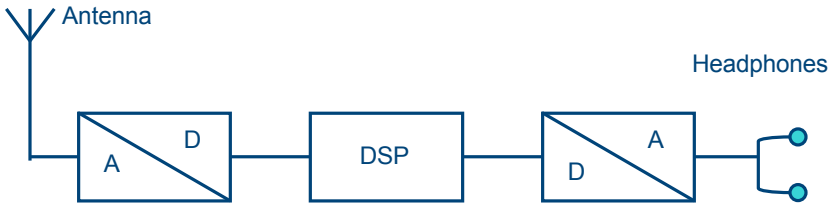
Software Defined Radios

Raj Dewan, N2RD

Software Defined Radio



A2D: Analog to Digital
Convert radio signals to digital data

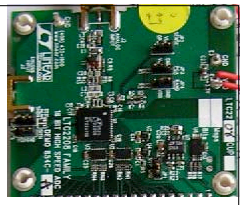
Digital Signal Processing
Process the digital data

D2A: Digital to Analog
Convert digital data to sound signals

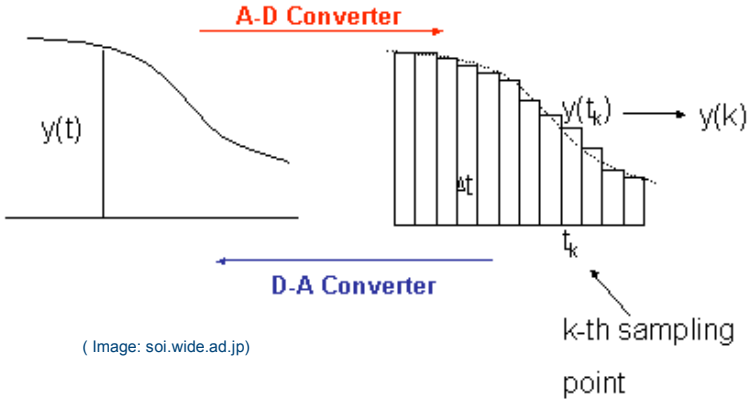
Digital Down Conversion (DDC)

Almost all of the radio is implemented using digital processing.

(Image From HPSDR Mercury WIKI)



A2D and D2A Converters



(Image: soi.wide.ad.jp)

Digital Signal Processing

(Image: KK7p's DSPx)

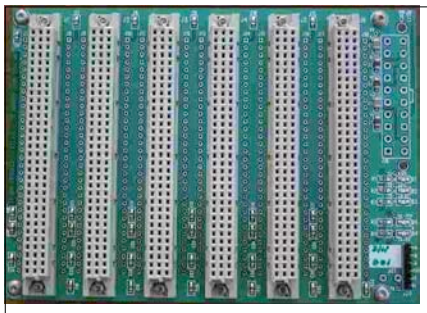
- Process the digital data that represents the signal
- May be done in the PC or by a special purpose chip
- Many companies make special purpose chips
  - Analog Digital, Motorola, Texas Instruments, etc

www.hpsdr.org

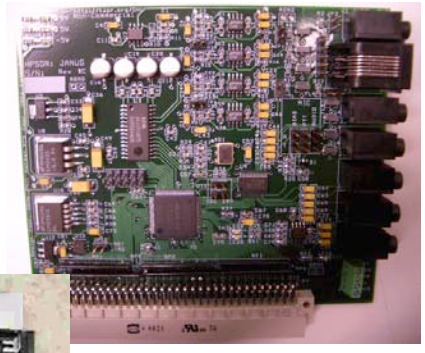
HPSDR – a open design of DDC

- Public domain design of DDC receivers
- Sold in kit form by TAPR (tapr.org)
- Includes
  - Atlas (motherboard, that connects all pieces together)
  - Janus (A2D and D2A on the audio side)
  - Ozymandias (PC interface, controller)
  - Mercury – HF (0 to 30Mhz) DDC

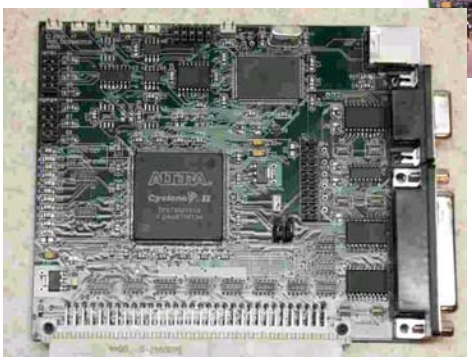
(Image: hpsdr.org)



Atlas



Janus



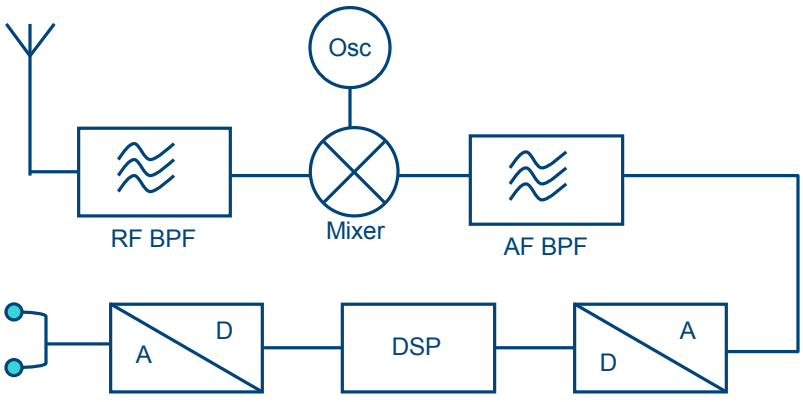
Ozymandias

(Images: hpsdr.org)

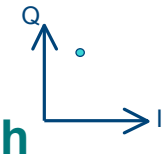
Issues with the DDC approach

- A2D converters that can handle HF are very expensive
  - Especially ones that have enough dynamic range and sensitivity
- Few suitable products that are affordable
  - HPSDR uses Linear's LT2208 (16 bit, 130MS, $100)
- Too much data to process
  - Decimation (throw out 999 out of every 1000 samples)
  - Have to do some processing before decimation to select band
  - HPSDR uses high speed Field-Programmable Gate Arrays (FPGA) for this purpose, then the data is sent to a PC via USB2 for processing
- Still hard to produce a world class receiver using this approach
- Many groups are trying
- Join TAPR and get the kits to experiment

Use Direct Conversion Receivers

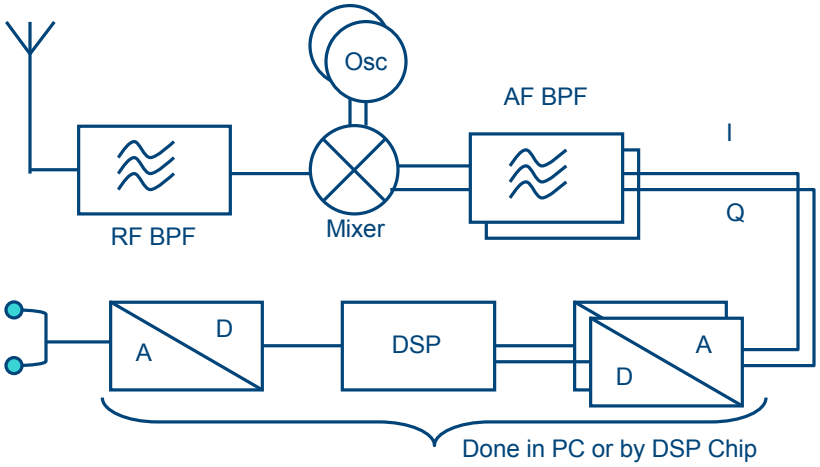


Problems with this approach



- All the deficiencies of direct conversion receivers
  - Hard to reject images
  - Not a single signal receiver
  - As you tune a signal you have two equally clear images
  - Cannot decode many kinds of signals
- Solution
  - Use two oscillators, 90° apart
  - (I: in phase, Q: in quadrature)
  - Two mixers are fed into two A2D
  - The two streams of data are processed as related I/Q streams
  - This provides the two datapoints (like X and Y) that helps in 'locating' signals in phase/amplitude space

Using I and Q streams

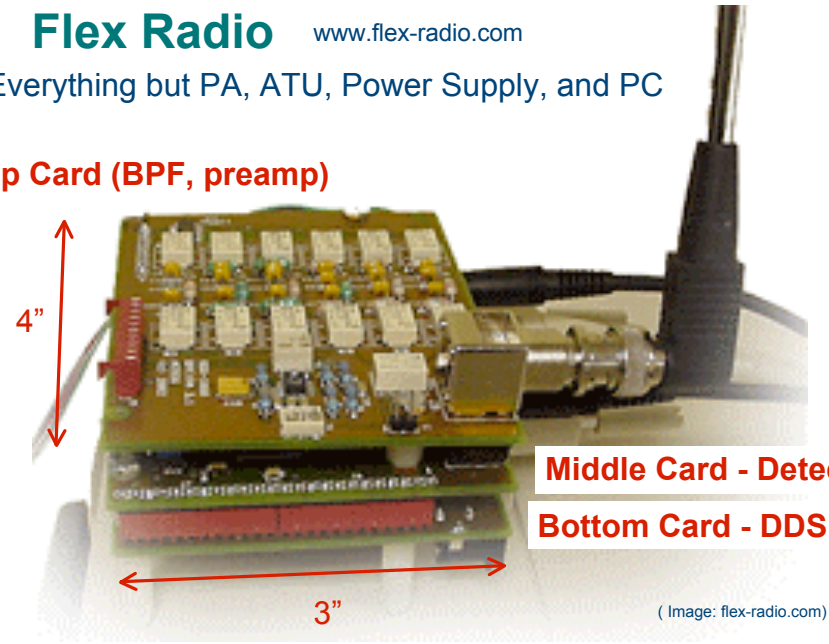


Flex Radio

www.flex-radio.com

Everything but PA, ATU, Power Supply, and PC

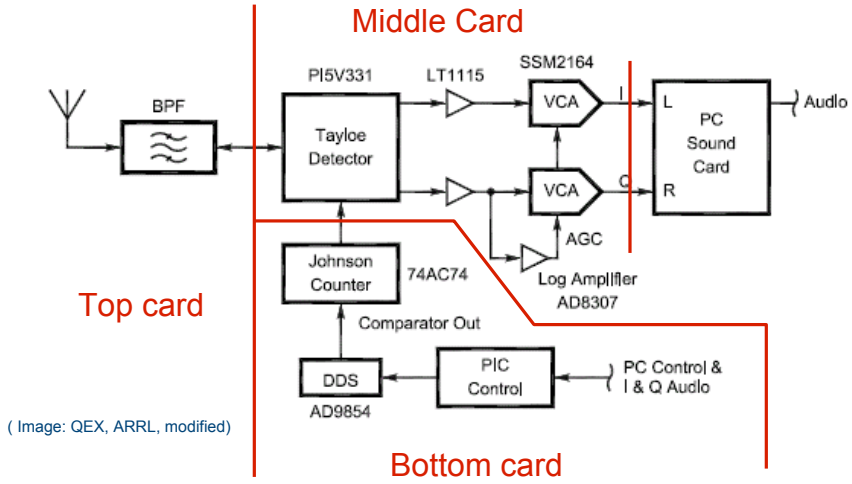
Top Card (BPF, preamp)



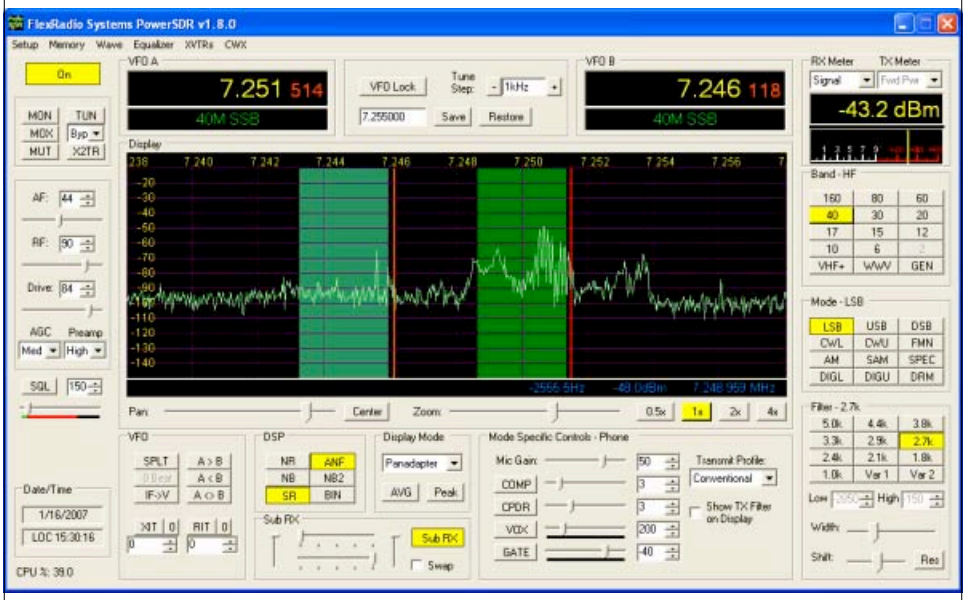
(Image: flex-radio.com)

SDR-1000 Block Diagram

Three 3”x4” Cards 1.8 to 60MHz Transceiver 1W



(Image: QEX, ARRL, modified)



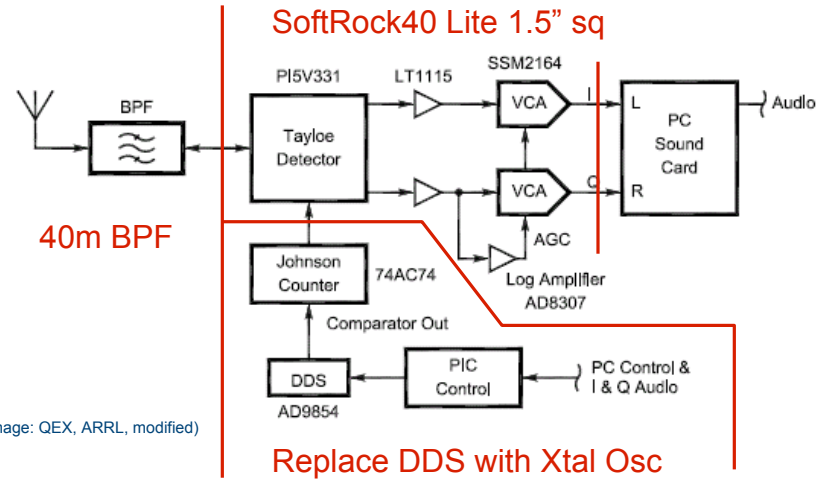
(Image: flex-radio.com)

Receiver Performance (20m)

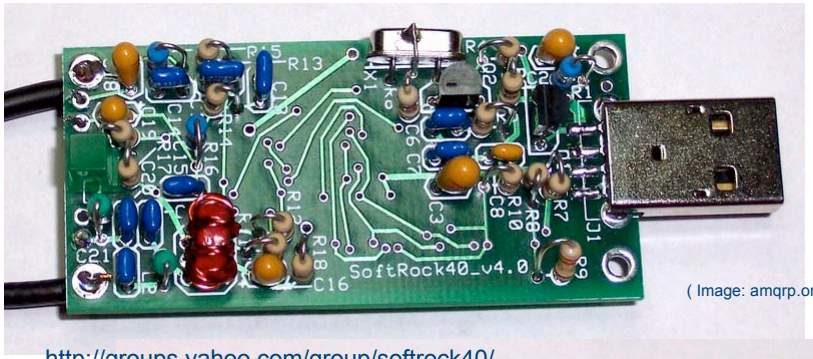
Radio	Blocking DR (dB)	3rd IM DR (dB)	3rd IM Inter (dBm)
Flex-Radio SDR-1000	111	98	+17
Icom 756 Pro III	113	99	+5
Yaesu 1000MP MkV F	122	97	+12

Soft-Rock-40 Block Diagram

Receive only, crystal controlled, 48KHz receiving bandwidth
Uses PowerSDR Software

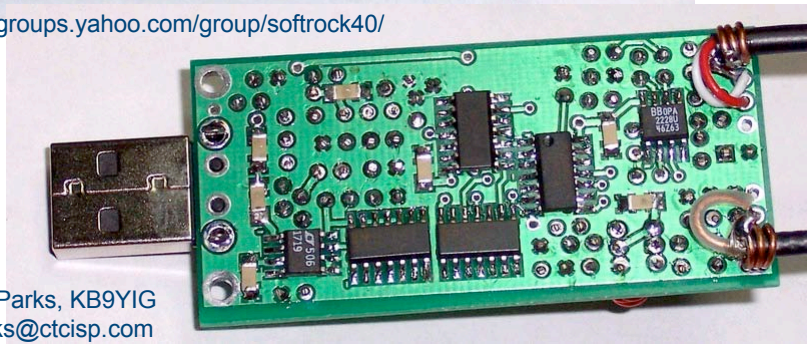


(Image: QEX, ARRL, modified)

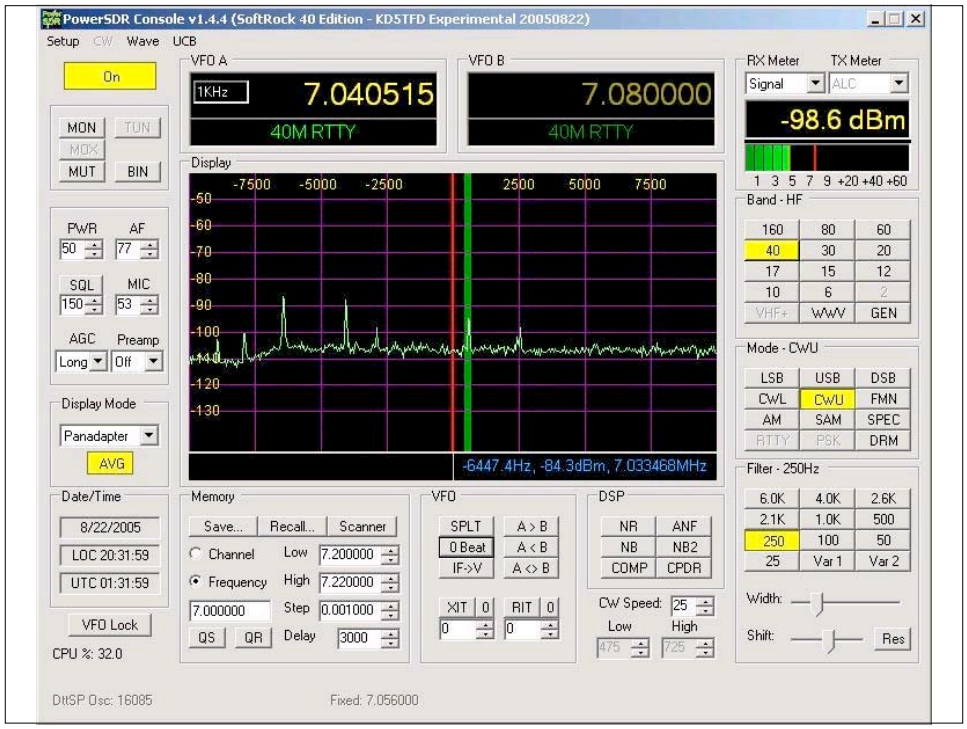


(Image: amqrp.org)

http://groups.yahoo.com/group/softrock40/



Tony Parks, KB9YIG
raparks@ctcisp.com



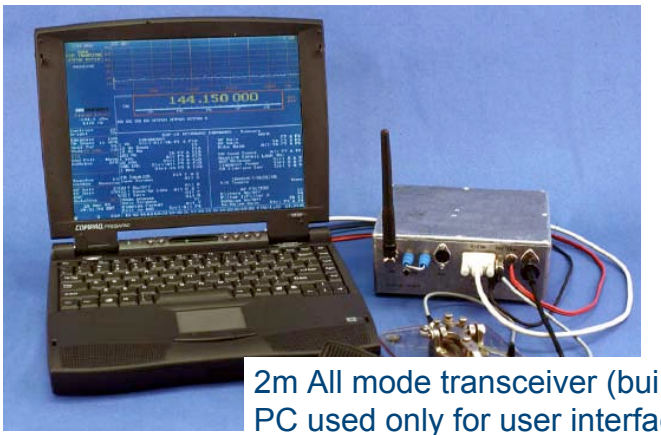
Problems with this approach

- Care and feeding of the A2D
  - No affordable A2D chips have adequate dynamic range or sampling rate
  - The sampling noise can be quite bad for low frequencies
- Need AGC, better control of bandwidth of signals sent to the ADC
- Easily done using
  - at least two superhet conversions before ADC
  - One conversion to 5 to 15MHz for which good quality crystal filters are available (roofing filter)
  - Good quality AGC/IF amp implementation
  - Second conversion to an IF of a few KHz
    - 15KHz IF, signals from 12Khz to 18KHz
    - Excellent A2D available for this frequency range
    - Less processing needed
- Another advantage: fine tuning done in DSP

Radios that use the double superhet conversion approach

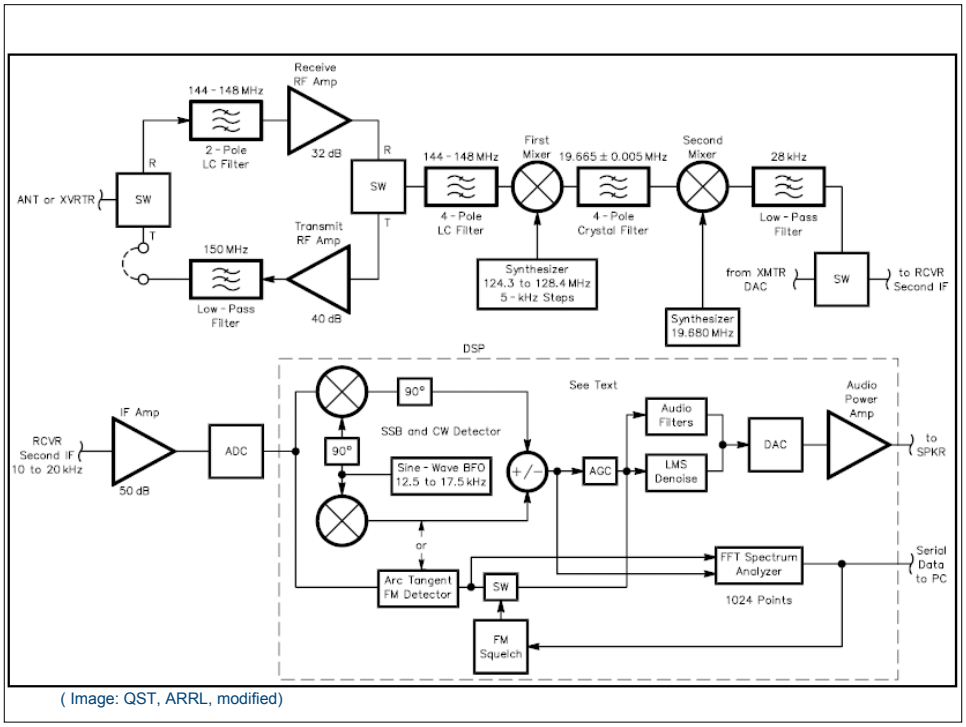
- Bob Larkin, W7PUA's, DSP-10 (QST '99)
  - 19.668MHz, 12Khz (higher IF for image rejection at 2m)
  - www.proaxis.com/~boblark/**dsp10**.htm
- Pic-A-Star by Peter Rhodes G3XJP (Radcom '00)
  - http://uk.groups.yahoo.com/group/**picastar**/
- Elecraft's K3 (just announced)
  - 8.215MHz and 15KHz
  - www.elecraft.com

Bob Larkin's (W7PUA) DSP-10

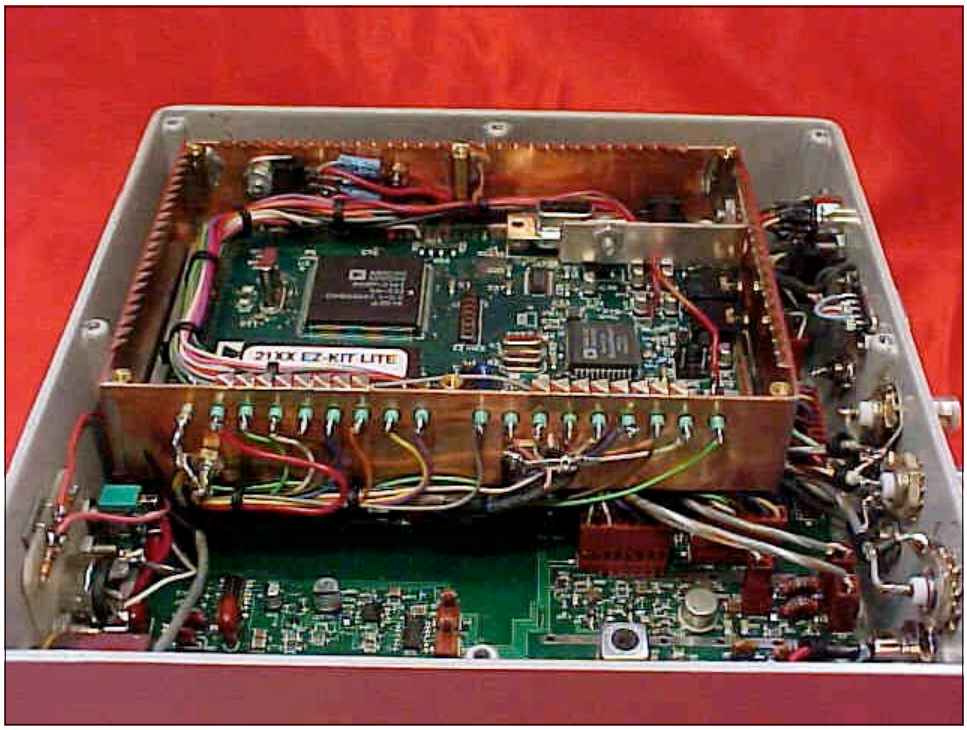


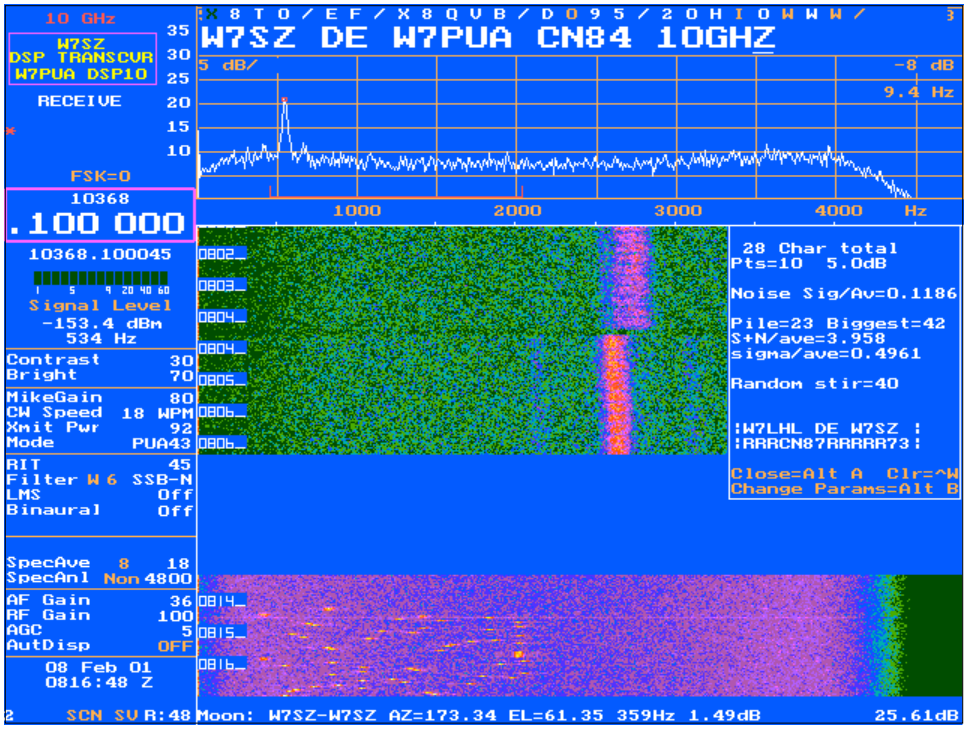
2m All mode transceiver (built in DSP)
PC used only for user interface

(Image: http://www.proaxis.com/~boblark/dsp10.htm)



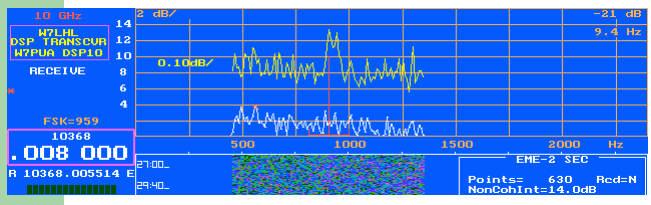
(Image: QST, ARRL, modified)





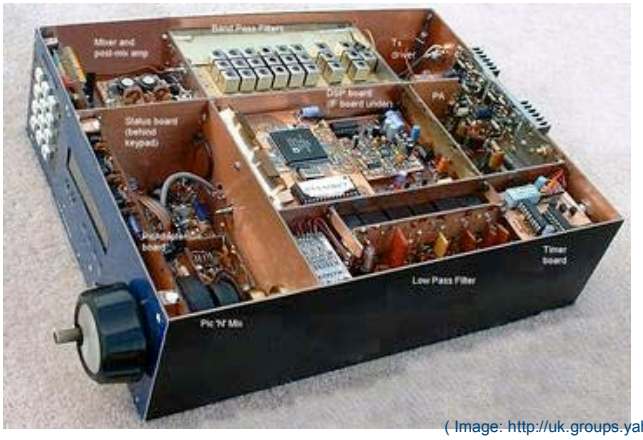
What can it do?

- Using special built in PUA43 mode
  - 5W 2m EME using single yagis
  - 5W EME qso on1296Mhz Band (tvro)
  - 10/15W 10GHz EME using TVRO
  - 1.2W 10GHz EME Self echo



(Image: http://www.proaxis.com/~boblark/dsp10.htm)

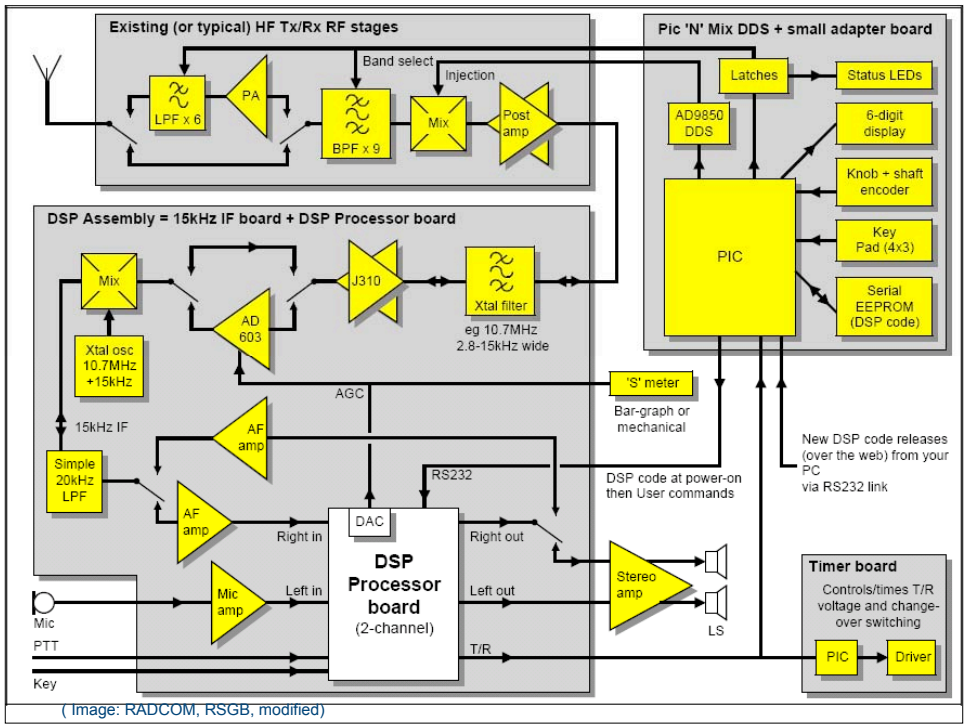
Pic-A-Star
Built by Peter G3XJP



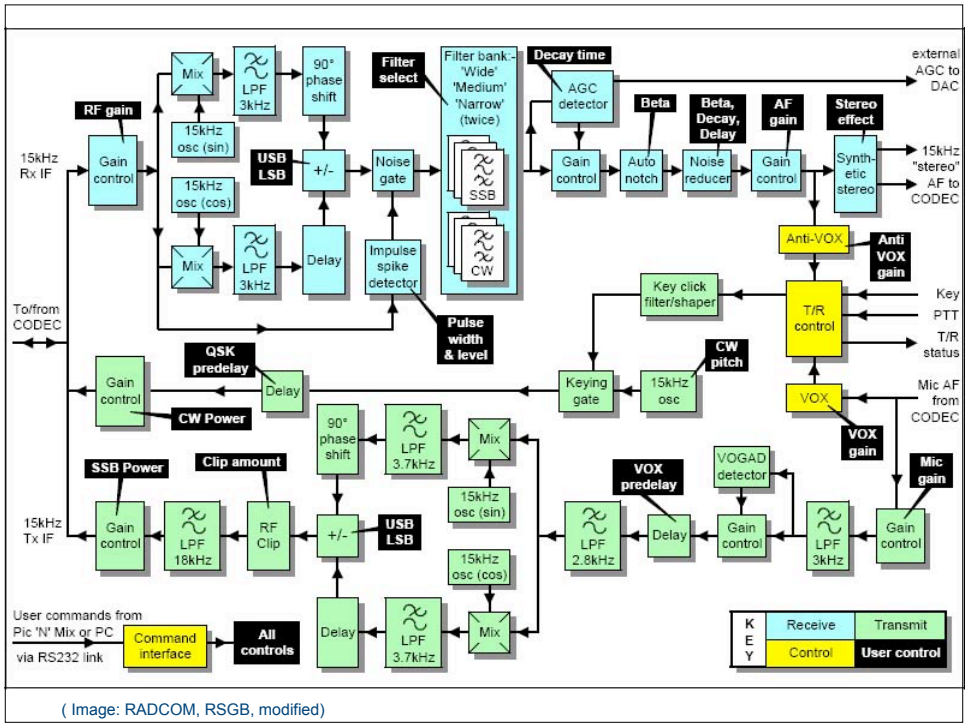
(Image: http://uk.groups.yahoo.com/group/picastar)

Pic-A-Star

- HF Transceiver, all band, all mode
- No PC needed/used
- All software is built in as firmware
  - Field upgradeable
  - Many PIC, DSP processors
  - Direct Digital Synthesis, Double conversion
  - World class performance
  - You build it yourself (including pcbs!)
- Designed by Peter Rhodes G3XJP
  - Serialized in over 20 articles in RADCOM



(Image: RADCOM, RSGB, modified)



(Image: RADCOM, RSGB, modified)

VOX in Pic-A-Star

- Careful sequencing of many stages
  - Controlled by a separate PIC processor
- Uses DSP to process for VOX
  - Voice is detected by the DSP, starts TX Cycle
  - Digitally delay transmission to remove clipping
  - Keeps transmitting for a short while after you stop speaking
  - No need to minimize transitions
  - Very rapid, frequent transitions, between syllables
  - Very clean, no pops because of careful sequencing of rx/tx chain
  - QSK for SSB!!!

More on Vox – Anti-Vox and AGC

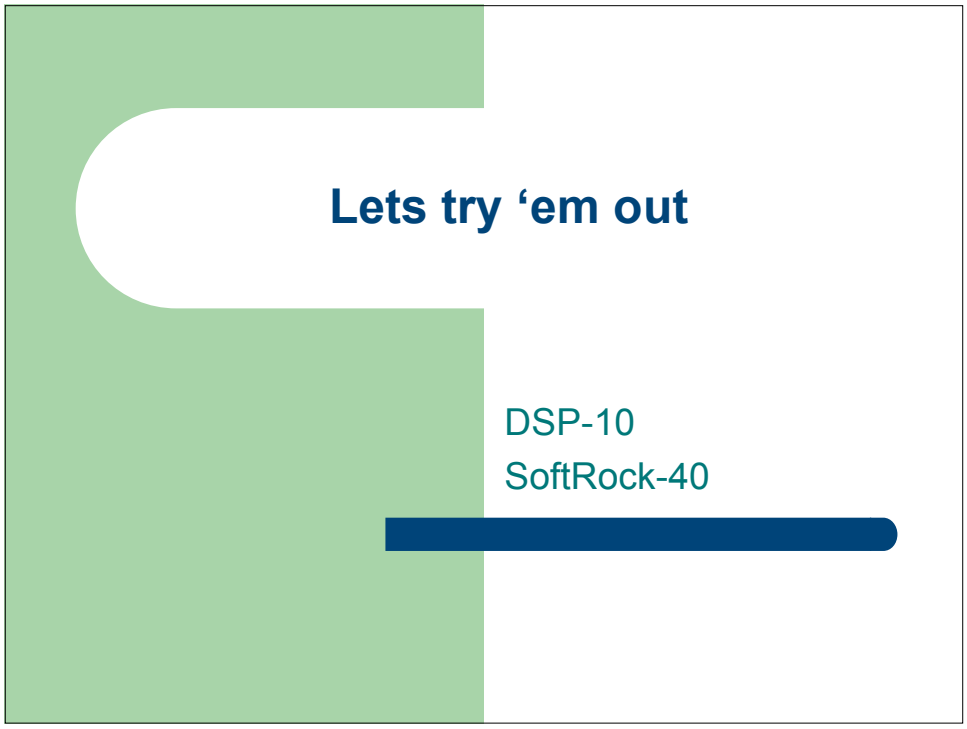
- Anti-Vox
  - Prevents receiver audio from keying the transmitter
  - time for sound to from speaker to mic, about 4', in air
  - compare mic input to speaker output 4ms ago
  - Activate only if mic input not same as speaker output 4ms ago
- Digitally remembers AGC level
  - When RX is un-muted, it does not start at max sensitivity
  - Uses the AGC value from last RX session for the next RX session
- Extremely smooth VOX

Receiver Performance (20m)

Radio	Blocking DR (dB)	3rd IM DR (dB)	3rd IM Inter (dBm)
Flex-Radio SDR-1000	111	98	+17
Icom 756 Pro III	113	99	+5
Yaesu 1000MP MkV F	122	97	+12
Pic-A-Star		103	+31

Elecraft K3

(Image: elecraft.com)


Lets try ‘em out
DSP-10
SoftRock-40