Modernization of QRP RADIOS and Development of the QCX transceiver

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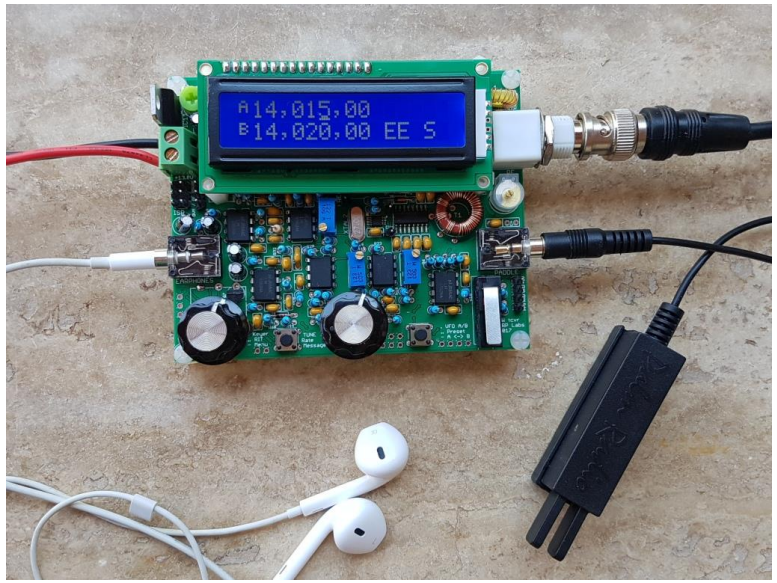


Introduction and 3 topics

- Introduction to the QCX transceiver
- Three topics:
  - 1. Improving QRP radio architecture
  - 2. Modern oscillators
  - 3. Microcontrollers in QRP rigs

Introduction to QCX transceiver

- 2013. The Tokyo hamfair with G0BBL, M0PUB
- KN-Q7A Chinese SSB tcvr, and CW version

YOTA 2017 Summercamp Buildathon

YOTA 2017

Kit Special

Youngsters On The Air

UK2017

www.rsgb.org/yota

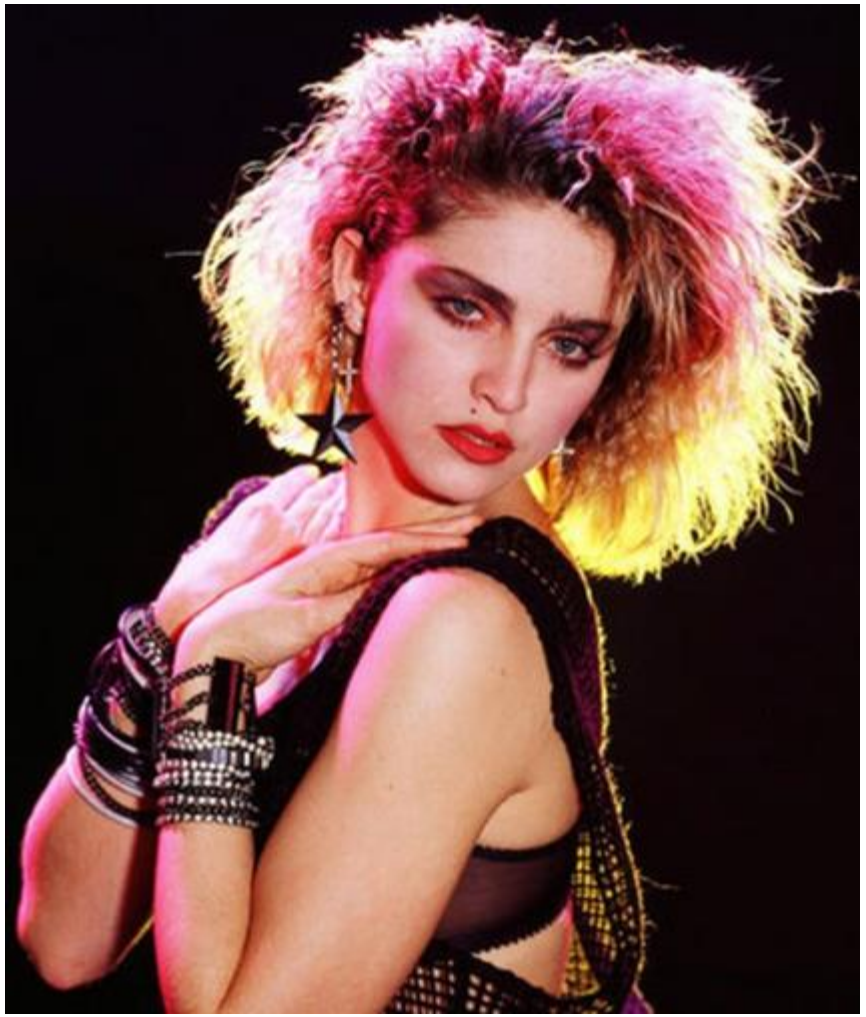
Peter Barnes
M0SWN

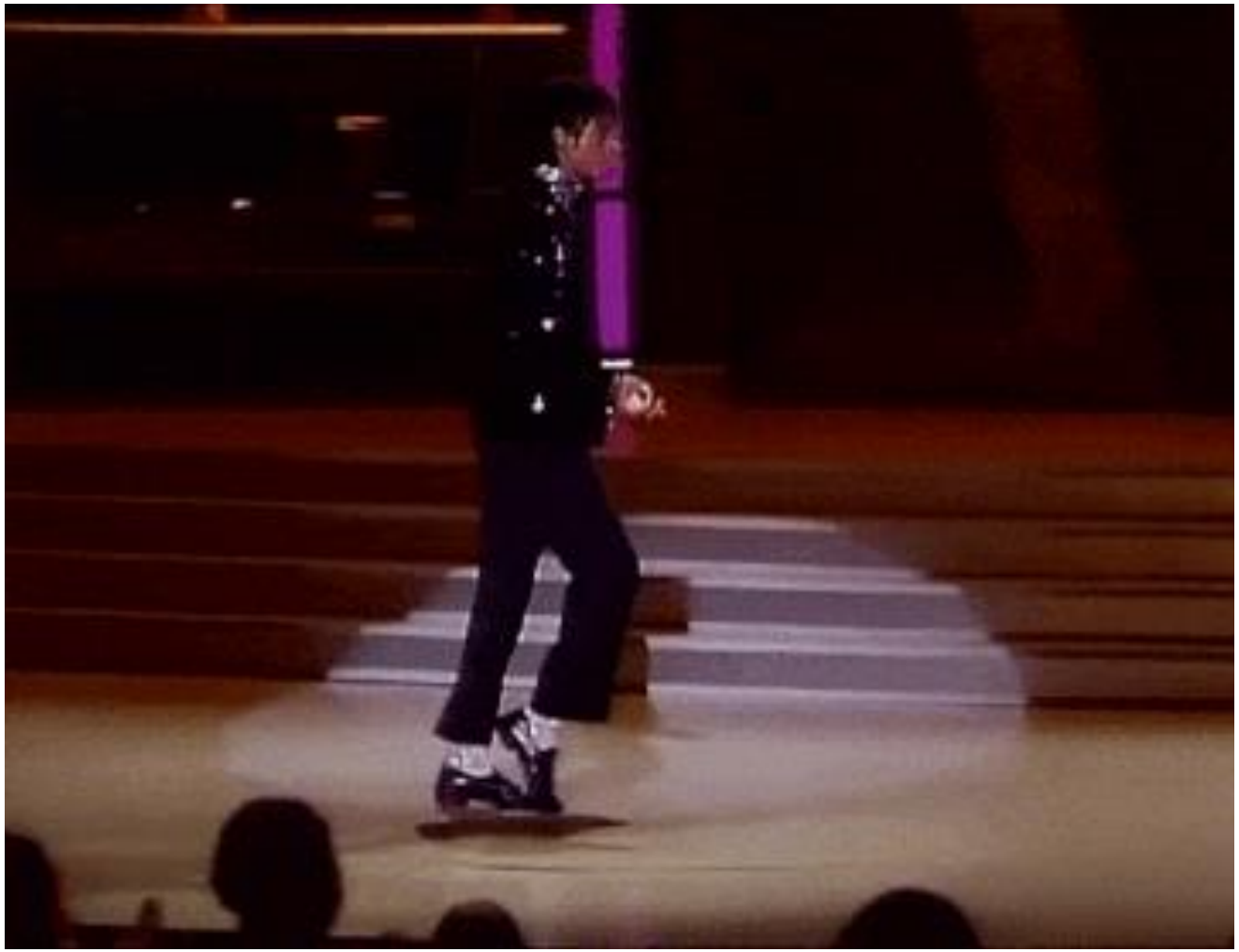
QCX: QRP Labs CW Xcvr (transceiver) - $49

- Easy to build, single-board design, 10 x 8cm, all controls are board-mounted
- Professional quality double-sided, through-hole plated, silk-screen printed PCB
- Choice of single band, 80, 60, 40, 30, 20 or 17m
- Approximately 3-5W CW output (depending on supply voltage)
- 7-16V recommended supply voltage
- Class E power amplifier, transistors run cool… even with no heatsinks
- 7-element Low Pass Filter ensures regulatory compliance
- CW envelope shaping to remove key clicks
- High performance receiver with at least 50dB of unwanted sideband cancellation
- 200Hz CW filter with no ringing
- Si5351A Synthesized VFO with rotary encoder tuning
- 16 x 2 blue backlight LCD screen
- Iambic keyer or straight key option included in the firmware
- Simple Digital Signal Processing assisted CW decoder, displayed real-time on-screen
- On-screen S-meter
- Full or semi QSK operation using fast solid-state transmit/receive switching
- Frequency presets, VFO A/B Split operation, RIT, configurable CW Offset
- Configurable sidetone frequency and volume
- Connectors: Power, 3.5mm keyer jack, 3.5mm stereo earphone jack, BNC RF output
- Onboard microswitch can be used as a simple straight Morse key
- Built-in test signal generator and alignment tools to complete simple set-up adjustments
- Built-in test equipment: voltmeter, RF power meter, frequency counter, signal generator
- Beacon mode, supporting automatic CW or WSPR operation
- GPS interface for reference frequency calibration and time-keeping (for WSPR beacon)

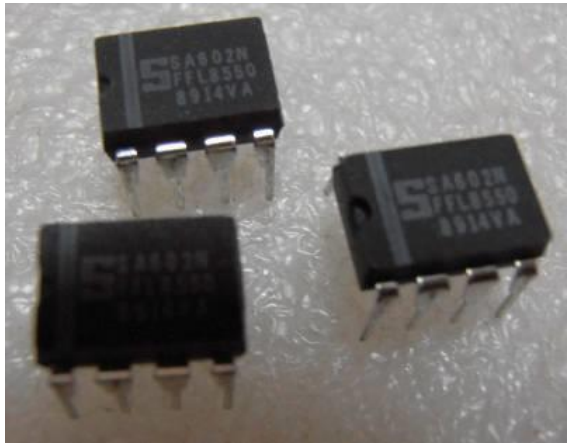
Who remembers these two?

Or these?

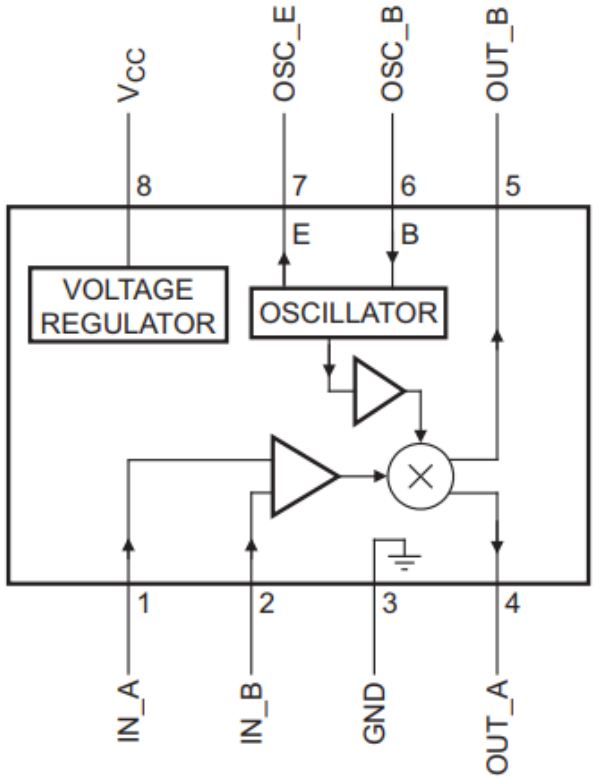




Signetics NE602 chip

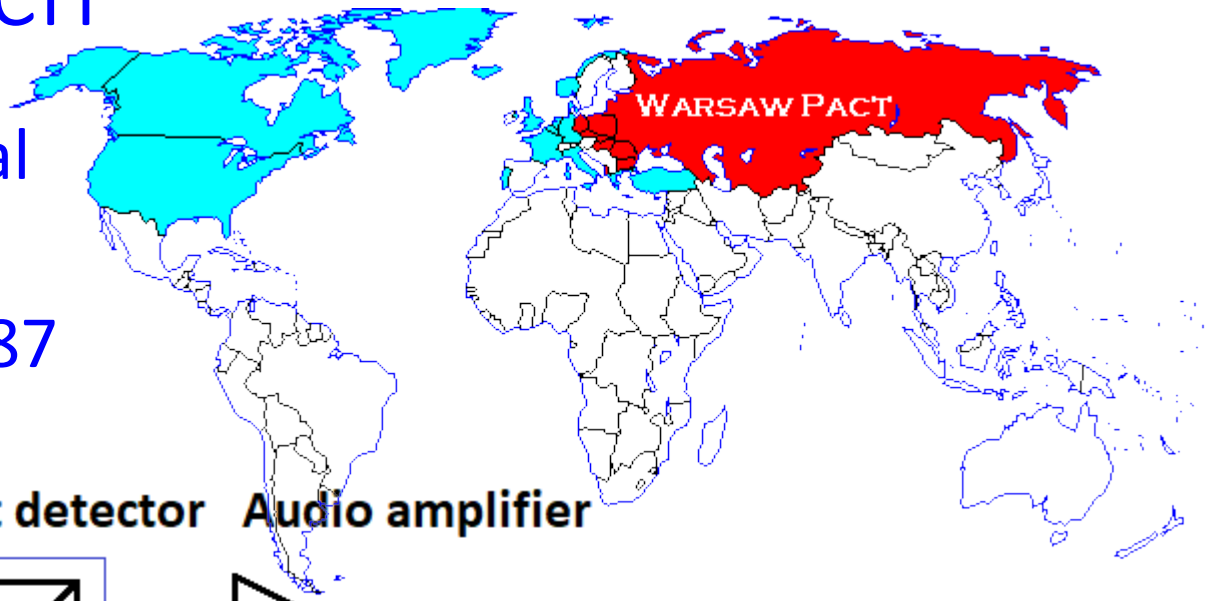


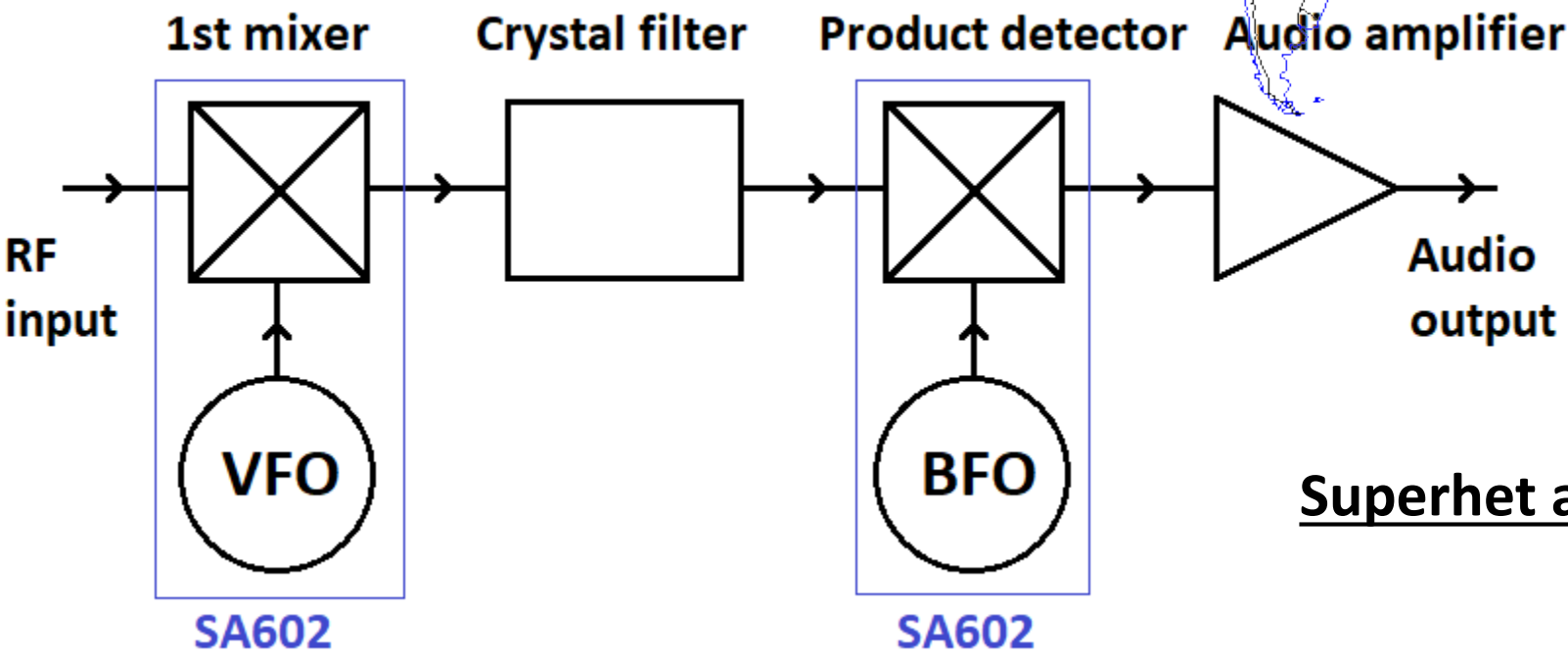
- Also known as NE612, SA602, SA612
- 1985? (old Signetics databook)
- Signetics -> Philips -> NXP
- Contains oscillator and Gilbert-cell mixer, and about 17dB of gain
- For cellular applications at 45MHz IF
- Quickly discovered by radio amateurs!



The Cold War sandwich

- Two slices of SA602 and a crystal filter filling please
- Rick K1BQT Ham Radio June 1987

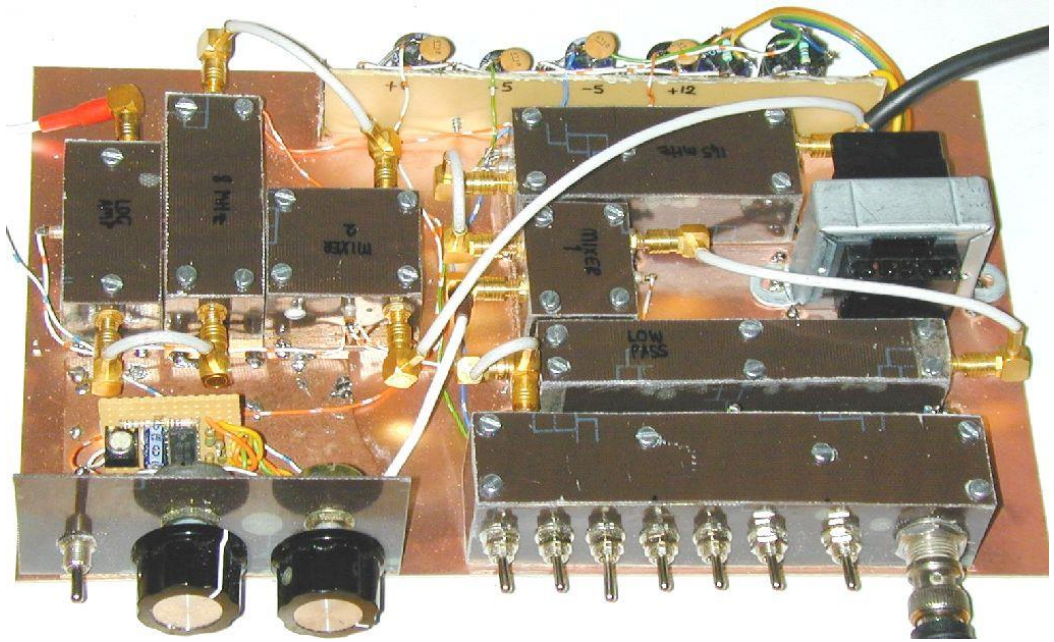


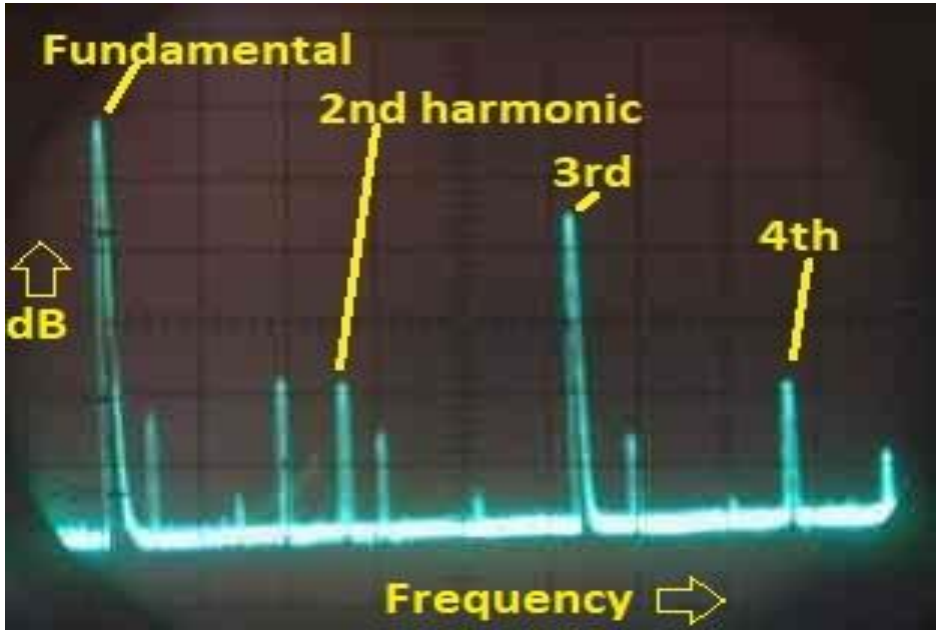


Superhet architecture

What's wrong with the SA602?

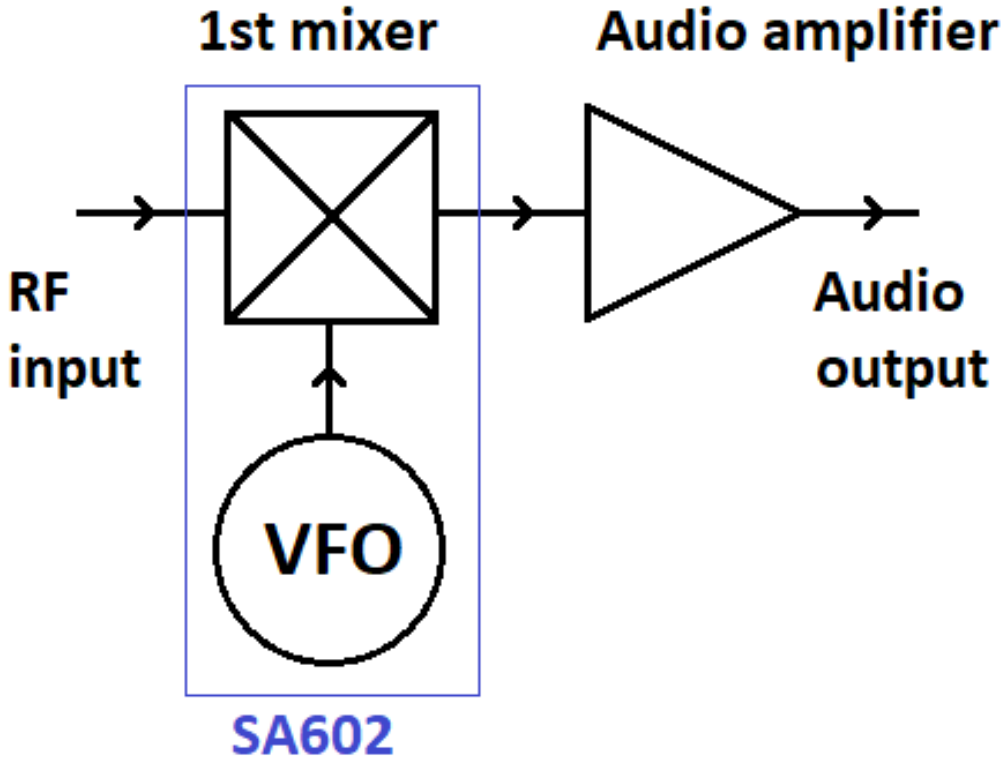
- Low dynamic range
- Third order intercept -13dBm
- Strong signal intermodulation
- Example: my 2003 homebrew spectrum analyzer





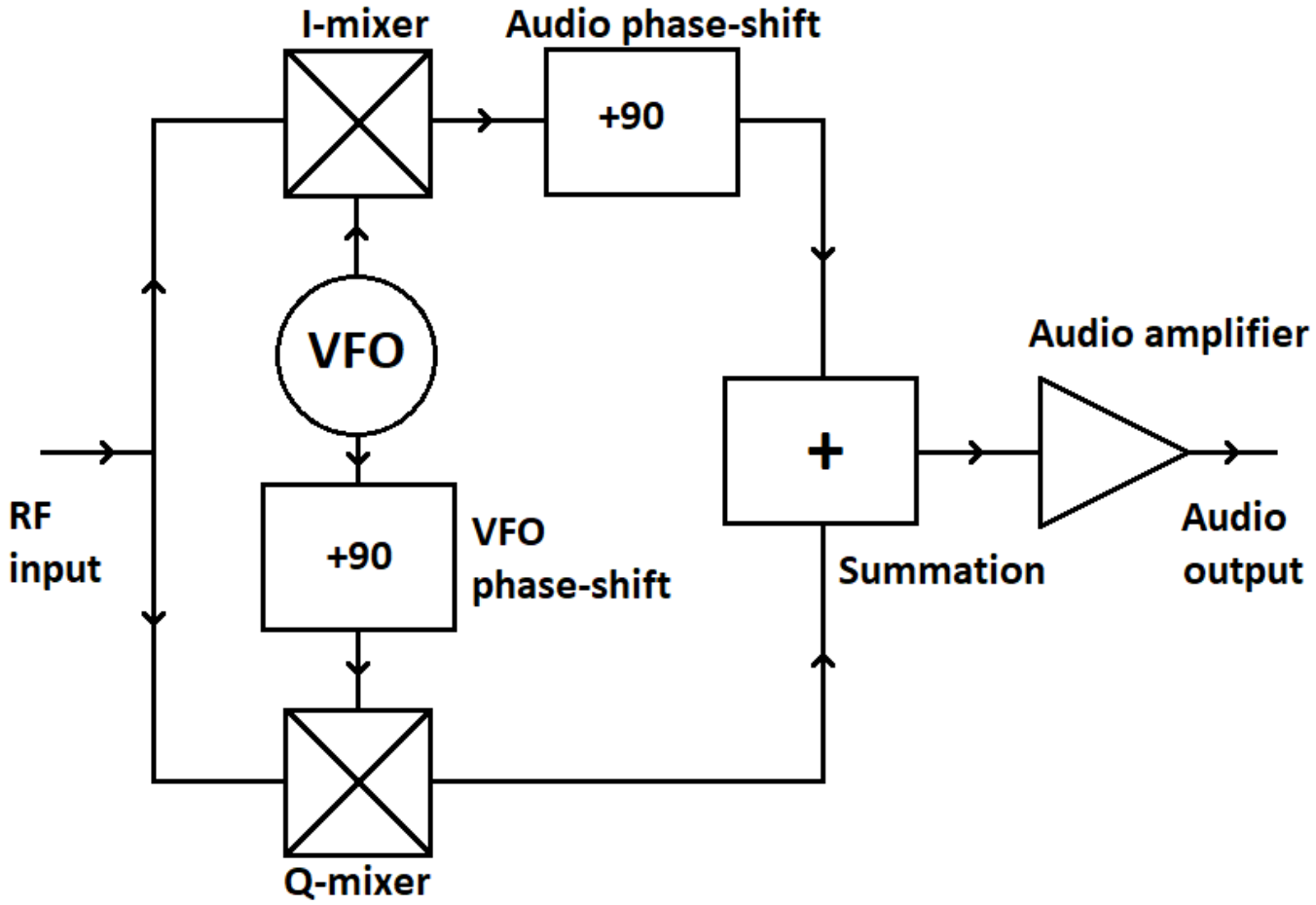
Direct Conversion receiver

- Cleaner sound than a superhet
- Avoids superhet alignment issues
- No unwanted mixing products “birdies”
- Main disadvantage: hears both sidebands at the same time!
- All the gain is at audio, so they can suffer microphonics and power line hum issues



Phasing method Direct Conversion

- 90-degree phase shift applied at RF, and at AF
- RF shift easiest at the VFO
- Some mathematics later:
  - One sideband reinforced
  - Other sideband magically disappears!
- Ideal in the digital world (SDR)
- Now used everywhere!



Quadrature Sampling Detector (Tayloe)

- Popularized and patented by Dan Tayloe N7VE
- 1:4 Multiplexer
- Very low loss, 1dB
- High dynamic range
- High IP3 e.g. +26dBm
- Convenient modern components like FST3253 bus switch

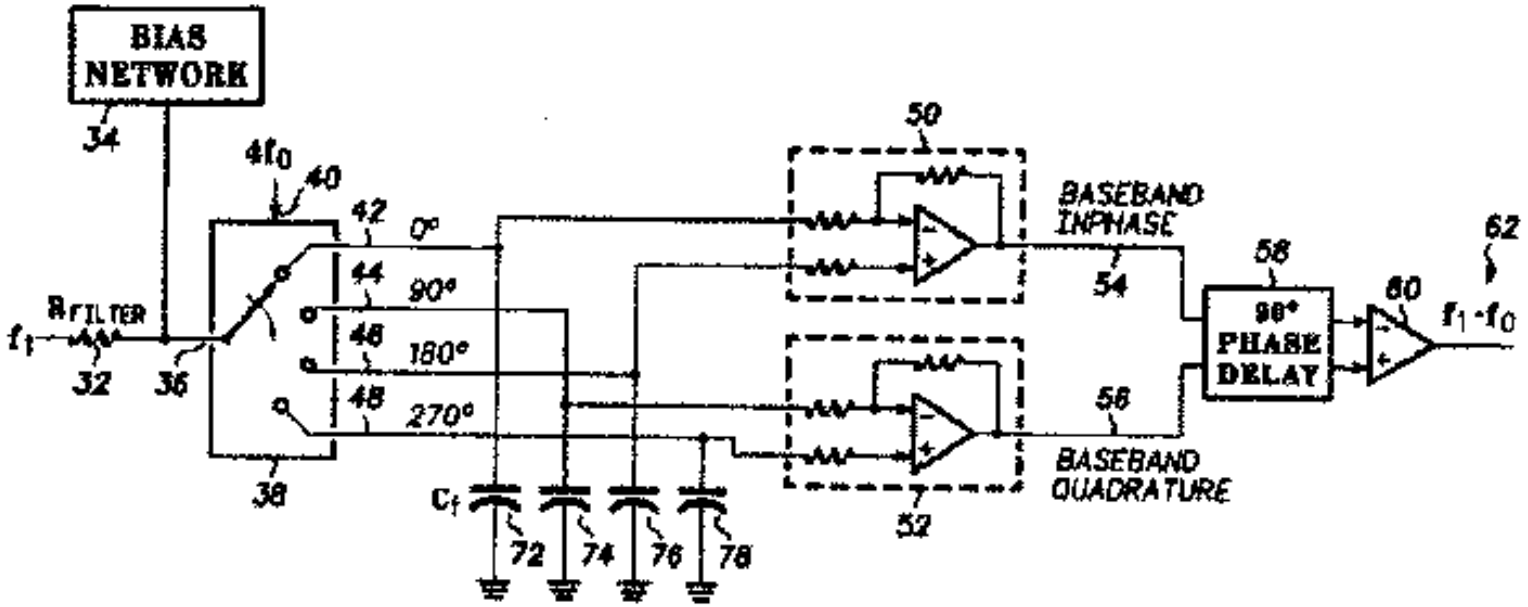
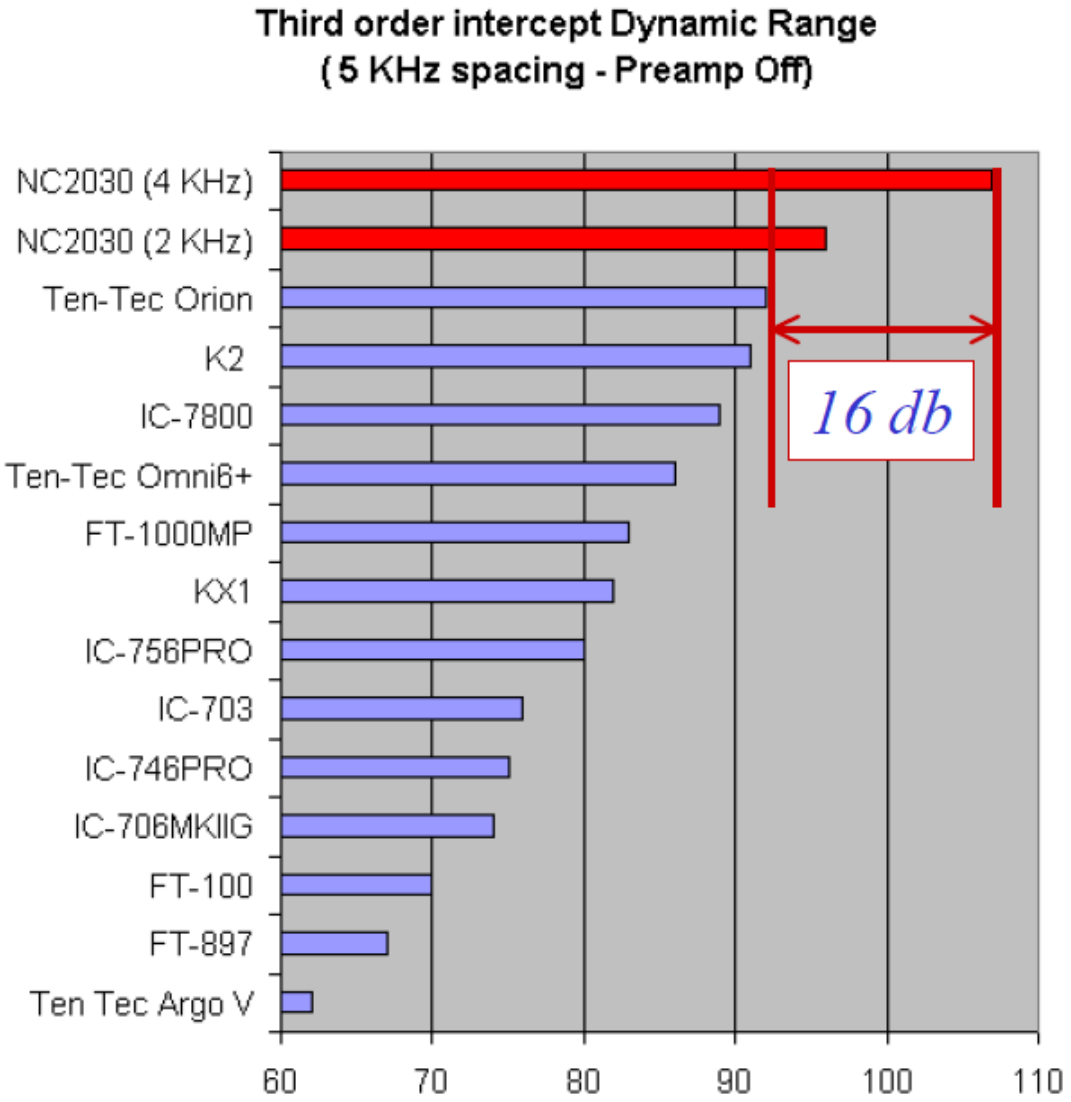


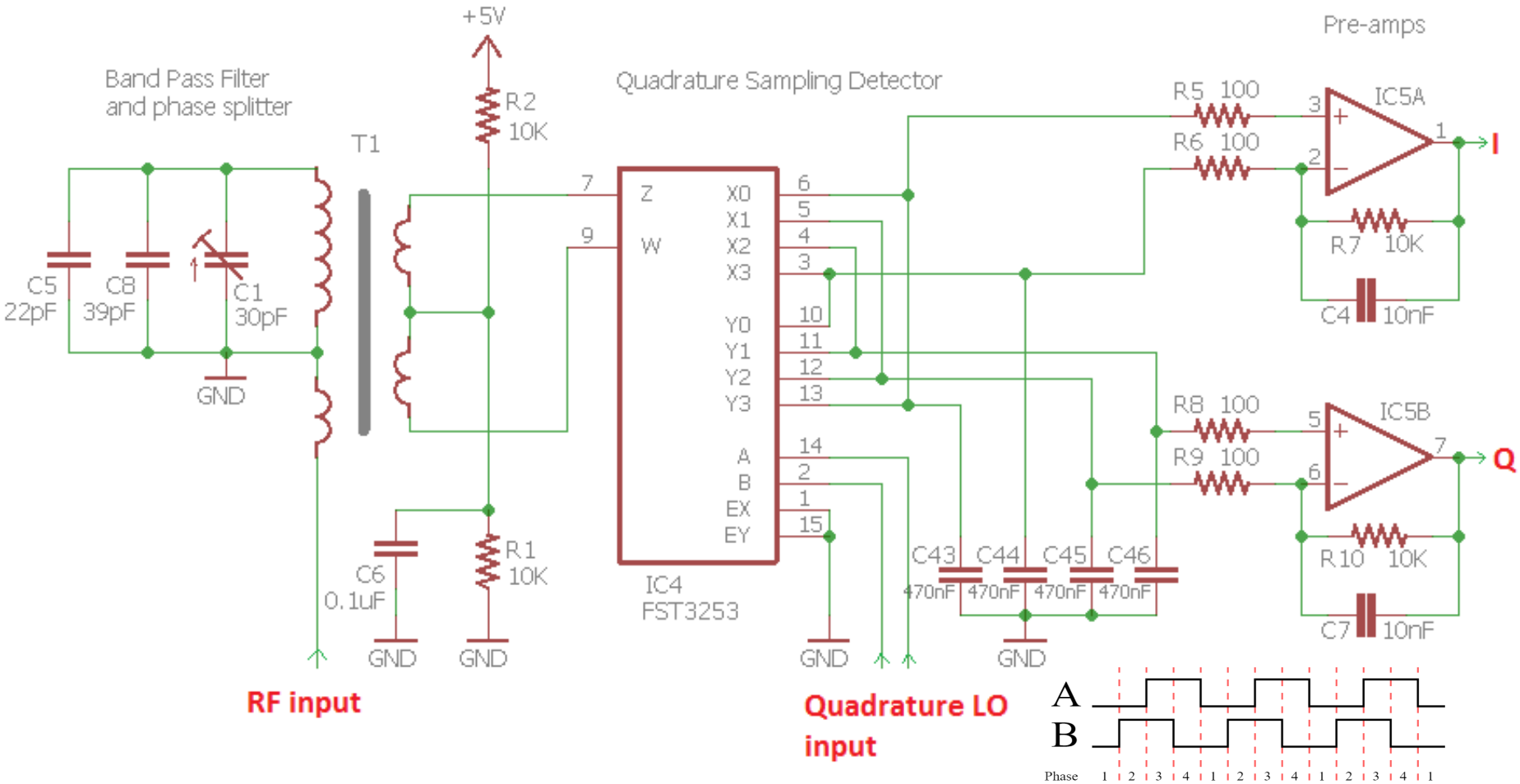
Fig. 1: Tayloe detector - electric diagram from the patent documentation

IP3 dynamic range comparisons with other radios

- From Dan N7VE's NC2030 transceiver presentation, 2004
- NC2030 outperforms famous radios from famous manufacturers, by a wide margin!

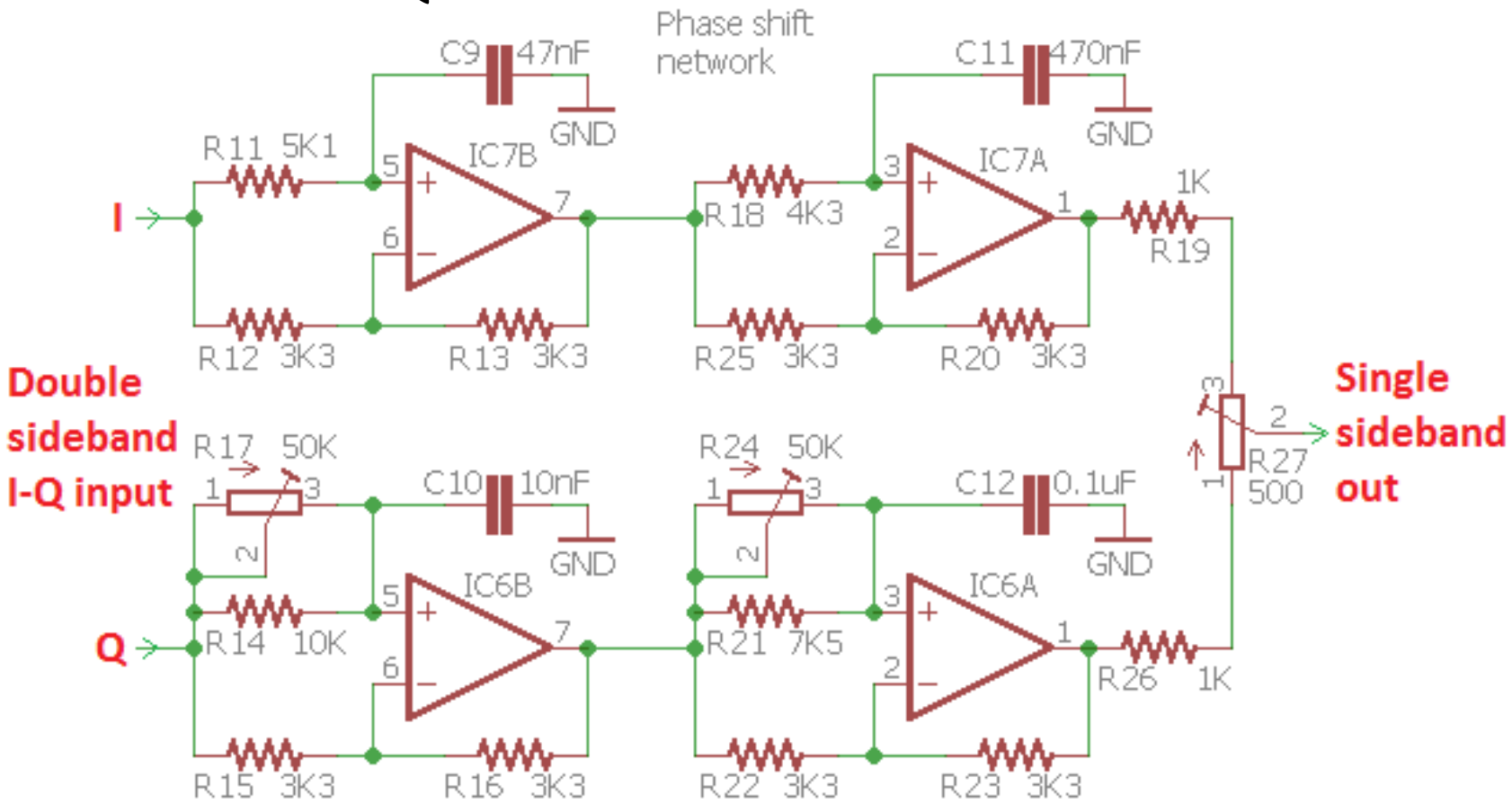


Double-balanced Quadrature Sampling Detector (QCX implementation)



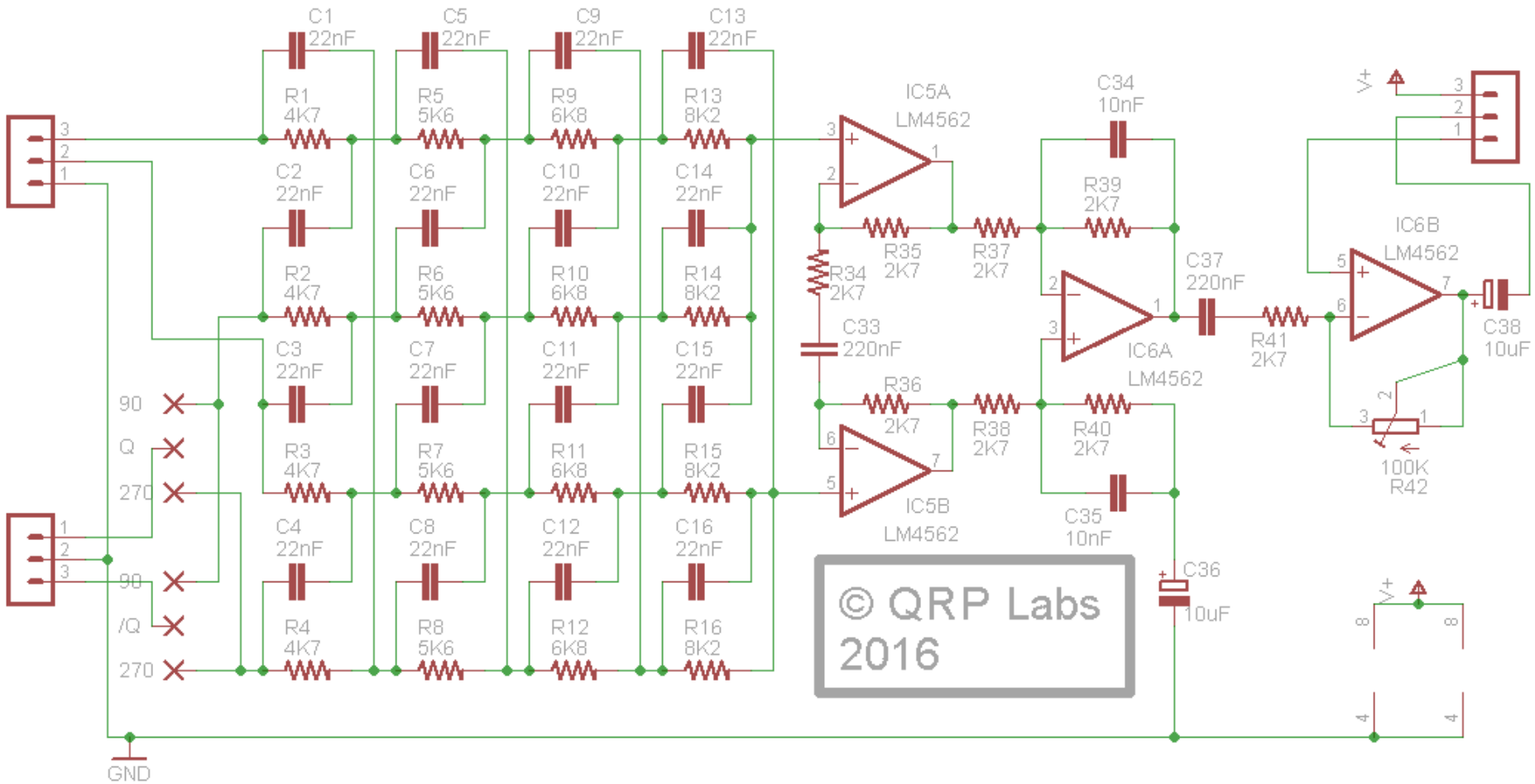
Audio phase shift: active all-pass network

- 90-degree phase shift network from the NC2030 transceiver, also used in the QCX



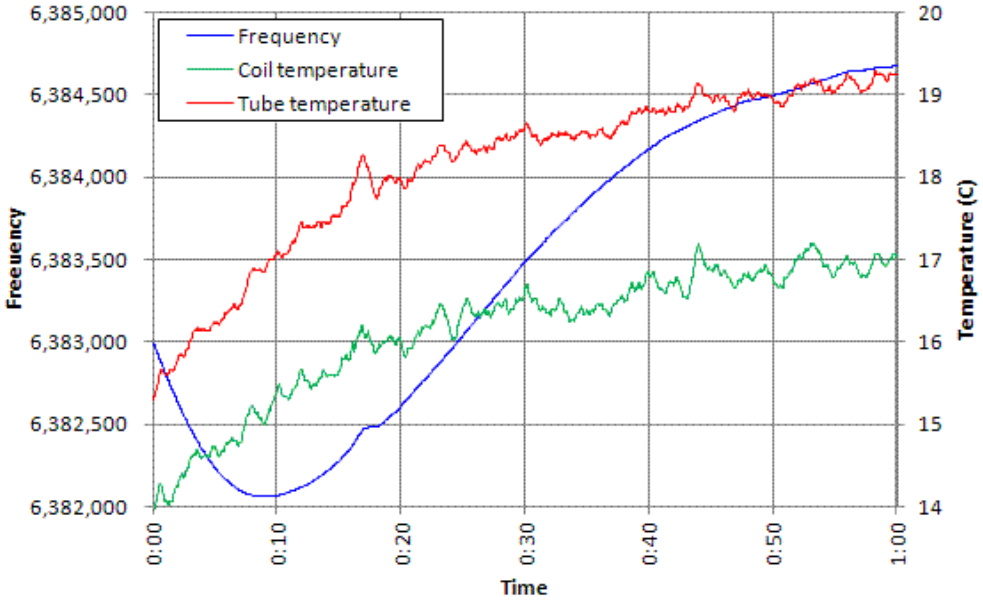
Audio phase shift: passive polyphase network

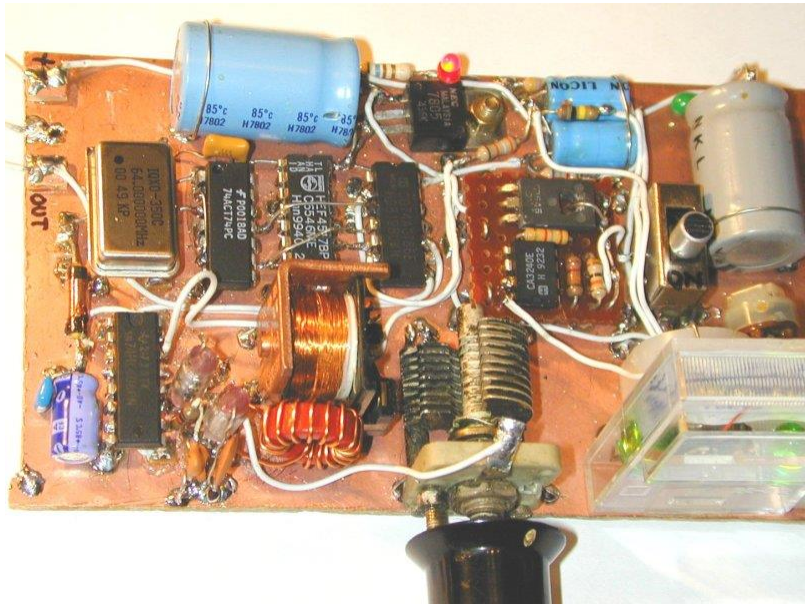
- Resistor-capacitor network used in QRP Labs Receiver module kit

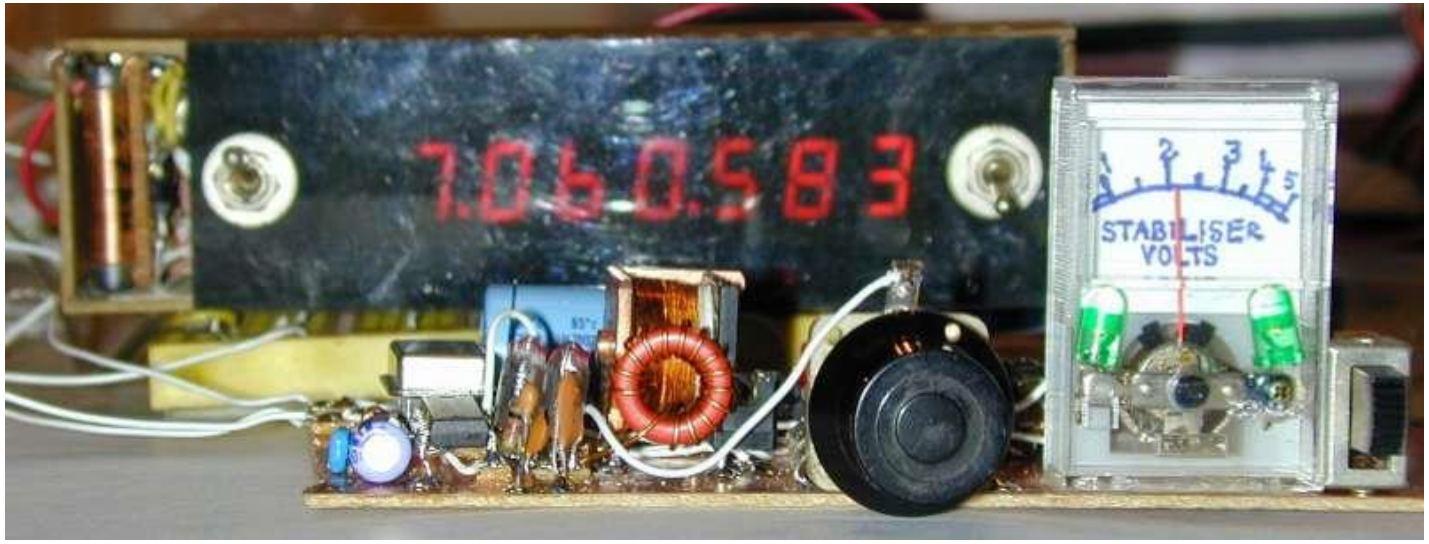


The oscillator problem

- We need a VFO that is:
  - Tunable over a reasonable range
  - Stable (no drift)
  - And tells us the frequency (a digital frequency readout or a mechanical dial)

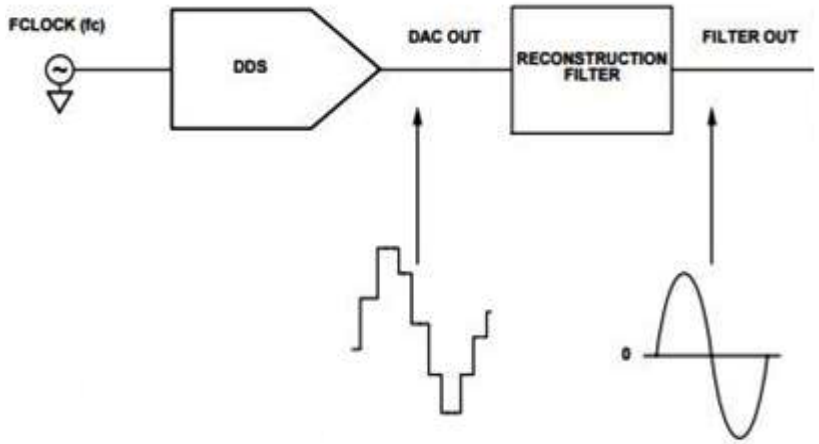


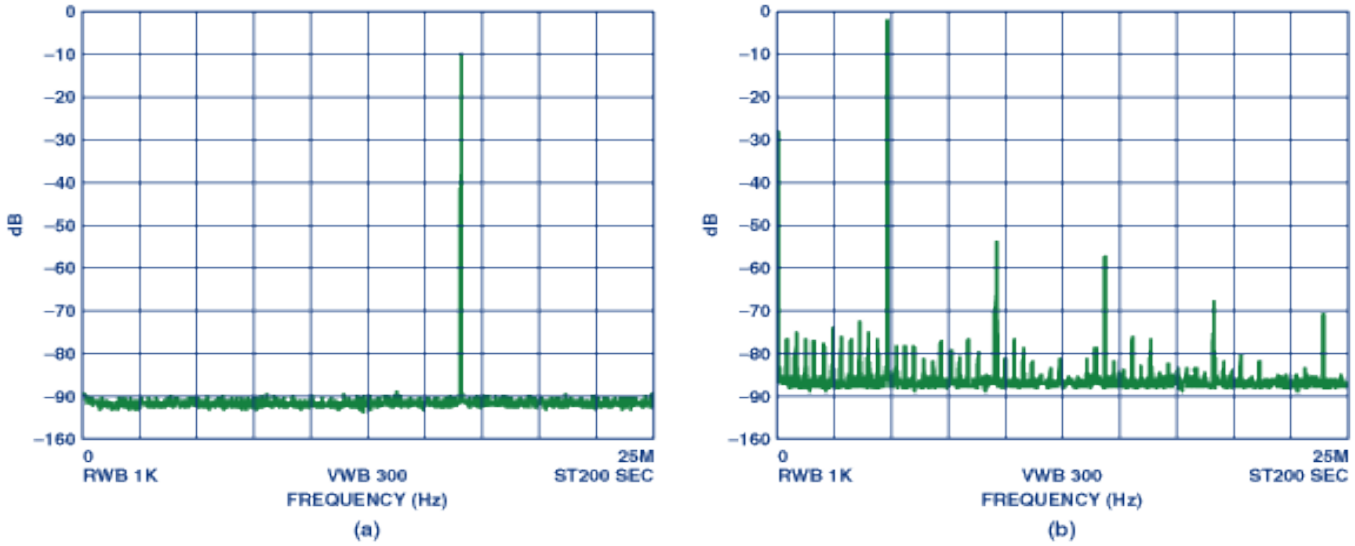




Direct Digital Synthesis (DDS) – e.g. AD9850

- DDS synthesizes a sinewave with a series of digital steps
- Fine control (0.034Hz) and crystal stability
- **BUT** – some low-level spurious outputs

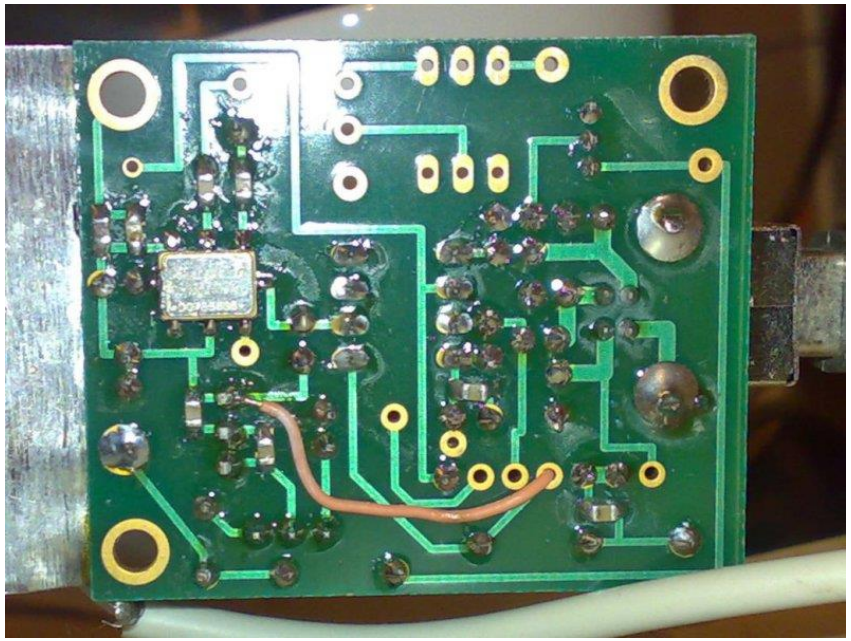




eBay
$14

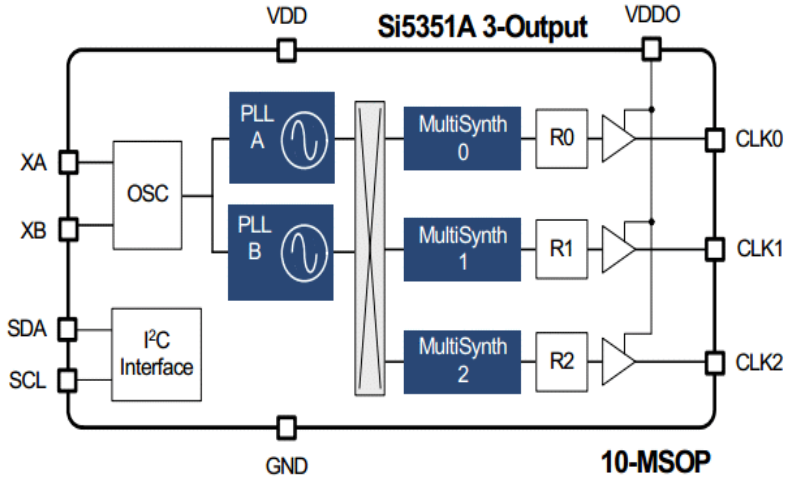
SiLabs Si570 Digital Phase Locked Loop chip

- 10MHz to 1.4GHz (depending on part number)
- Squarewave output
- I2C serial data programmable
- Integrated crystal gives rock-stable performance
- BUT – not very cheap at $11.50 (current Digikey price)



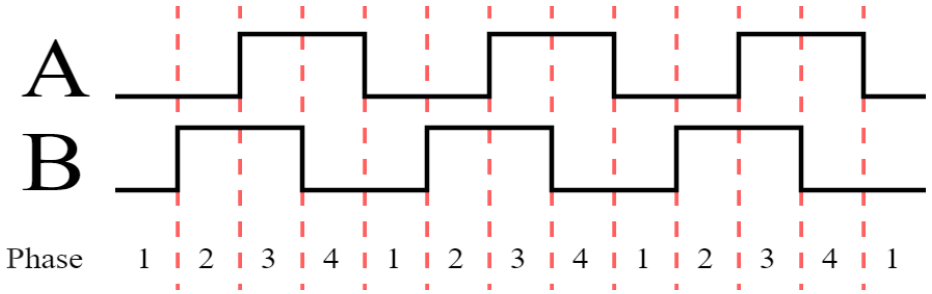
SiLabs Si5351A Digital Phase Locked Loop chip

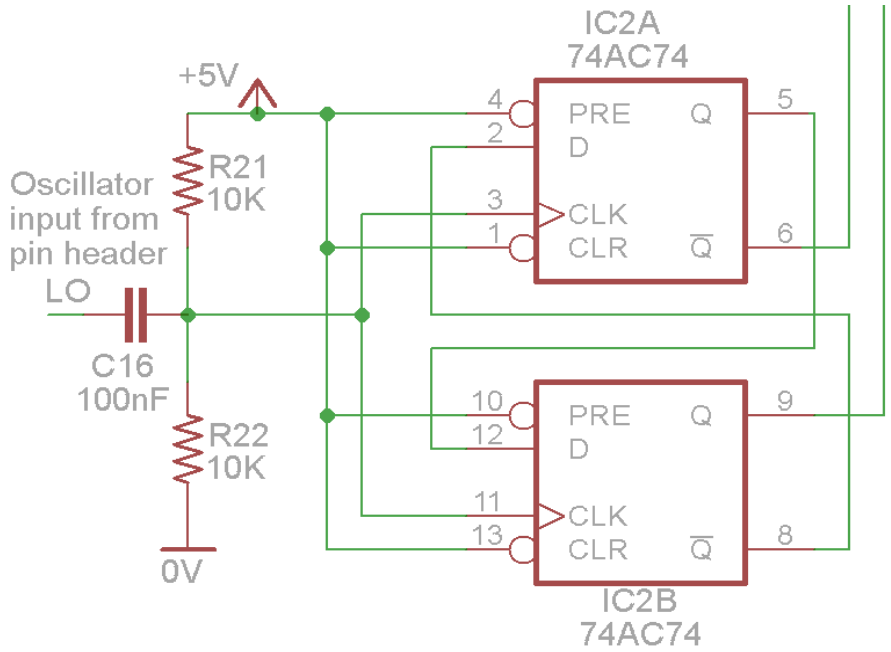
- Three independent outputs
- Squarewave output
- I2C Serial Data configurable
- External crystal provides rock-stable perfromance
- 3.5kHz to 200MHz range
- Very fine resolution
- Under a dollar! $0.92 (Digikey)
- Several “breakout” boards available
- Used in Elecraft KX2, KX3 and QRP Labs QCX



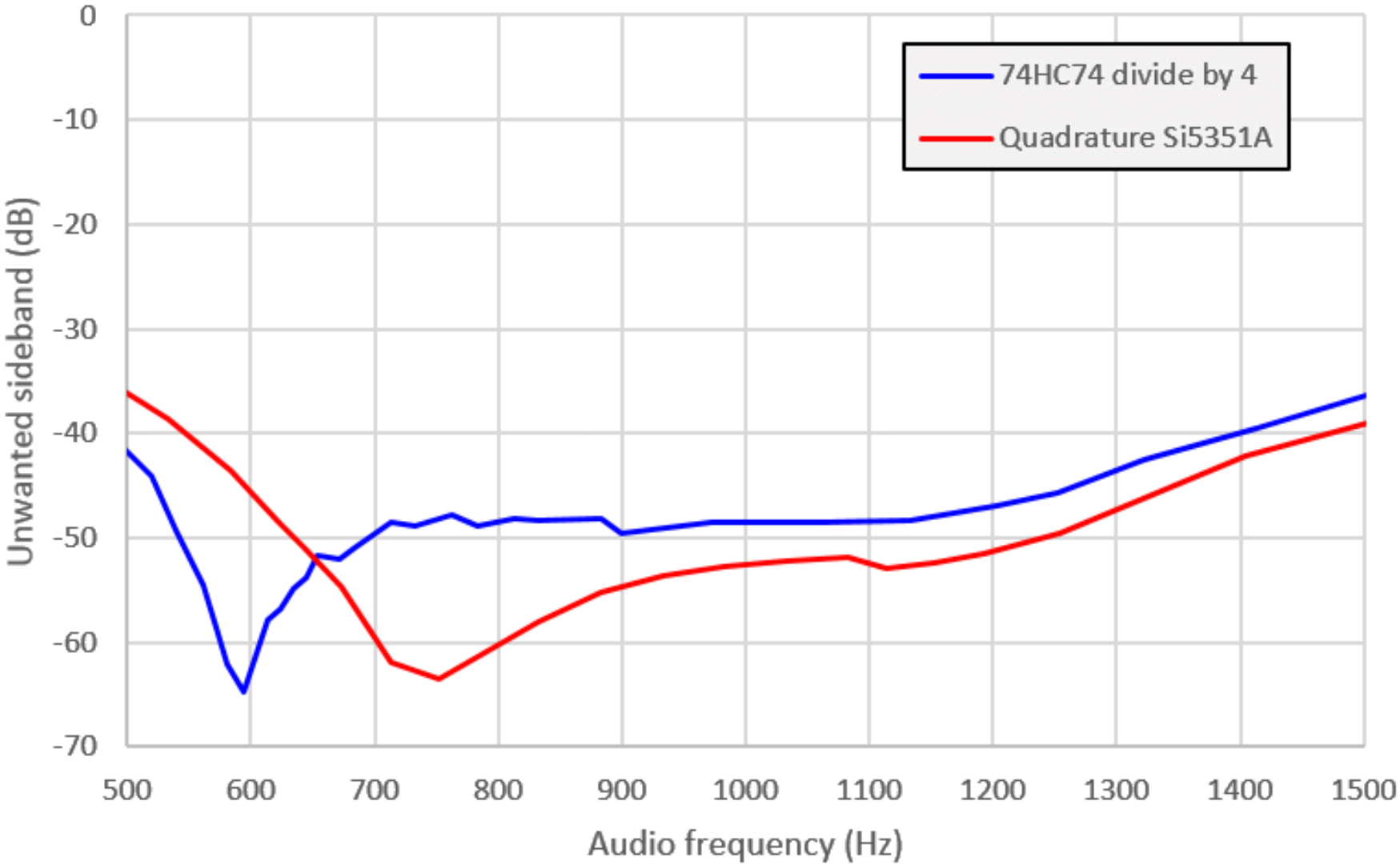
Quadrature LO for the Tayloe Detector (QSD)

- The QSD requires a quadrature LO (90-degree phase-shifted signals)
- Conventionally this has always been done with a dual D-type flip flop circuit and setting the LO at 4x the reception frequency
- Two Si5351A chip outputs can be set up with a 90-degree phase offset!
- QRP Labs were first to develop the technique for accurate, glitch-free quadrature LO tuning, implemented in the QCX transceiver





QCX unwanted sideband cancellation



Microcontrollers in your projects!

- A “microcontroller” is a microprocessor with several useful peripherals, all integrated on one chip.
- EEPROM for persistent storage
- Like a miniature and cheap computer-in-a-chip!
- We need it for programming the synthesizer (whether DDS, Si570 or Si5351A)

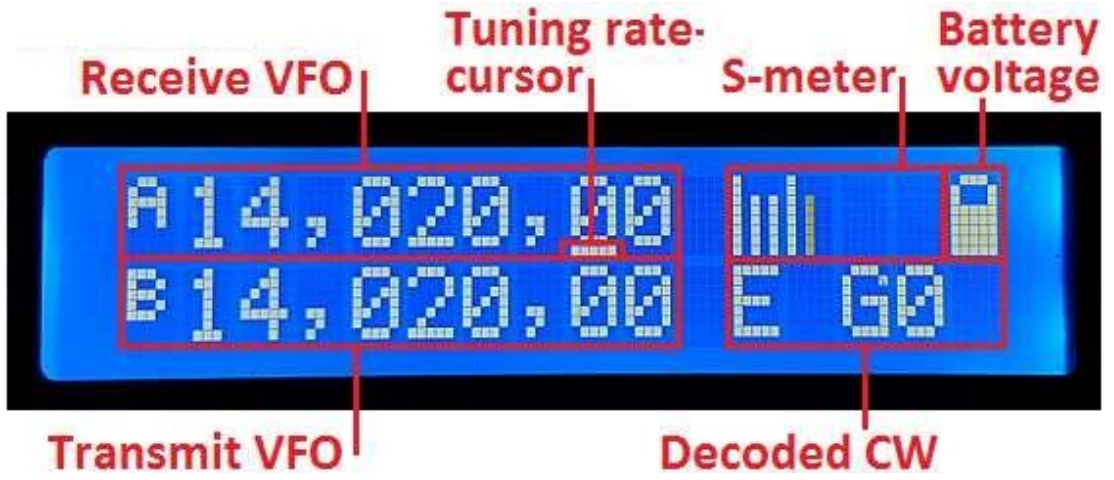
Arduino

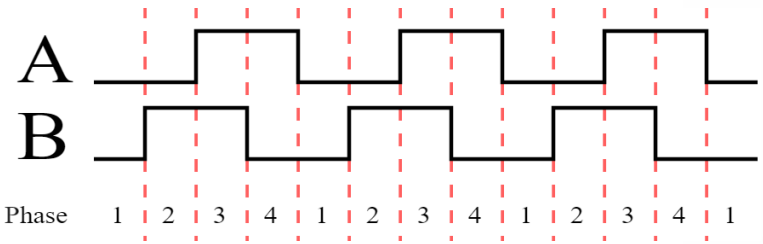
- A popular choice of micro board
- Free development environment
- Very easy to use
- Available in many different shapes and sizes
- Many plug-in shields
- Extensive examples, projects, support on the internet
- Highly recommended for beginners!

eBay
$2.50 →

VFO tuning. LCD

- Rotary encoder tuning
- Microcontroller configures the Si5351A Synth (example code available!)
- LCD readout
- VFO A/B/Split, RIT, Frequency memories, Offset etc



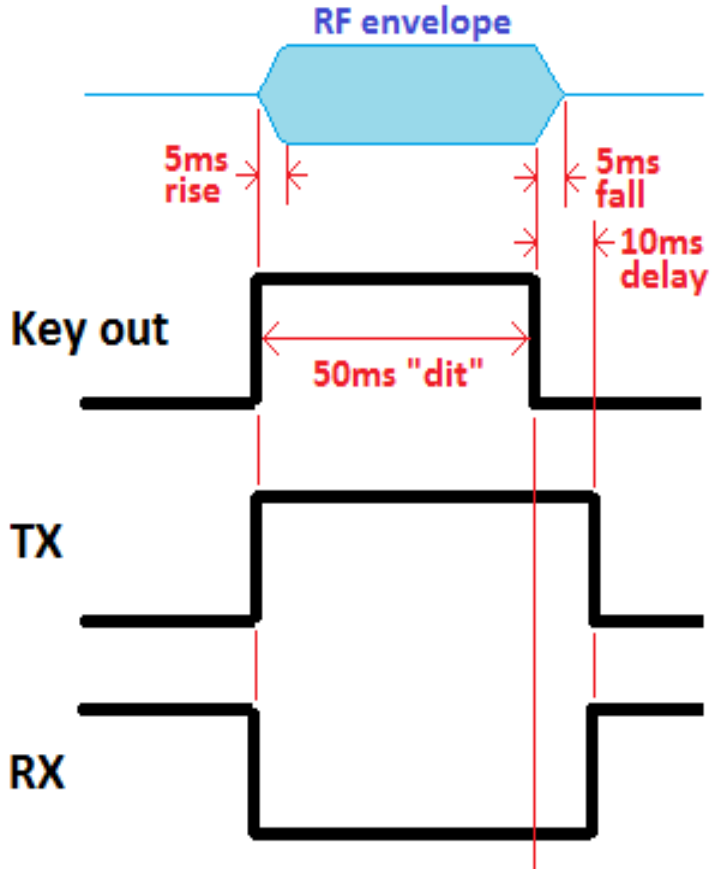


LCD ← eBay, $1.25

Rotary → encoder, eBay < $1

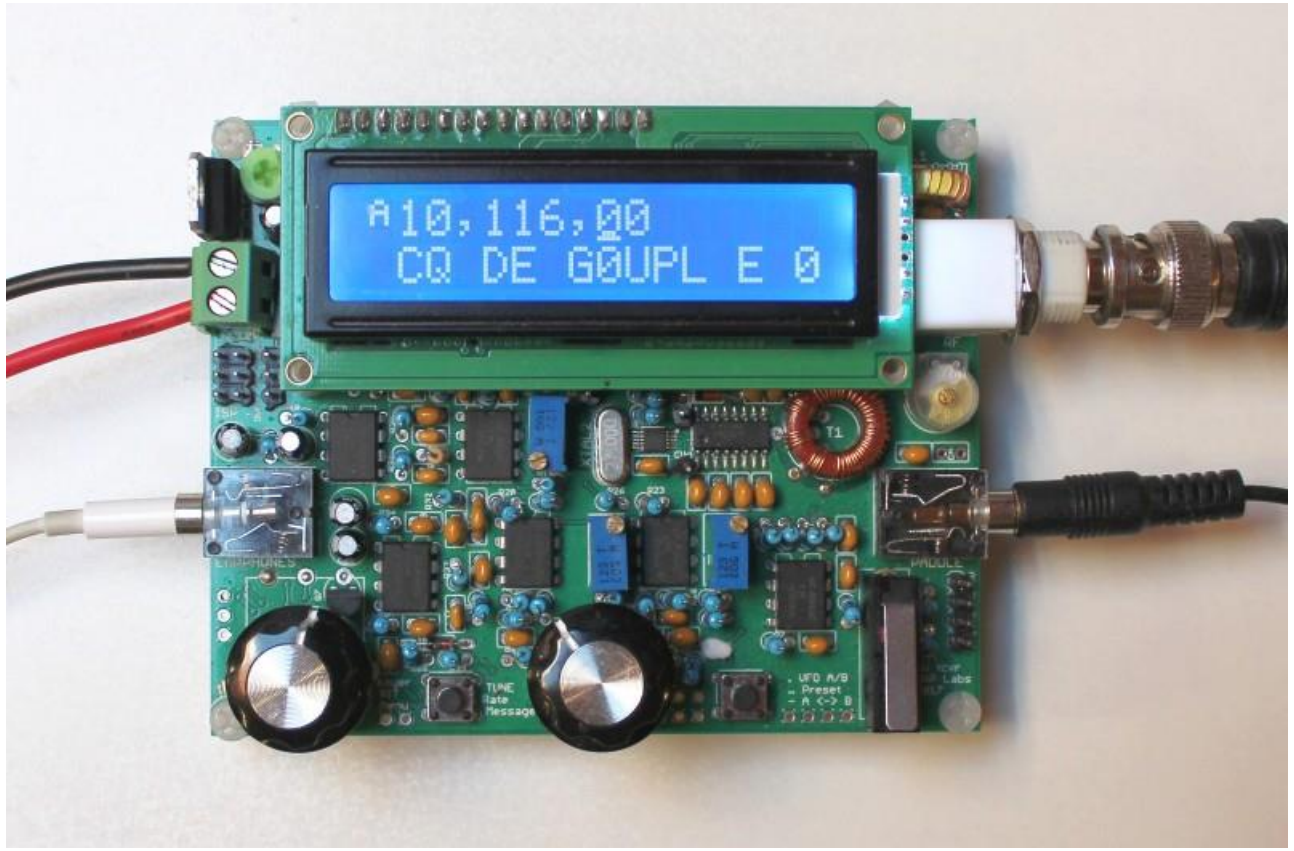
Iambic keyer, Tx/Rx sequencing, sidetone

- Include a keyer in the radio!
- The micro can handle Rx/Tx switching
- Timer outputs generate sidetone – with a configurable frequency and volume
- Message memories



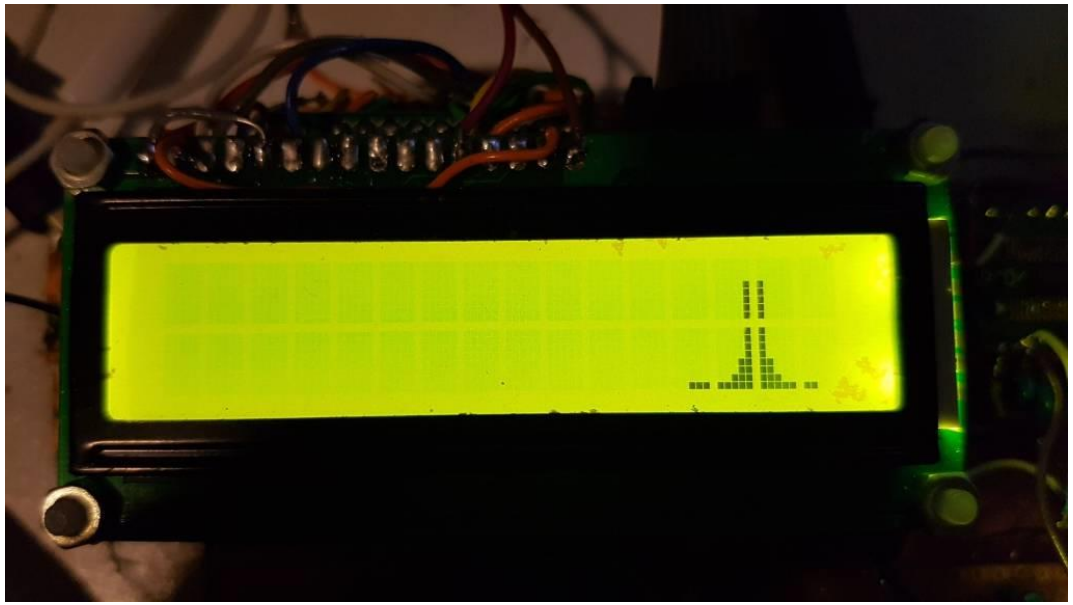
CW Decoder

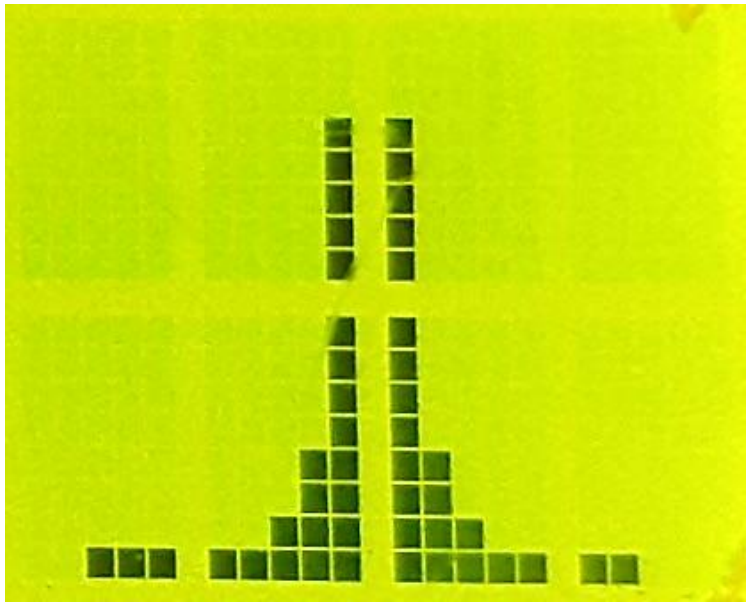
- The ATmega328 has a 10-bit, 6-channel Analogue to Digital converter (ADC)
- Digital Signal Processing?
- Goertzel algorithm is like a single FFT bucket
- CW Decoder has to track:
  - Amplitude (different signal strengths and QSB)
  - Sending speed



Panadapter (with 8-bit ATmega328 processor!)

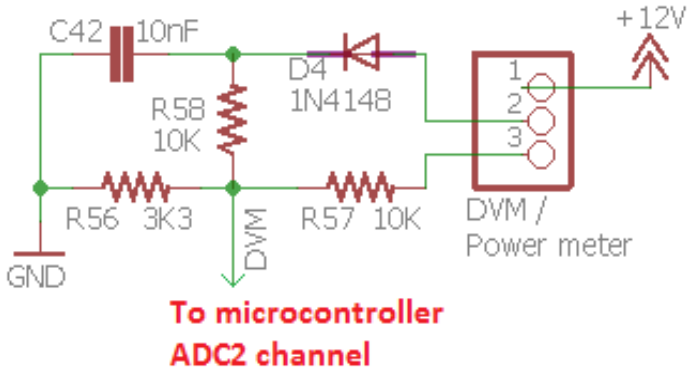
- Right 8 characters of display make a 20 x 16 pixel grid
- 20 buckets, 50Hz each centered on 700Hz
- Not very practical but perhaps useful as a tuning indicator?



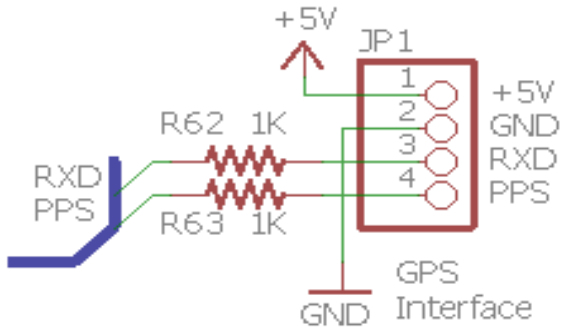


Built-in alignment tools and test equipment

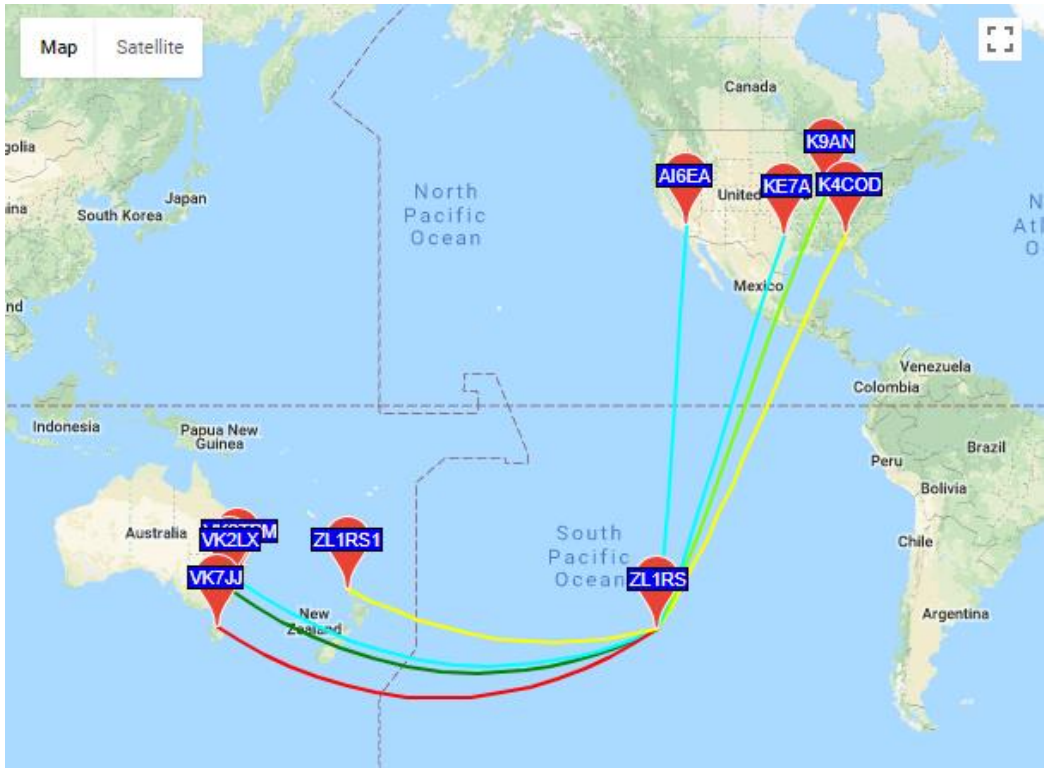
- Signal Generator 3.5kHz – 200MHz
- Digital Voltmeter (DVM) 0-20V
- RF Power meter 0-5W
- Frequency counter 0-8MHz
- Alignment tools, by signal injection into receiver front end: BPF, I-Q Balance, 90-degree audio phase shift



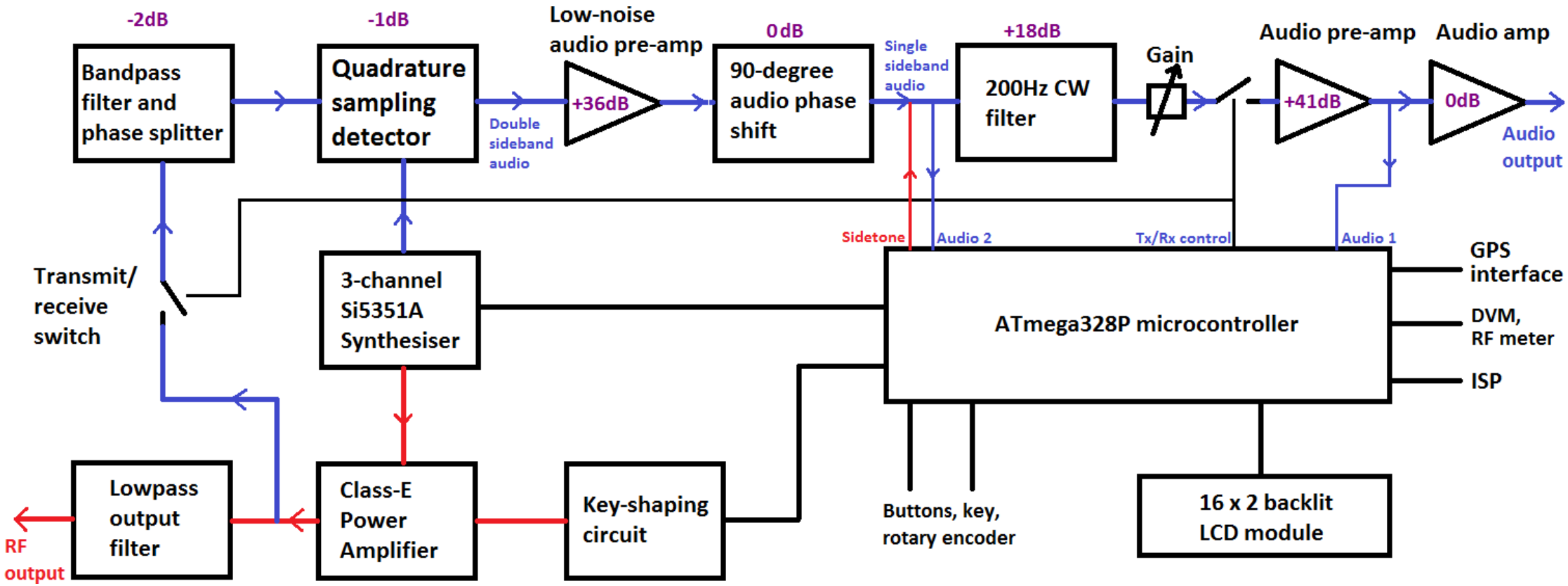
GPS interface and WSPR beacon



- Use the 1pps as a frequency counter gate, to measure the onboard 20MHz and 27MHz crystal frequencies
- Parse the serial data for Latitude, Longitude, convert to Maidenhead
- CW Beacon
- WSPR – Weak Signal Propagtion Reporter
  - Gridsquare
  - Callsign
  - Power (dBm)



QCX $49 5W CW transceiver block diagram



QRP Labs Lab Tech #2 (age = 21 months)