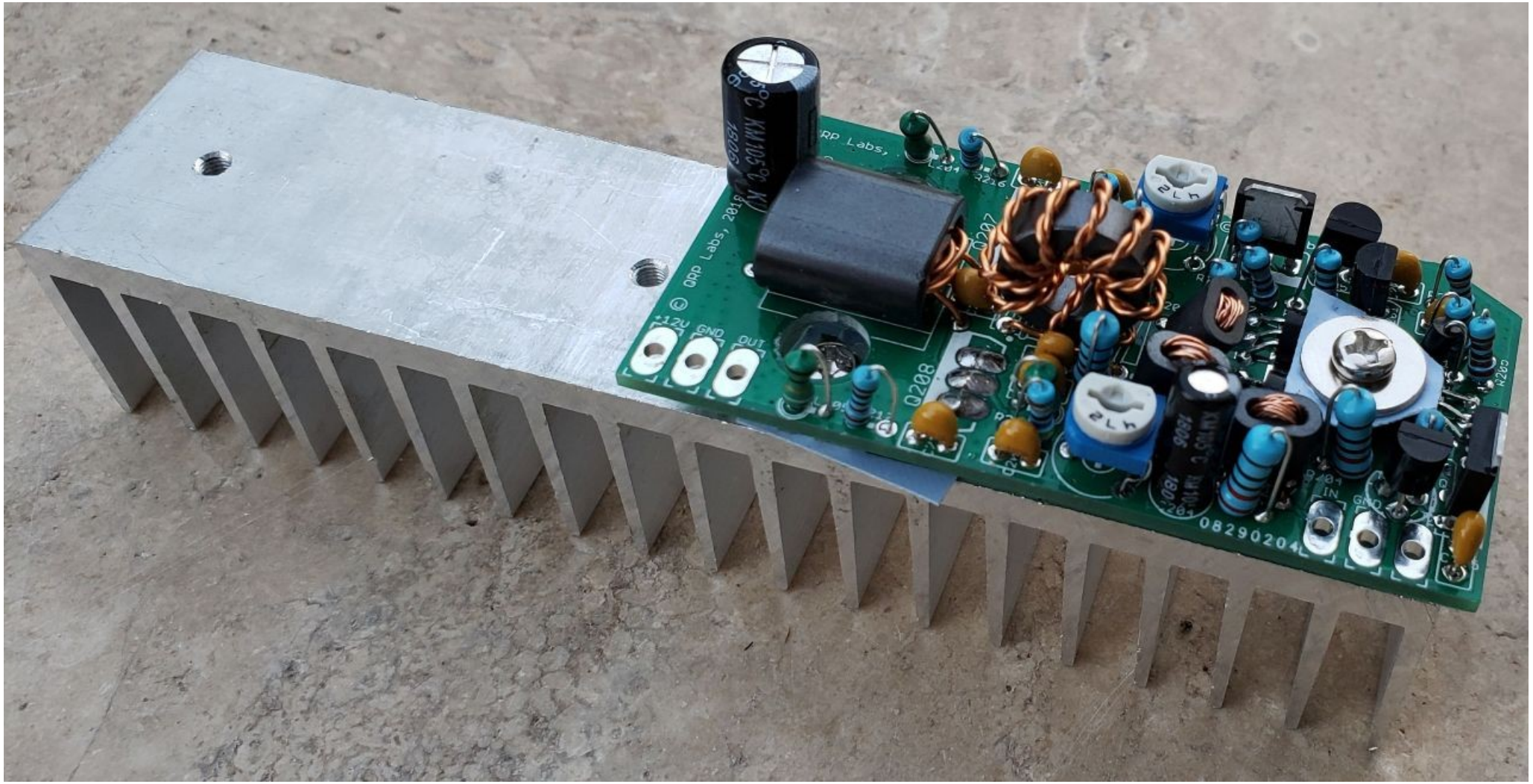
QSX 10W Linear PA module

- Relatively massive heatsink allows 100% duty cycle operation at 10W
- Low cost (inexpensive IRF510 MOSFETs)
- 26dB of gain, flat to +/- 1dB across 160m to 10m
- Push-pull BS170 driver, and push-pull IRF510 final, for excellent linearity
- Through-hole plated PCB, all through-hole components (no Surface Mount Devices)
- Standard inexpensive components throughout: eas replaced!
- ROBUST!

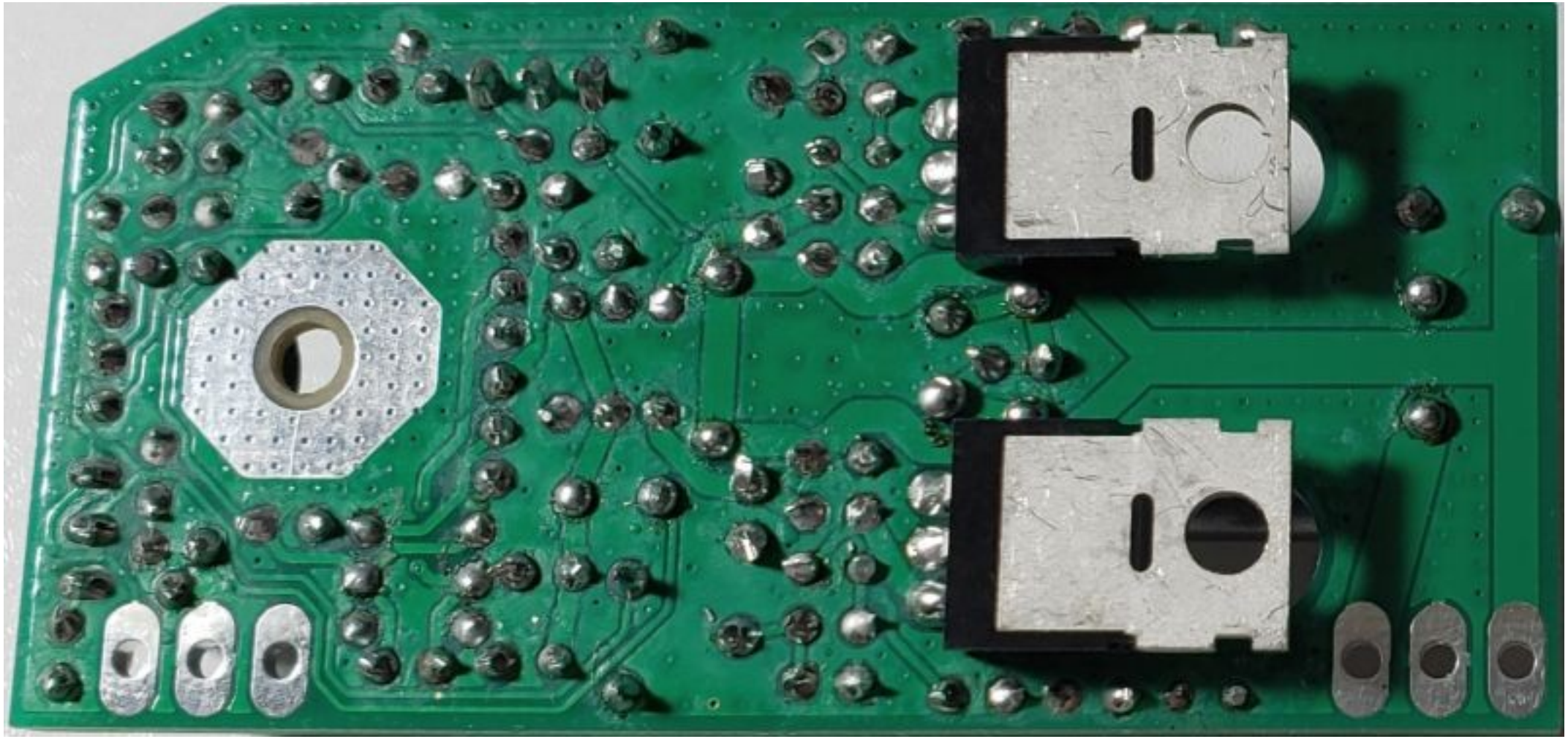
QSX Linear: circuit diagram



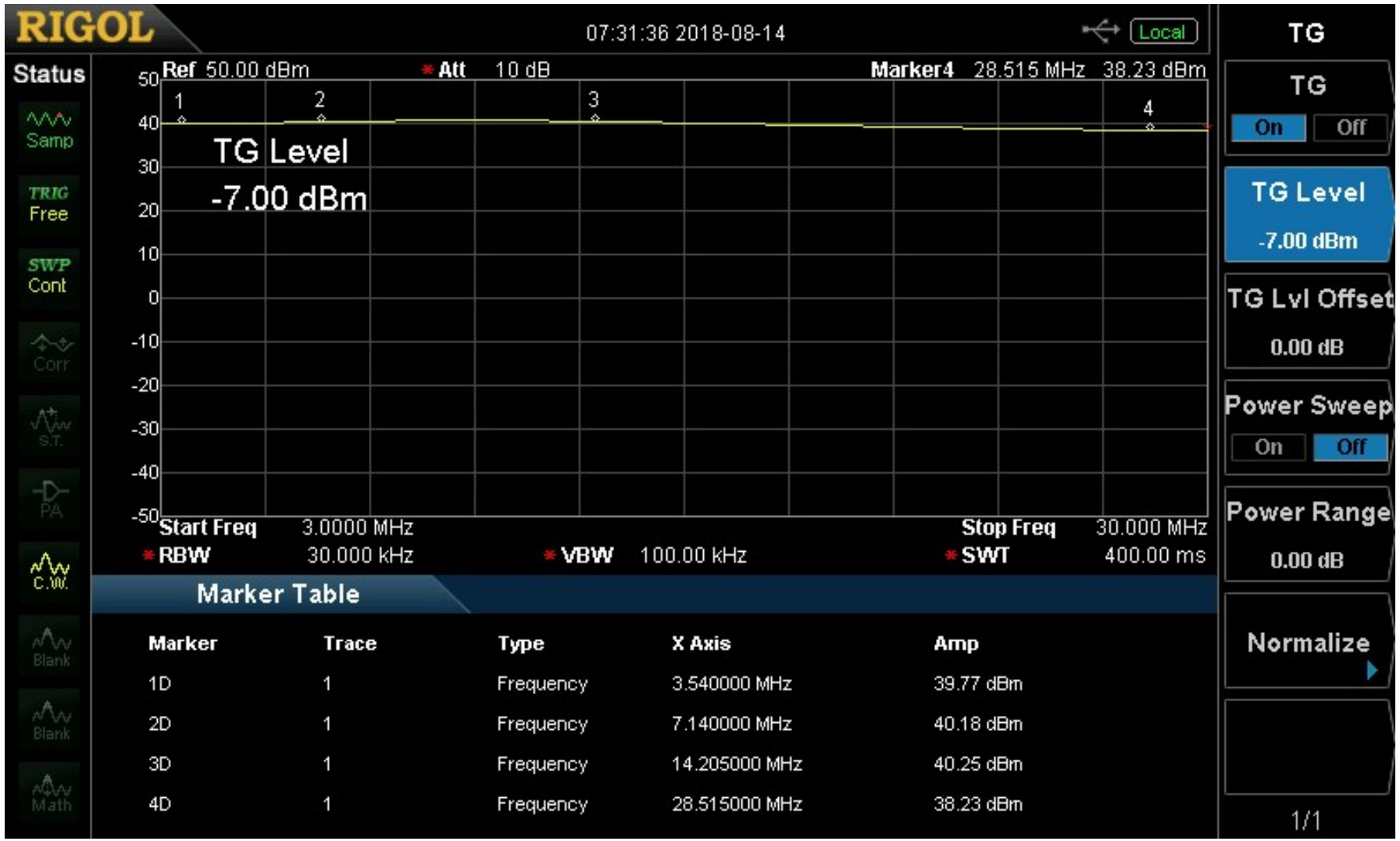
QSX Linear: heatsink 130 x 28mm, 25mm fins



QSX Linear: symmetric layout

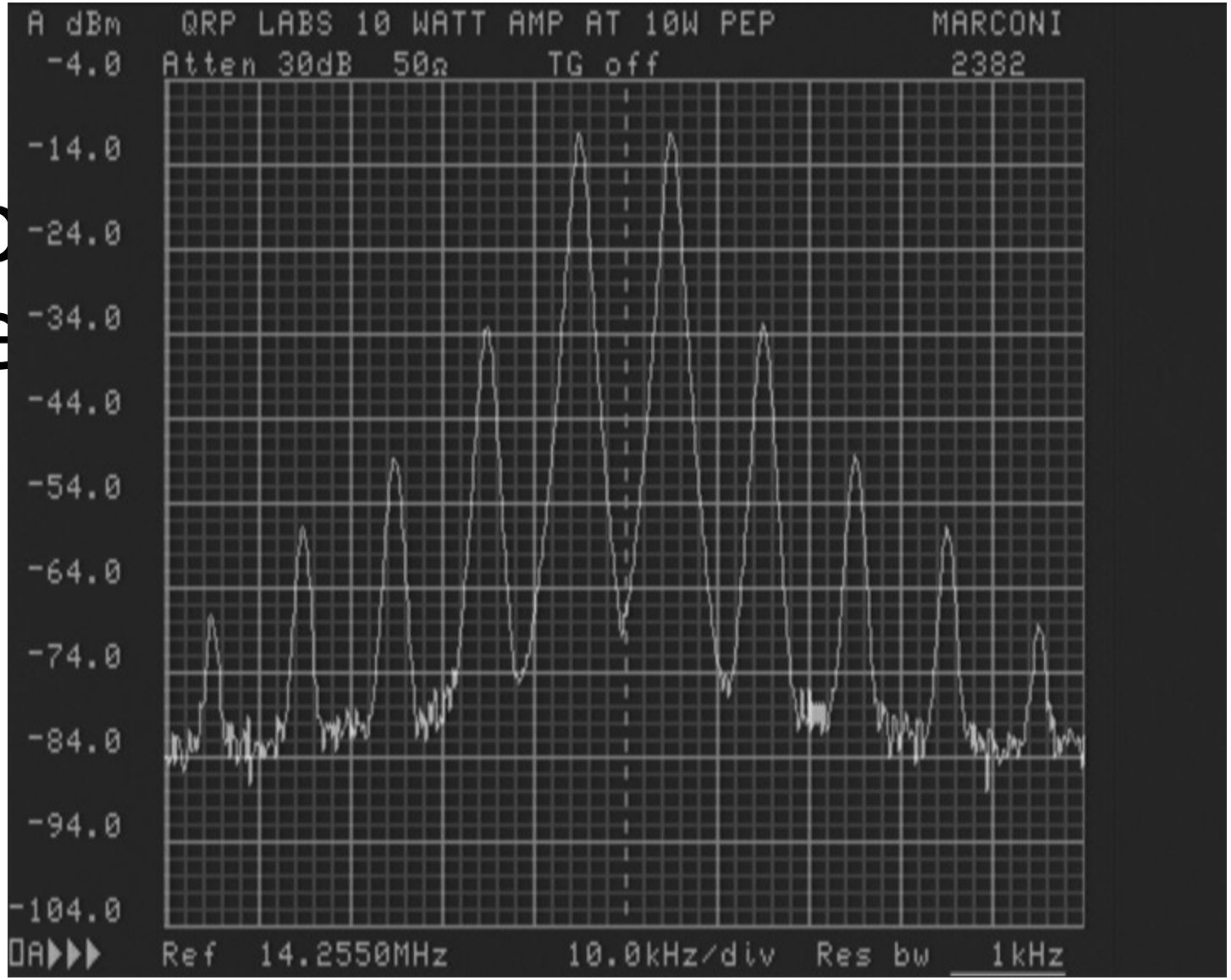


QSX 10W Linear PA module: gain



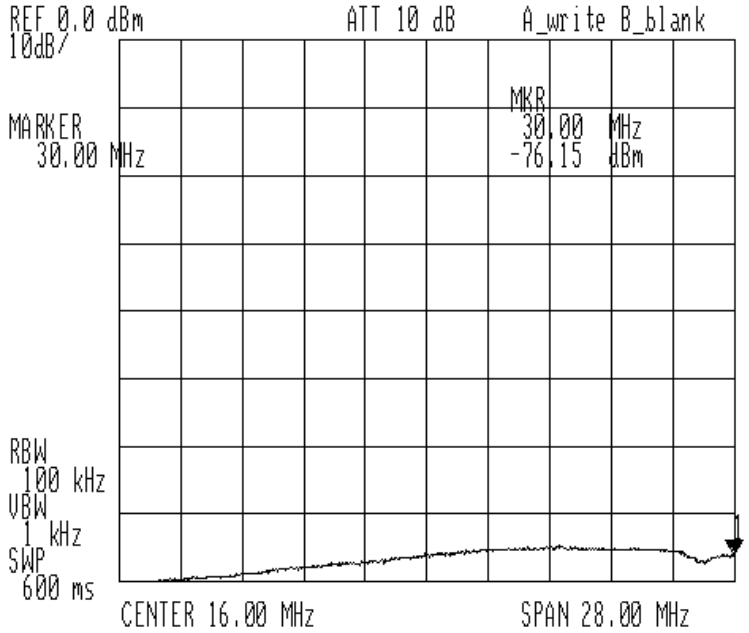
Good intermodulation performance

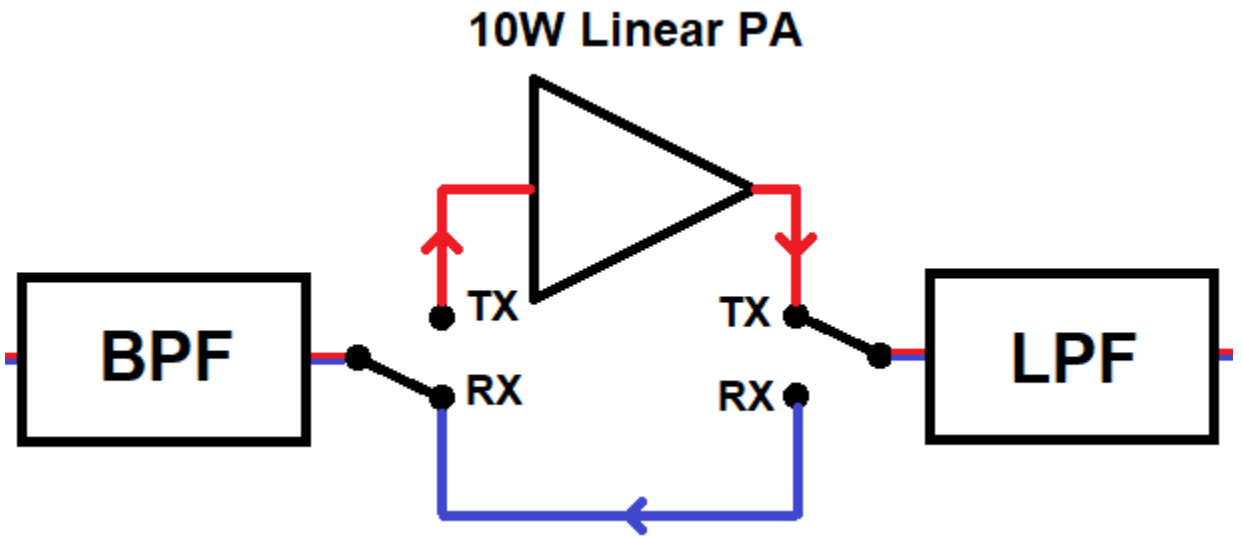
- Test on 20m at 12V supply, 10W PEP
- IMD3 -30dB relative to 10W PEP
- IMD5 -45dB
- Predistortion?



Transmit/Receive switch

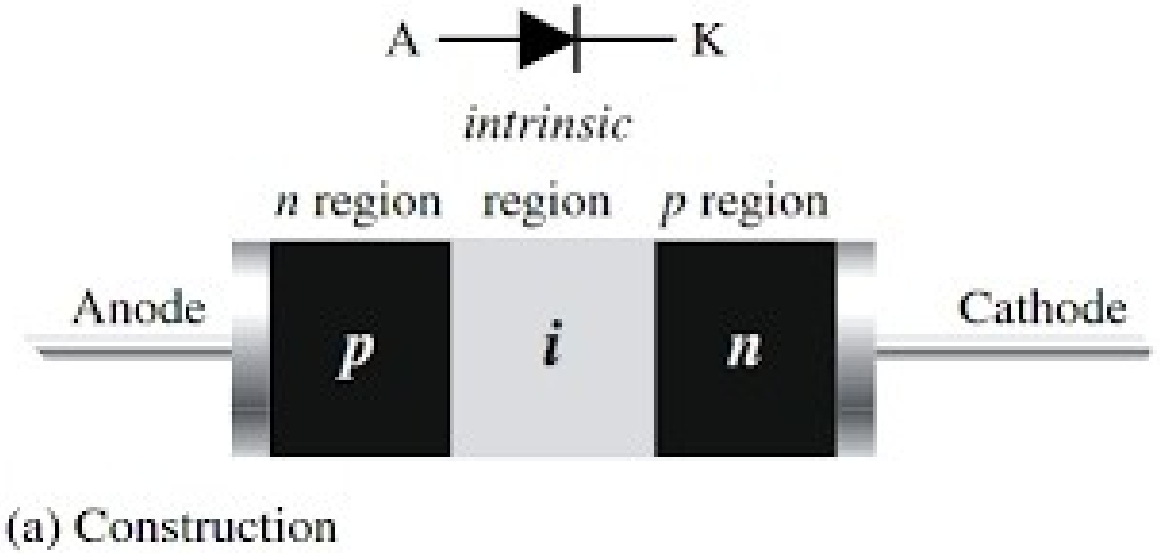
- All solid state, no relays: Fast and high performance (CW QSK)
- Low cost, high performance 1N4007 “PIN diode” switch
- RX bypass in “TX” mode has 75+ dB attenuation
- PA output to LPF only 0.1dB insertion loss in TX





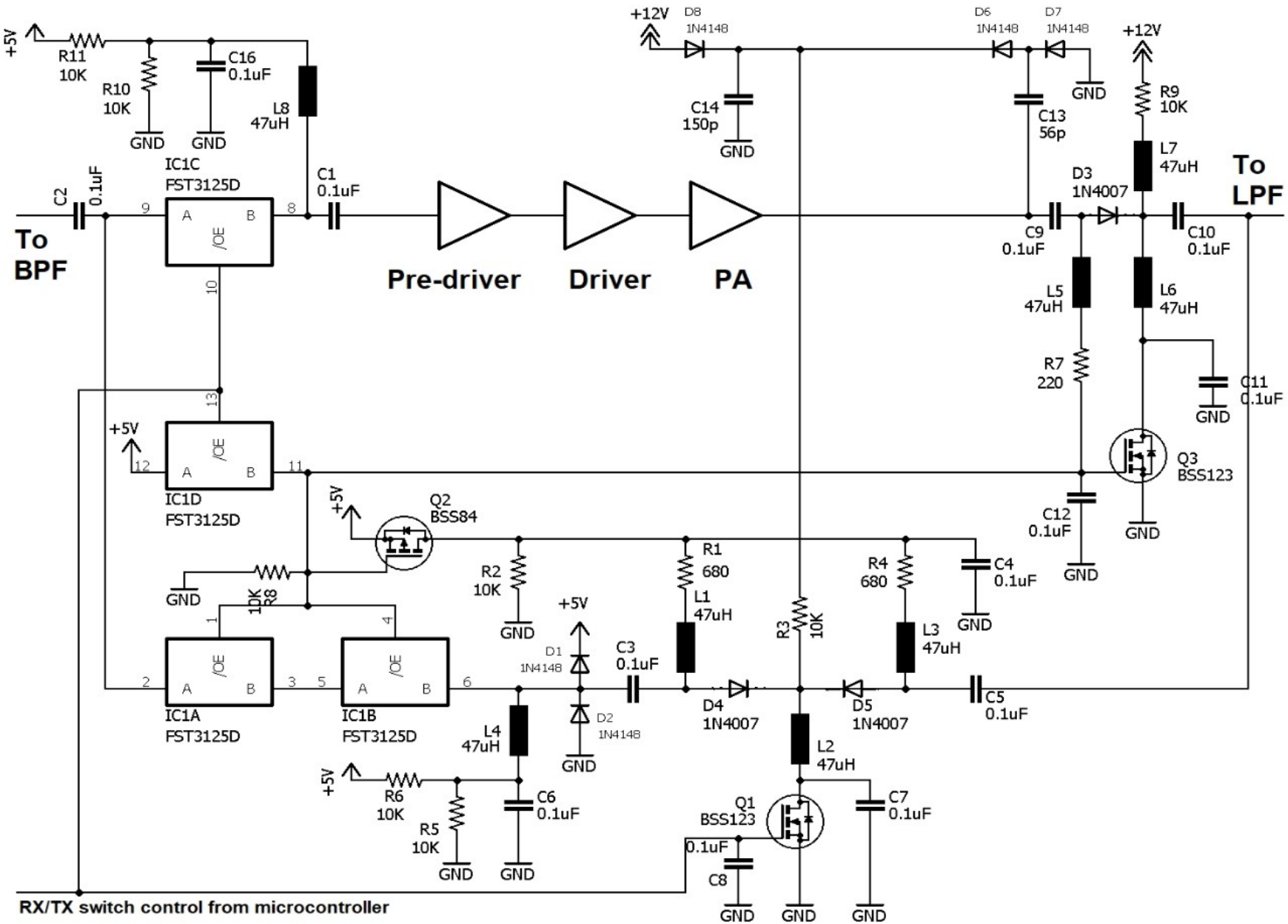
PIN diode rules

- Real PIN diodes are expensive
- 1N4007 works well as PIN!
- The rules:
- ON requires some forward bias current, 10mA is enough
- OFF requires reverse bias voltage (very little current) higher than the peaks of the RF voltage being blocked



(a) Construction

High performance Tx/Rx switch



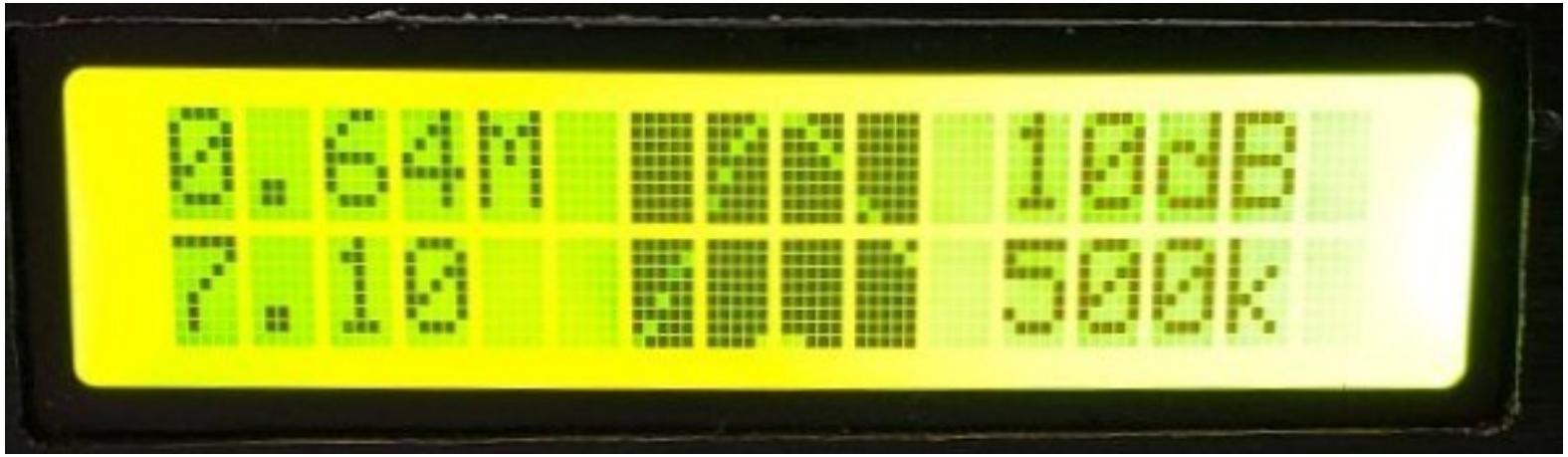
Built-in test equipment

- Signal generator
- frequency counter
- DVM
- Inductance meter
- RF power meter
- SWR
- Spectrum analyzer

Spectrum analyser function for BPF alignment

Display shows:

- Filter bandwidth
- Center frequency
- Vertical scale (dB/division)
- Horizontal scale (Frequency/division)

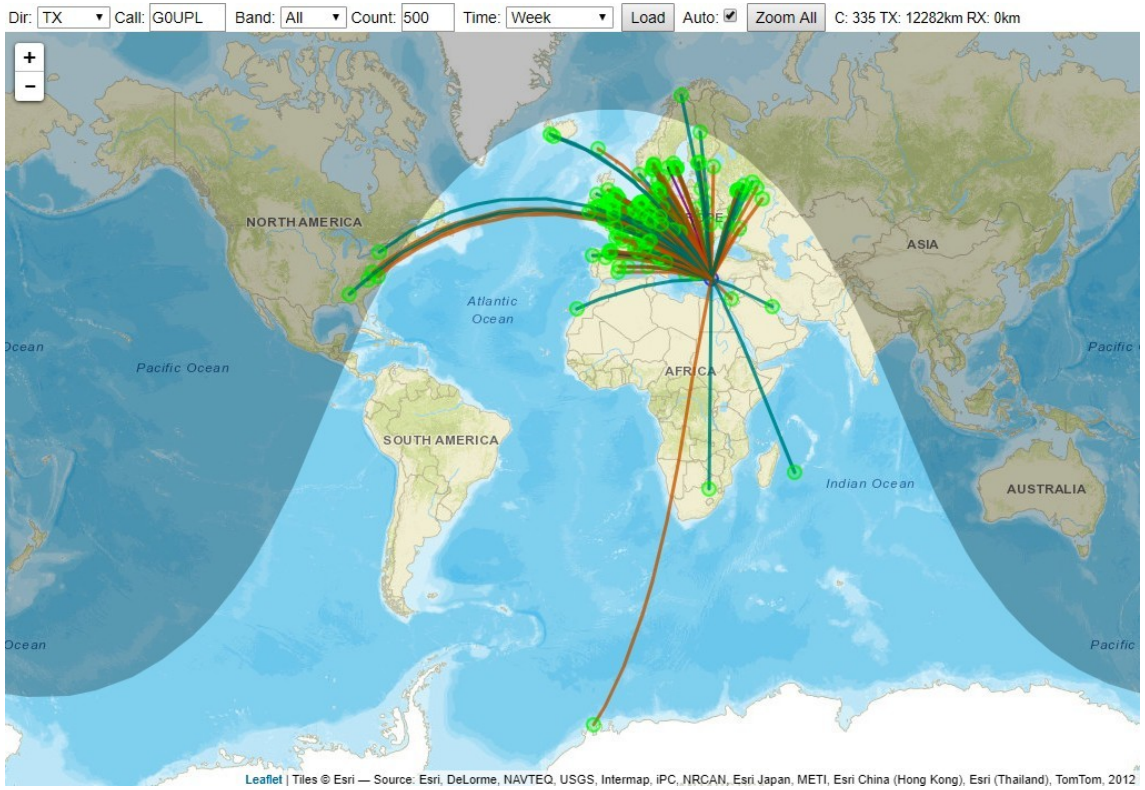


Rotary encoder knobs let you adjust center frequency and bandwidth

See YouTube video: https://www.youtube.com/watch?v=_bMoR3Q6gzM

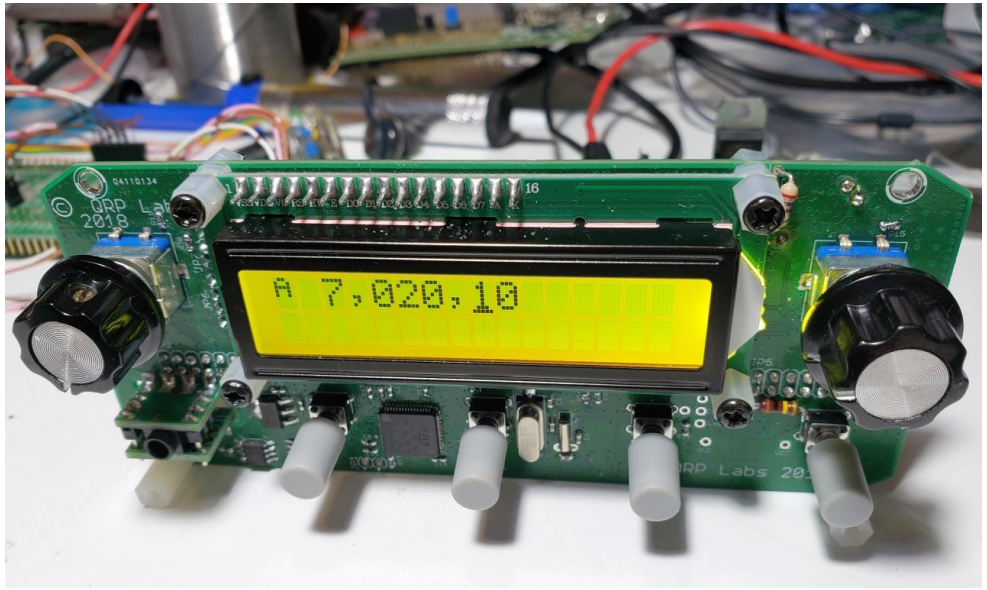
Weak-signal mode support (standalone, no PC)

- WSPR (Weak Signal Propagation Reporter)
- CW beacon, RTTY, PSK31
- FT8 beacon
- QRSS modes
  (QRSS, FSKCW, DFCW, Slow-Hell)
- Opera
- Pi4
- JT4, JT9, JT65 beacon
- ISCAT (A/B)
- See also Ultimate3S kit
  http://qrp-labs.com/ultimate3/u3s



SUMMARY – see http://qrp-labs.com/qsx

- High performance all-band, all-mode 10W HF transceiver
- Fun, flexible educational, customisable
- Performance of a top-range radio at 1/10th the price
- Price target:
  - **$75** basic 1-band QSX-40
    (can also be built for any other single band)
  - **$150** with all options:
    10-band module and aluminium enclosure



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