Homebrewing A Software Defined Radio (SDR)

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NAØTC - 285 TechConnect Radio Club

http://www.naøtc.org/

Goal

- **Stimulate Interest in Homebrewing**
  - **Simple projects**
    - .
    - .
    - .
  - **High performance SDR transceivers**

What We Will Cover

- How to Get Started
- Who offers kits for ham radio applications
- What is a Software Defined Radio
- Who offers Software Defined Radio Kits
    1. Beginner
    2. Intermediate
    3. Experienced
- Genesis G59 HF SDR Transceiver: Project Overview
    1. Goals
    2. Approach
    3. Overview of Design
    4. Performance summary
    5. Lessons Learned
- Summary

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- How to Get Started
- Who offers kits for ham radio applications
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- Who offers Software Defined Radio Kits
    1. Beginner
    2. Intermediate

This discussion will focus on receivers

    1. Goals
    2. Approach
    3. Overview of Design
    4. Performance summary
    5. Lessons Learned
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How to Get Started

- Identify Goals
  - Homebrewing can cost more than buying used
- Assess Complexity
  - Review build instructions before purchasing a kit
  - A SDR may not be the best choice for a first time builder
    - Building a SDR can require:
      - Circuit design knowledge (digital, analog and RF)
      - Build experience (probably SMD experience)
      - Test/troubleshooting experience
      - Knowledge of how to set up software applications
      - A variety of test equipment
      - Need for technical support
- Support
  - Find an Elmer
    - The TechConnect Radio Club has a list on their website
  - Internet based support groups
    - Yahoo Groups
  - Can you send your item to someone to get it working?

How to Get Started – cont'd

- **Who offers kits for *amateur radio* applications (*short* list):**

  - Elecraft
  - Communications Concepts Inc
  - Fox Delta
  - Softrock
  - Genesis
  - Emtech
  - Small Wonders Lab
  - Almost-All-Digital-Electronics
  - Vectronics
  - Lazy Dog Engineering
  - Cross Country Wireless
  - Ten Tec
  - HFprojects (K5OOR)
  - Kits and Parts
  - Ramsey
  - Wilderness Radio

- **For those with some homebrewing experience:**

  "Experimental Methods in RF Design", Hayward, et al

What is a Software Defined Radio?

A **Software Defined Radio (SDR)** is a radio which has been designed to allow some, or all, of the ***traditional functionality*** of a radio to be handled in software/firmware on a computer, rather than in hardware.

- Note that SDR ***does not mean*** **control** of a radio using software

- SDR ***means*** the ***implementation*** of a radio ***in firmware or software***
  - Implies "**Digital Signal Processing**" (**DSP**)
  - Debate continues among the "experts" as to what constitutes "implementation of a radio"
    - RF based DSP
    - IF based DSP
    - Analog to digital conversion at the antenna (Flex 6000)

Signal Processing

- **What is Signal Processing?: Anything intentionally done to improve the recovery of signal information**
  - **Amplification**
  - **Filtering**
  - **Noise Limiter**
  - **Detection**
  - **Demodulation**
  - **Automatic Gain Control**
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Digital Signal Processing (DSP)

- Amplification
- Filtering
  - "Brickwall" Filters*
  - Auto Notch
  - Tracking Notch
- Noise Limiter
- Noise Reduction*
- Detection
- Demodulation
- Automatic Gain Control
- .
- .

*: Not achievable with analog signal processors

Digital Signal Processing (DSP)

- Amplification
- Filtering
  - "Brickwall" Filters*
  - Auto Notch
  - Tracking Notch

1. DSP is simply the newest technique for implementing traditional functionality
2. DSP offers some features not available with Analog Signal Processing

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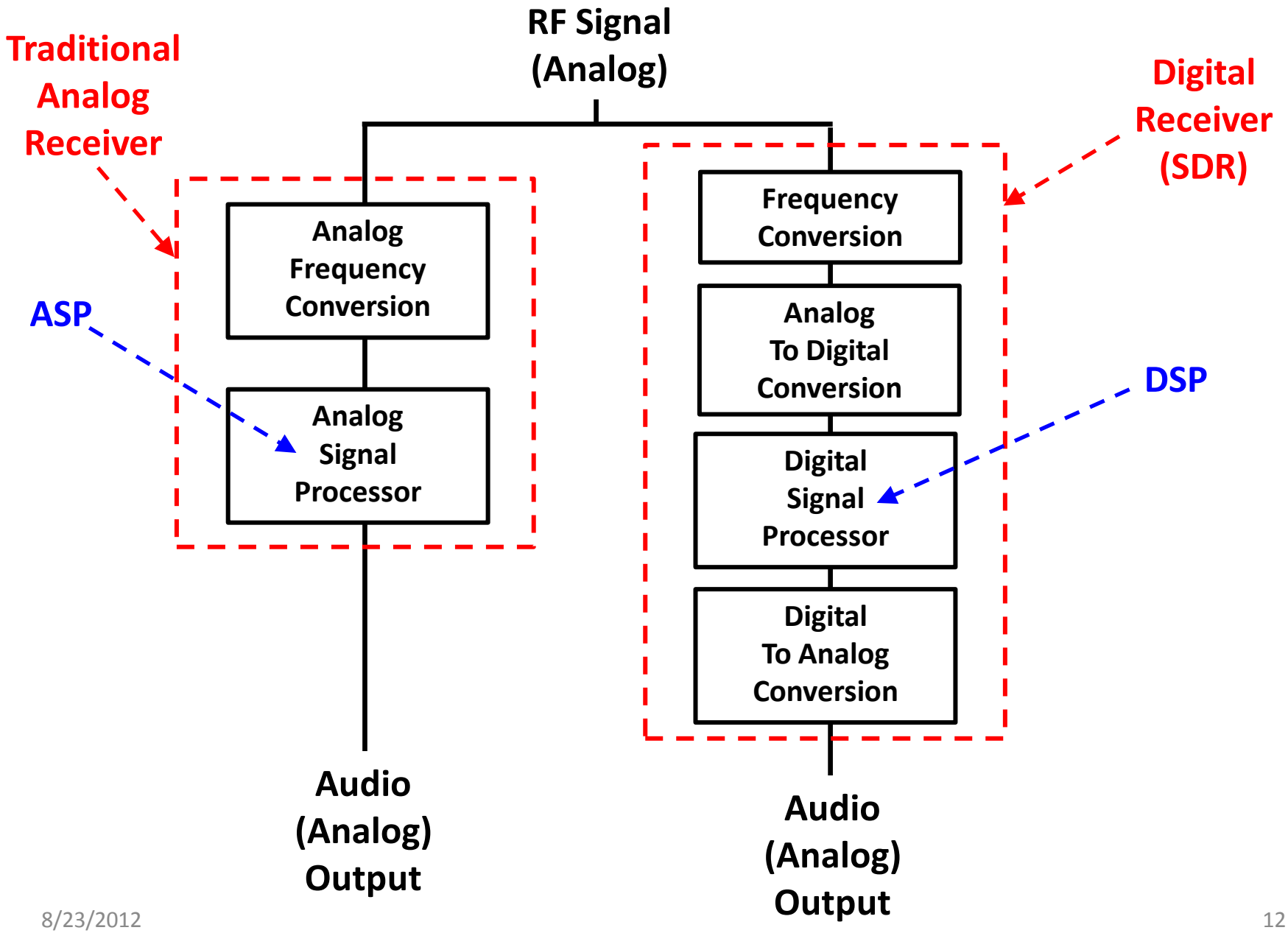
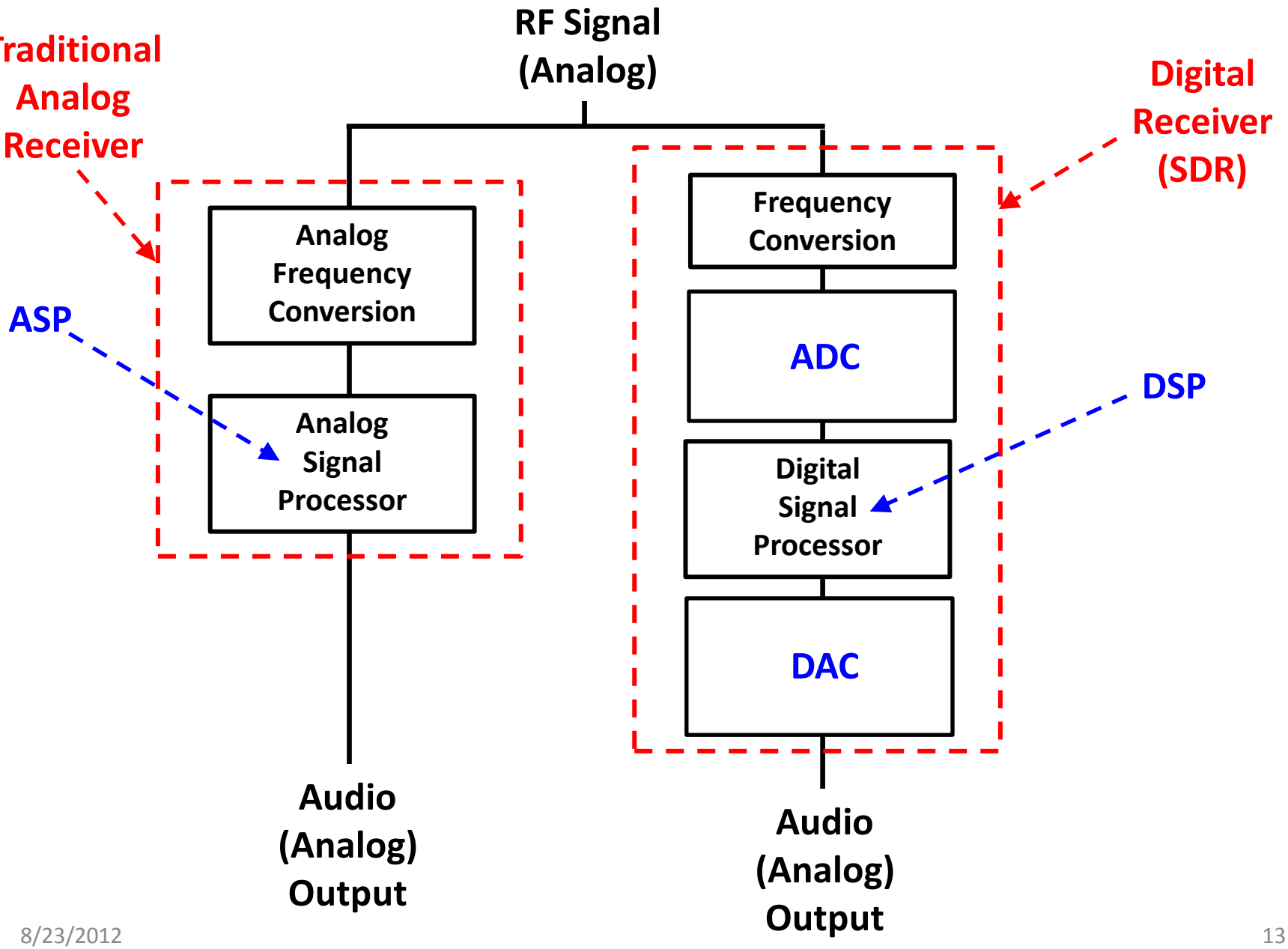
- .

*: Not achievable with analog signal processors

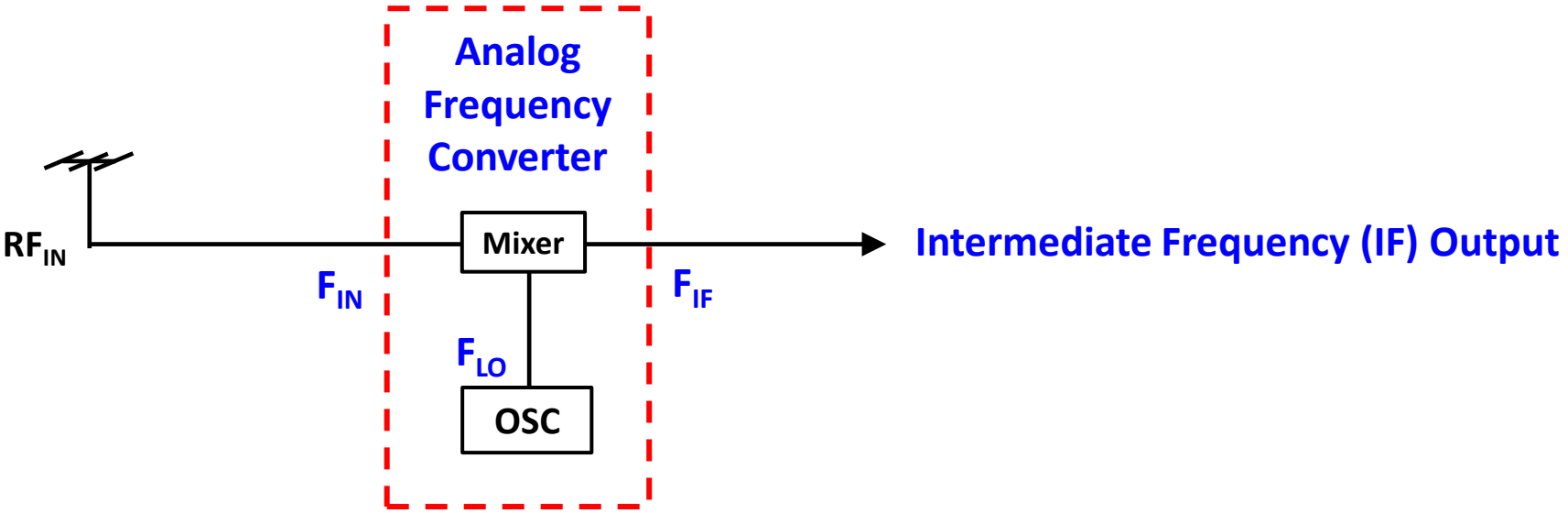
Analog vs. Digital *Signal Processing*



Analog vs. Digital *Signal Processing*



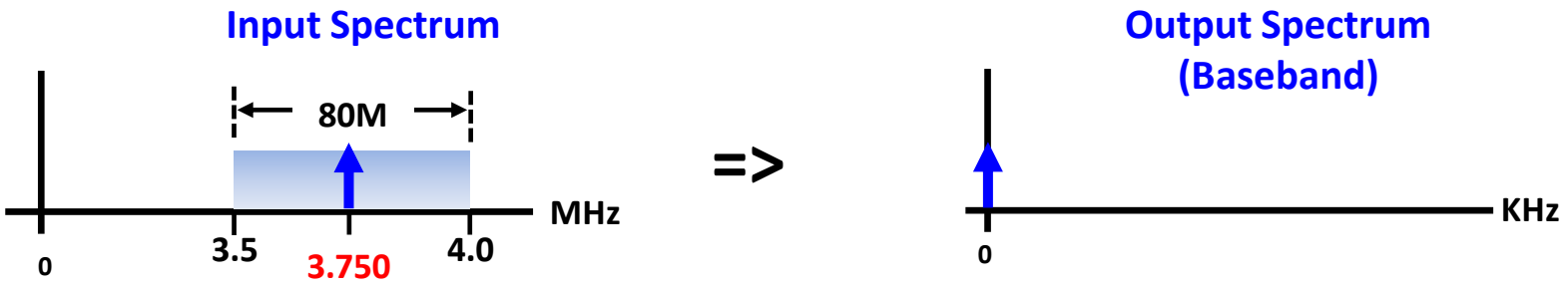
Analog Frequency Converter (AFC)



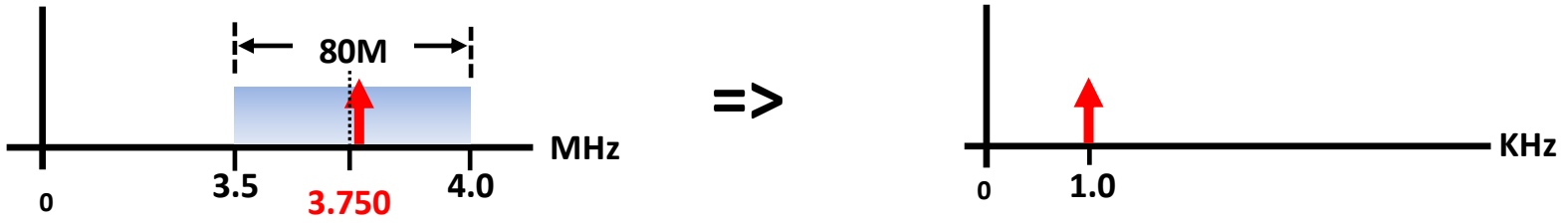
- When $F_{LO} = F_{IN}$ => F_{IF} = 0 Hz (DC) => "Direct Conversion"
  - No Image rejection => BIG problem
  - Output is frequently referred to as being at "Baseband"

Analog Direct Conversion

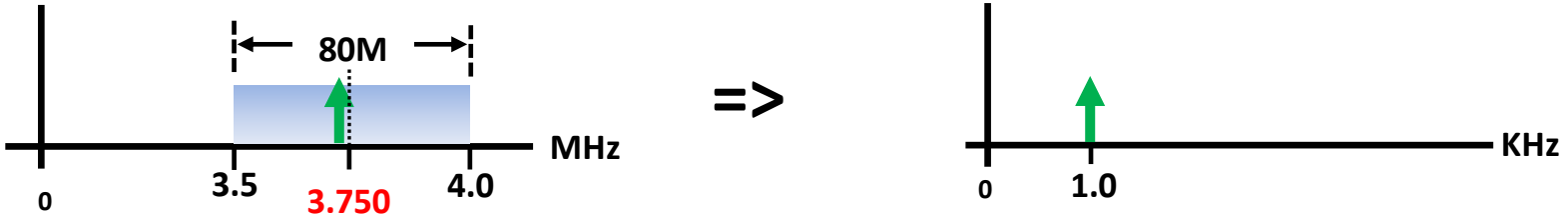
- CW input signal at 3.750 MHz, F_{LO} tuned to 3.750



- Input signal at 3.751 MHz, F_{LO} tuned to 3.750

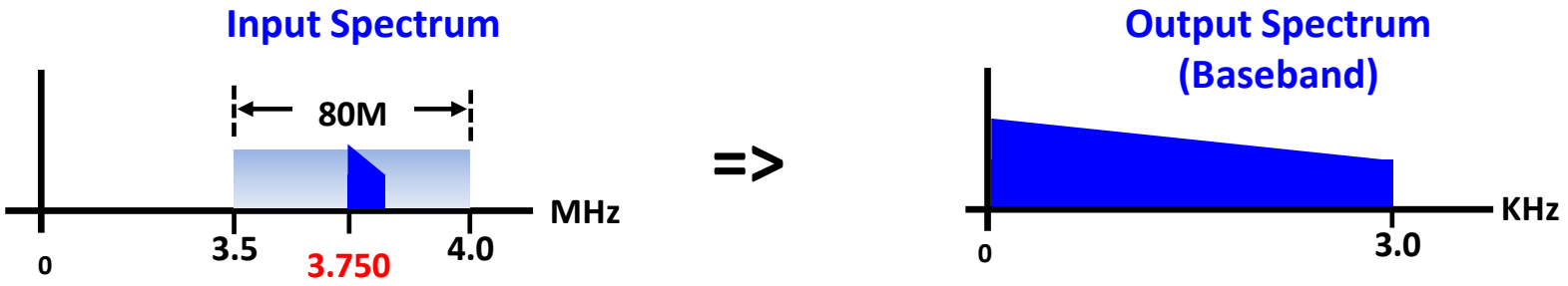


- Input signal at 3.749 MHz, F_{LO} tuned to 3.750

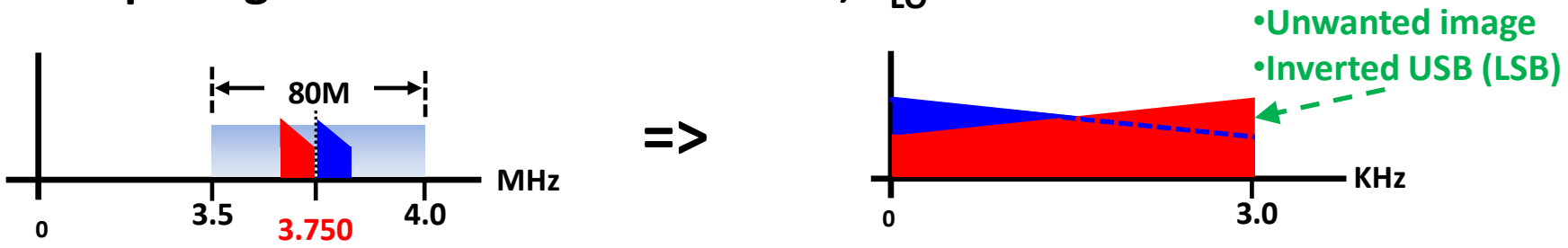


Analog Direct Conversion

- USB input signal at 3.750 MHz, F_{LO} tuned to 3.750



- USB input signals at 3.747 & 3.750 MHz, F_{LO} tuned to 3.750

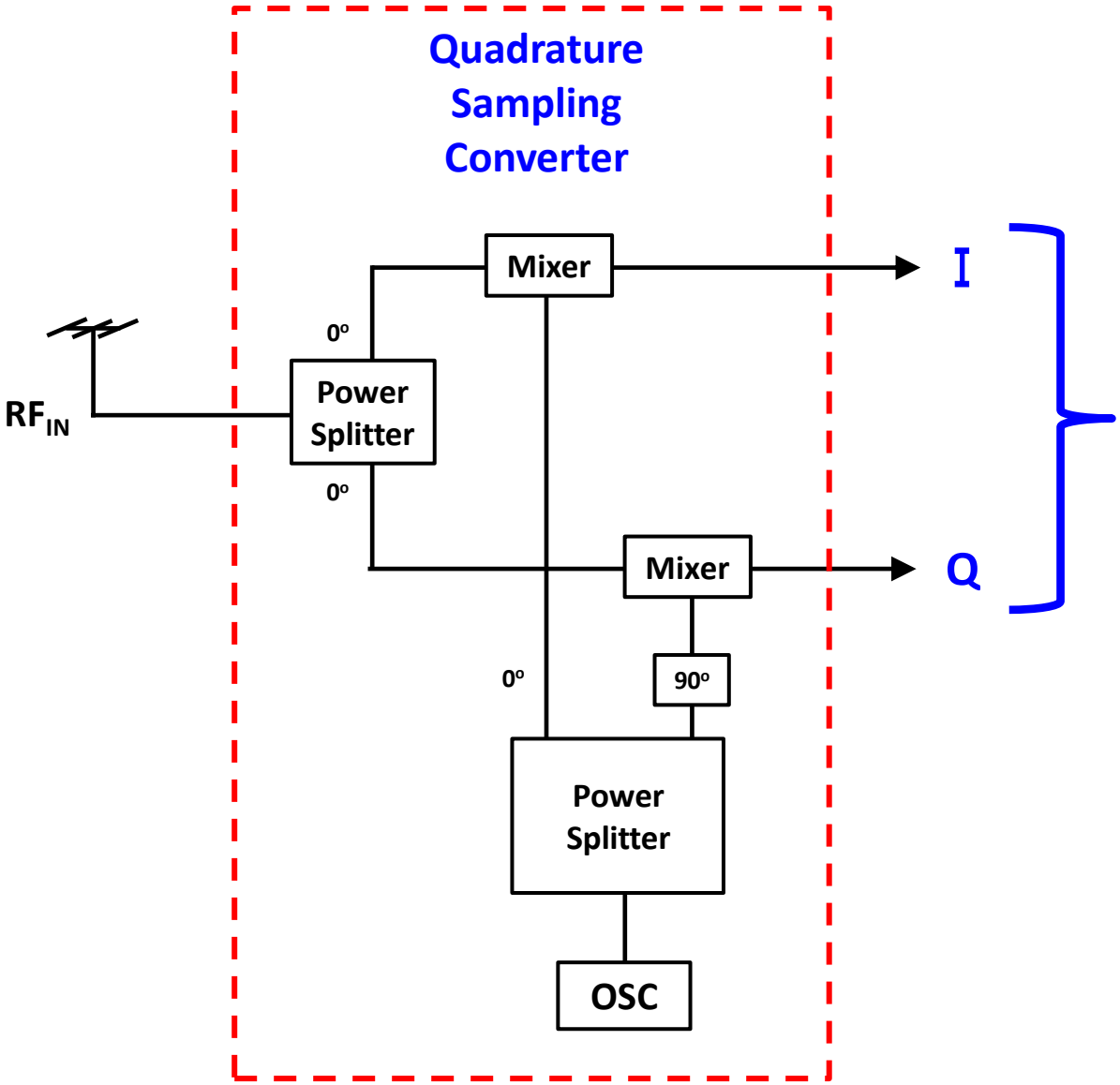


- Rejection of unwanted images is important
  - Using *Quadrature (I & Q) Conversion* can be a good solution
    - >60 dB rejection is achievable
      - Usually requires ***both*** hardware & software techniques
  - *Direct Digital Conversion* gives the best image rejection (>80 dB)

Types of SDRs

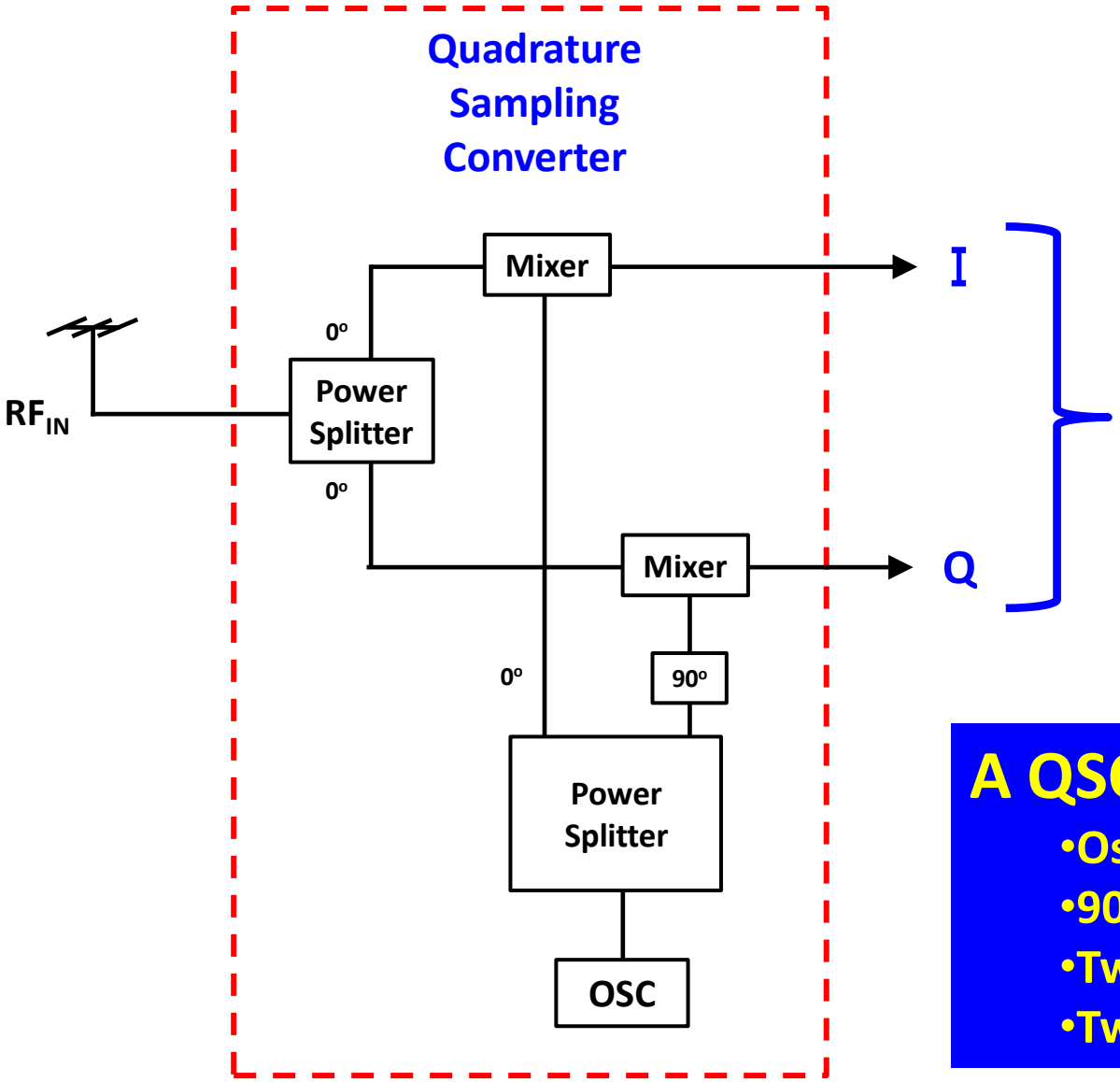
- **Two Basic Types:**
  - **Quadrature Sampling Conversion (QSC)**
    - aka "**Direct Conversion**"
      - A direct conversion radio may or may ***not*** be an SDR
    - Uses a **Quadrature Sampling Detector** (**QSD**) for down conversion to baseband
      - Direct conversion process that **generates two (I & Q) baseband signals**
      - Design challenge: rejection of unwanted image and sideband
    - Softrock "Ensemble II", Genesis G59/G11
  - **Direct Digital Conversion (DDC)**
    - **Direct conversion from *RF to bits***
      - "No IF frequency used" => not strictly true
      - Design challenges:
        - Extremely high data rates => Cost
        - Rejection of unwanted "Aliasing" signals
          - Easier problem to solve than image rejection
    - Perseus, QuickSilver, Flex 6000 series radios

Quadrature Sampling Conversion (QSC)



- Identical Analog Signals
- 90 degrees out of phase
  - "Quadrature"
  - "Complex" signals

Quadrature Sampling Conversion (QSC)



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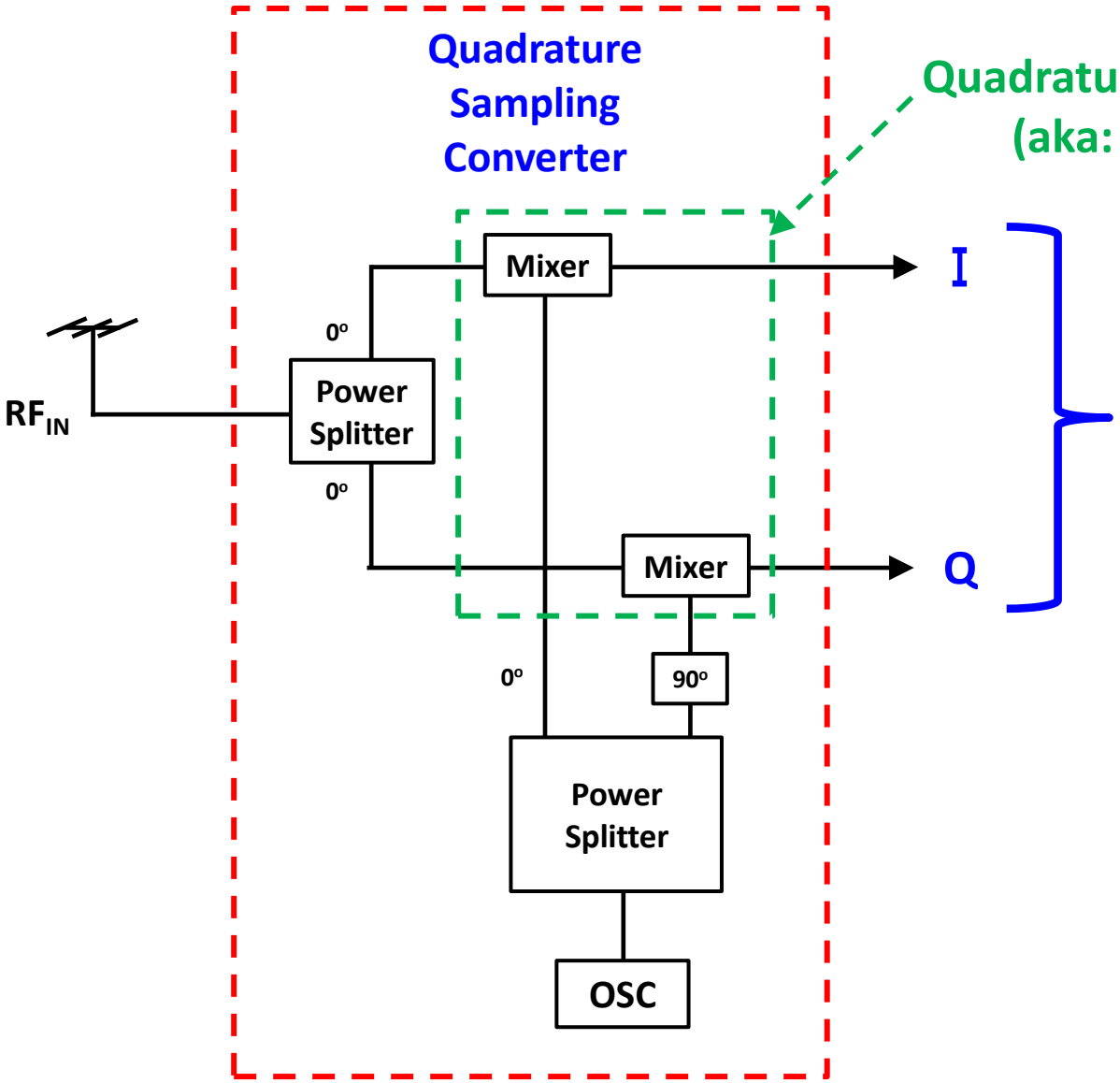
A QSC = Two AFC's:

- Oscillator
- 90° phase shifter
- Two power splitters
- Two mixers

Quadrature Sampling Conversion (QSC)



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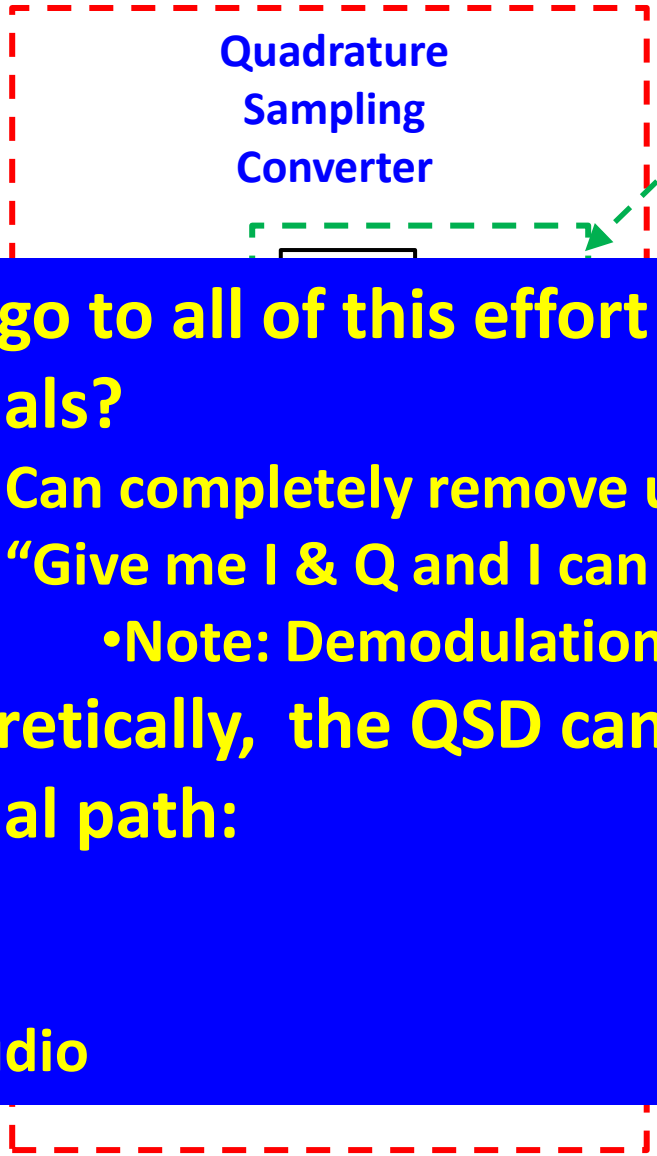
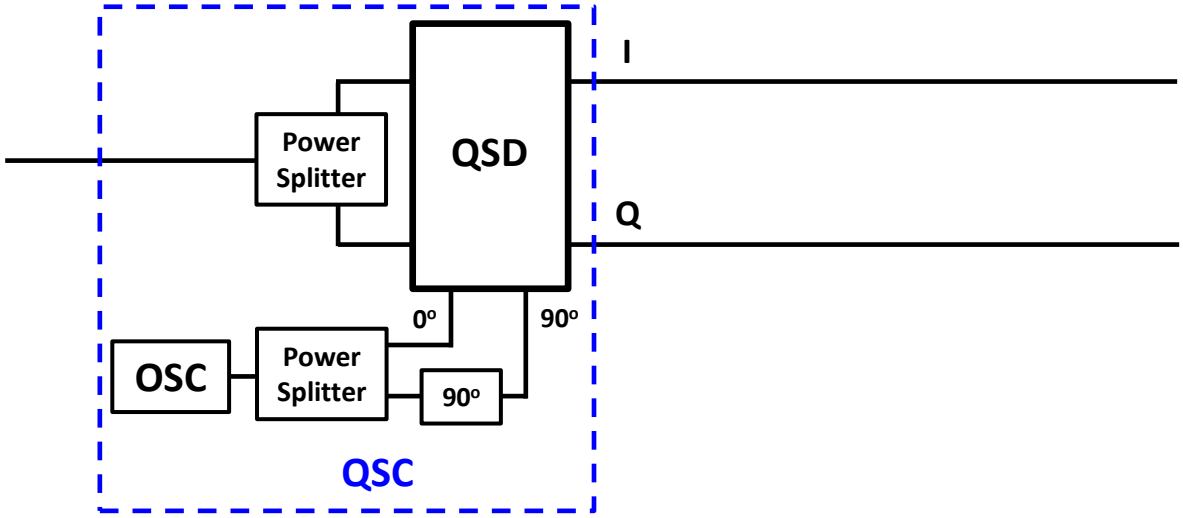


Quadrature Sampling Detector (QSD)
(aka: "Tayloe Detector")

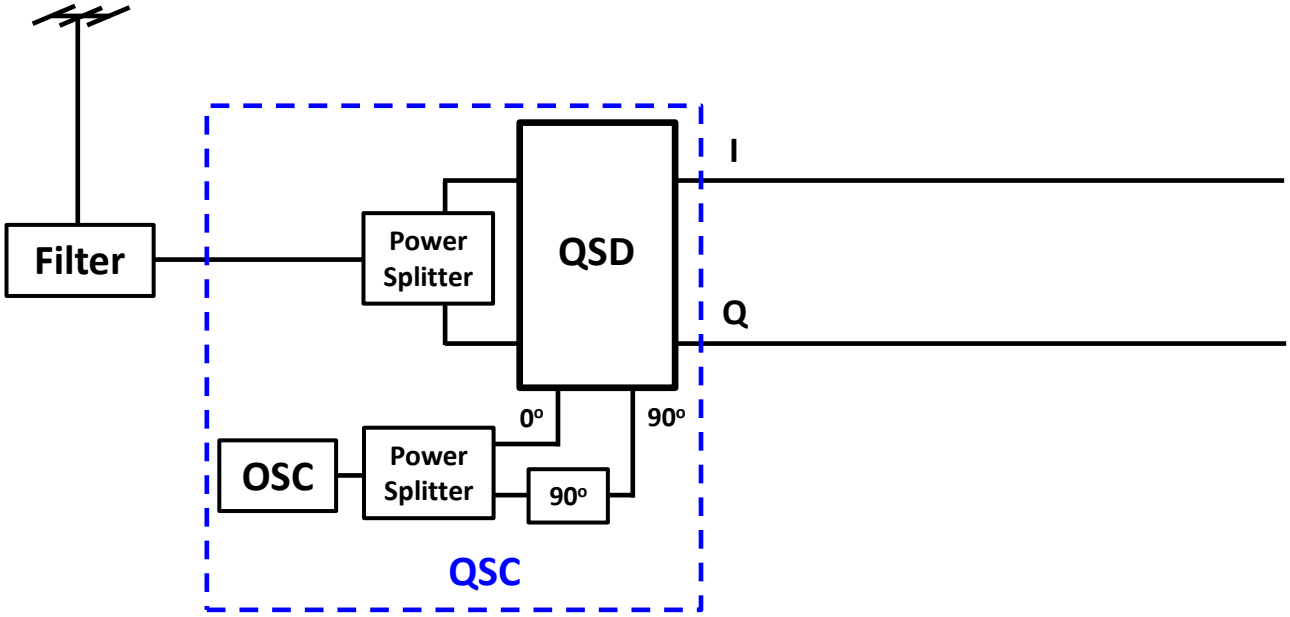
R

- Why go to all of this effort to generate two identical signals?
  1. Can completely remove unwanted image (theoretically)
  2. "Give me I & Q and I can demodulate any signal"
     - Note: Demodulation is done in *software*
- Theoretically, the QSD can be located anywhere in the signal path:
  - RF
  - IF
  - Audio

Quadrature Sampling Receiver



Quadrature Sampling Receiver



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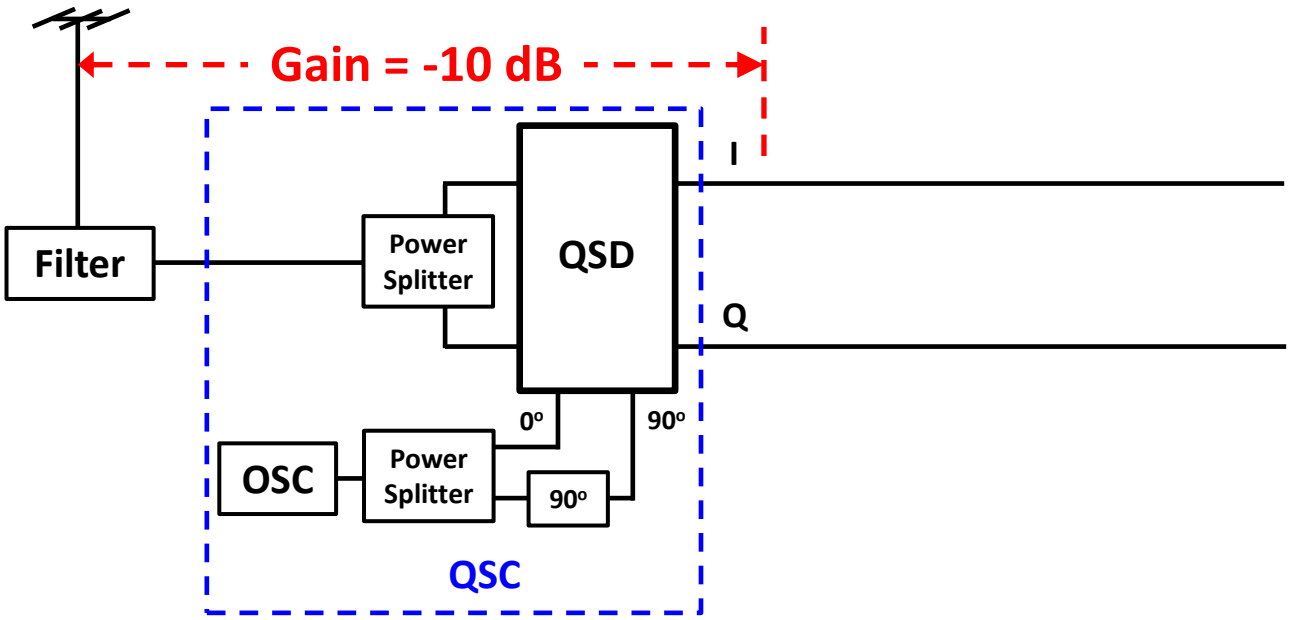

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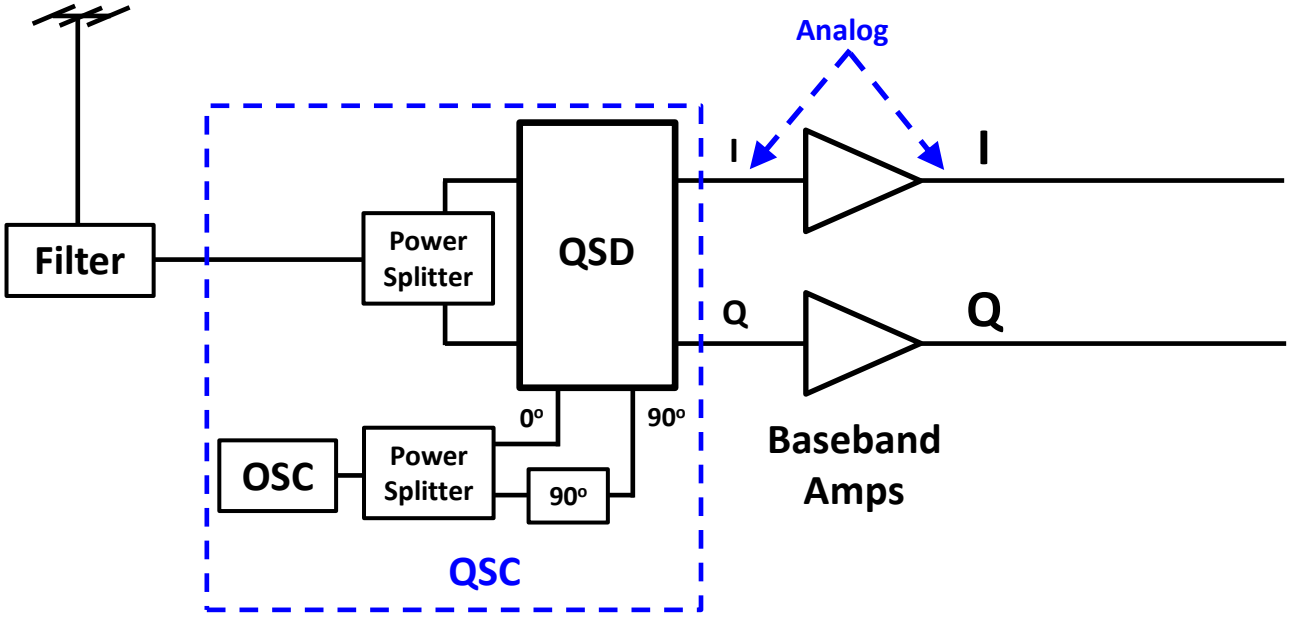
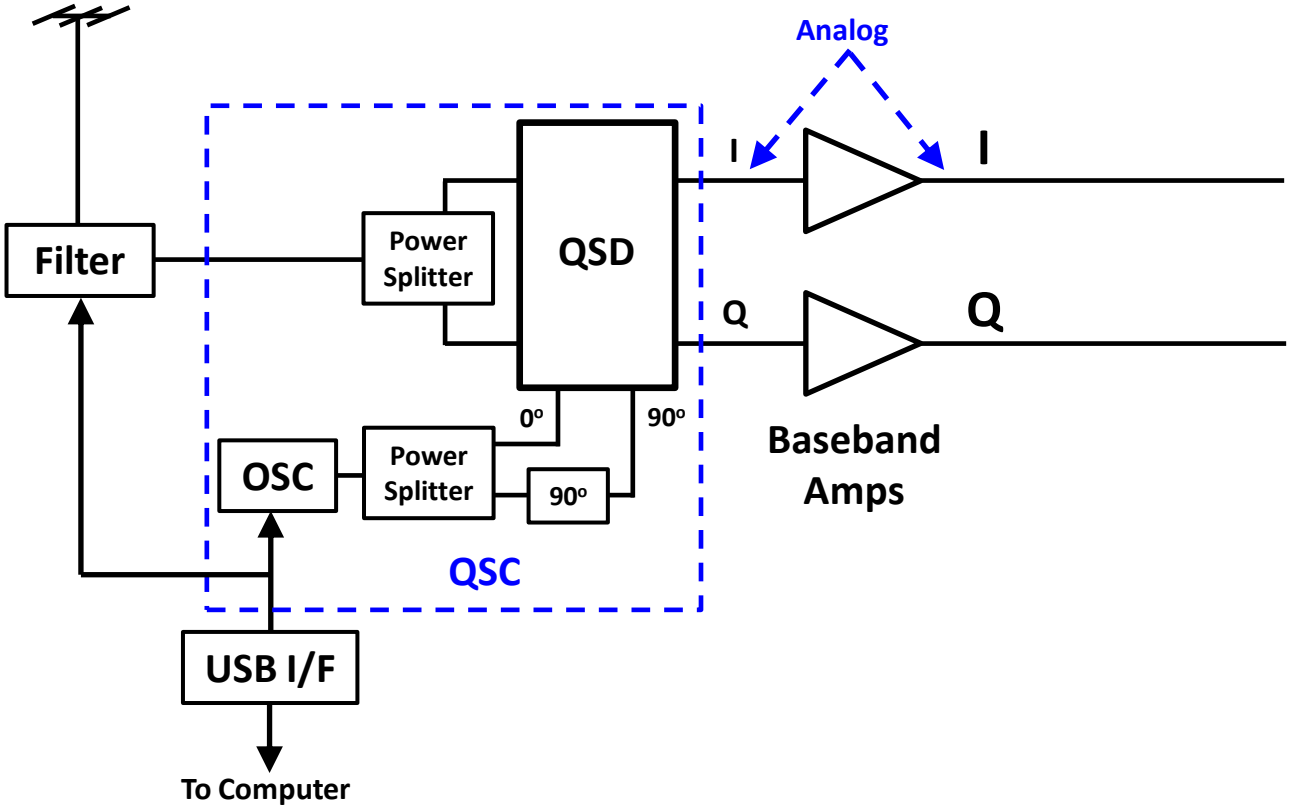


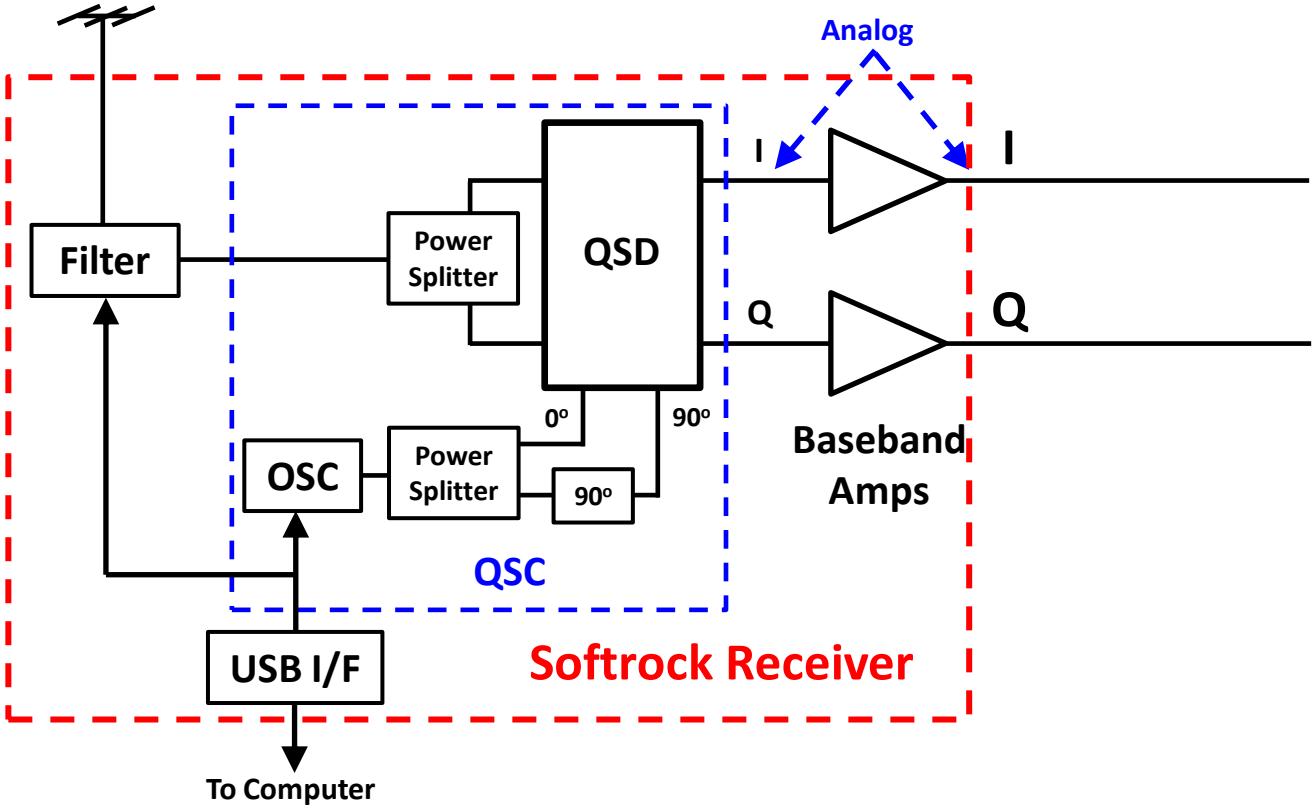
Baseband Amps need to have:

- Moderate gain
- Low Noise
- High Dynamic Range

Quadrature Sampling Receiver

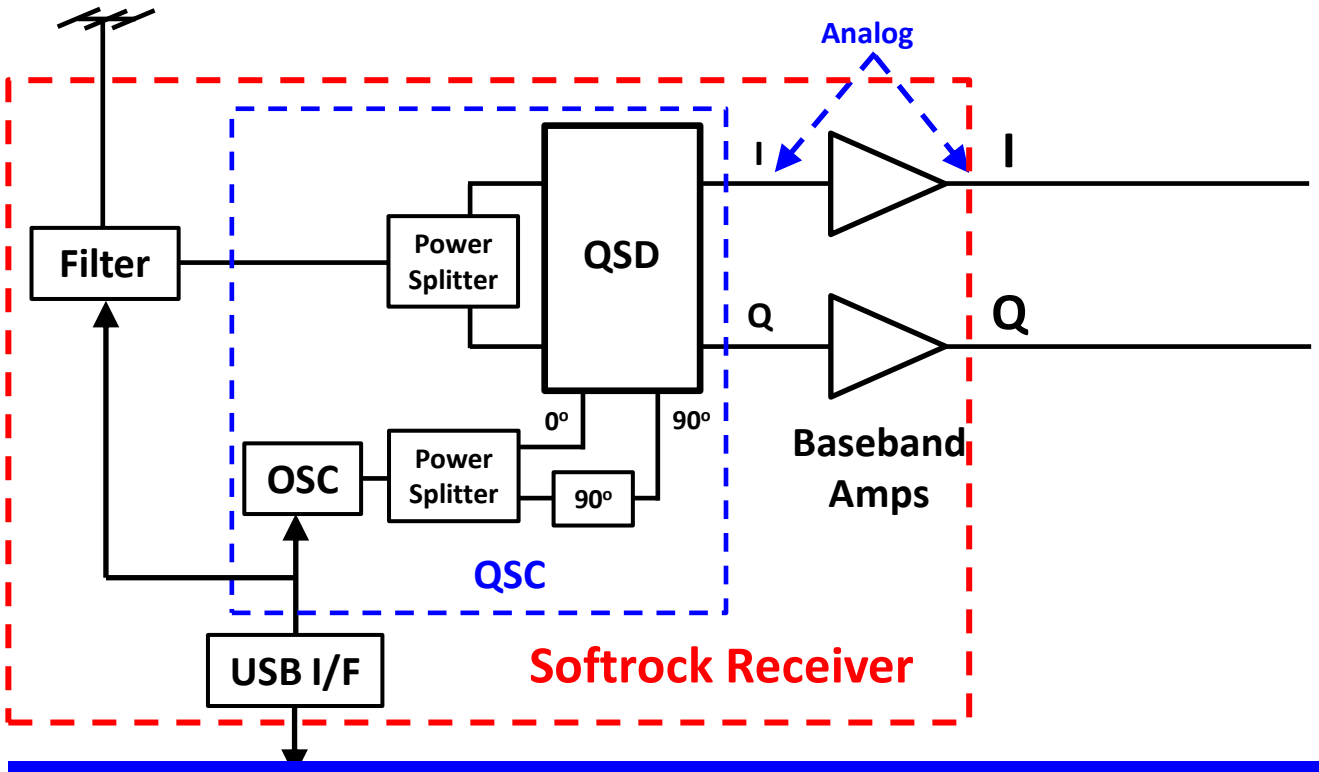


"Softrock" Receiver



- Softrock receiver = Filter + QSC + 2 op amps + I/F
- Softrock I & Q outputs are Analog signals

"Softrock" Receiver



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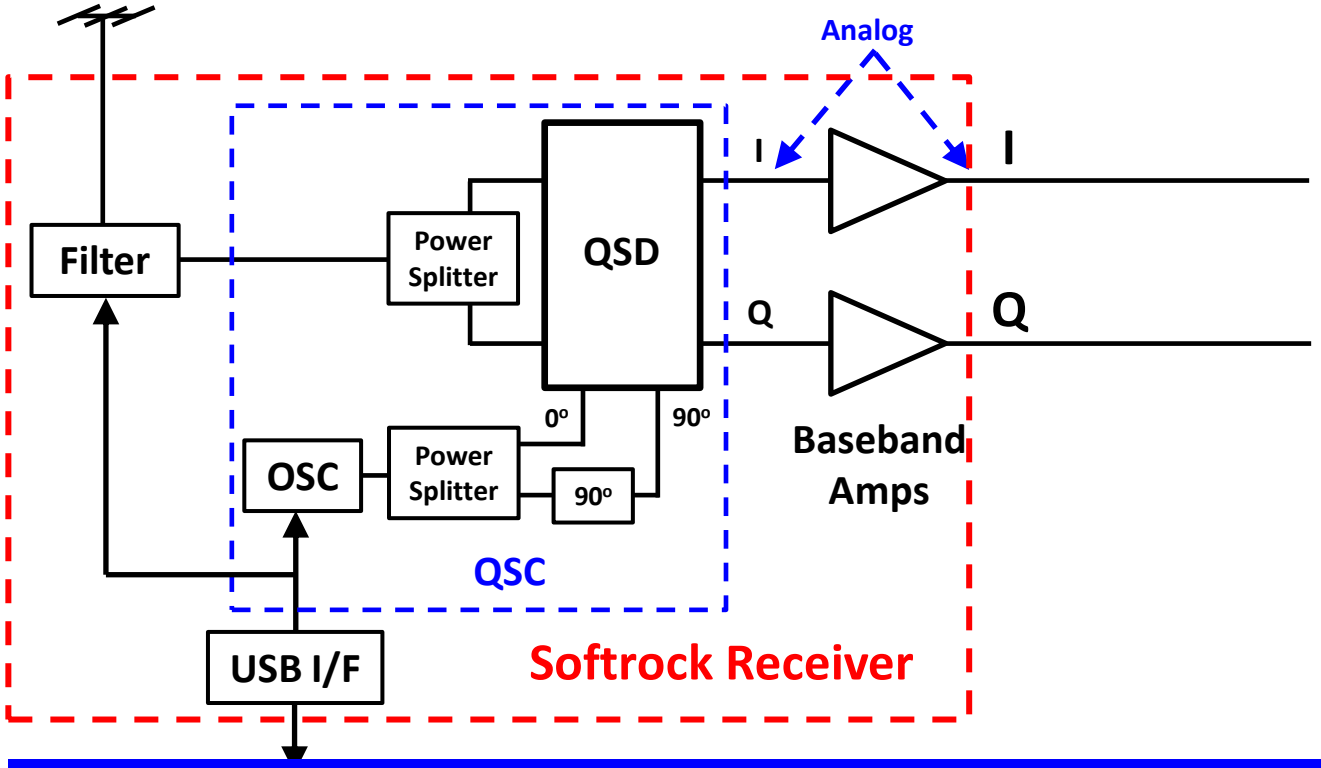
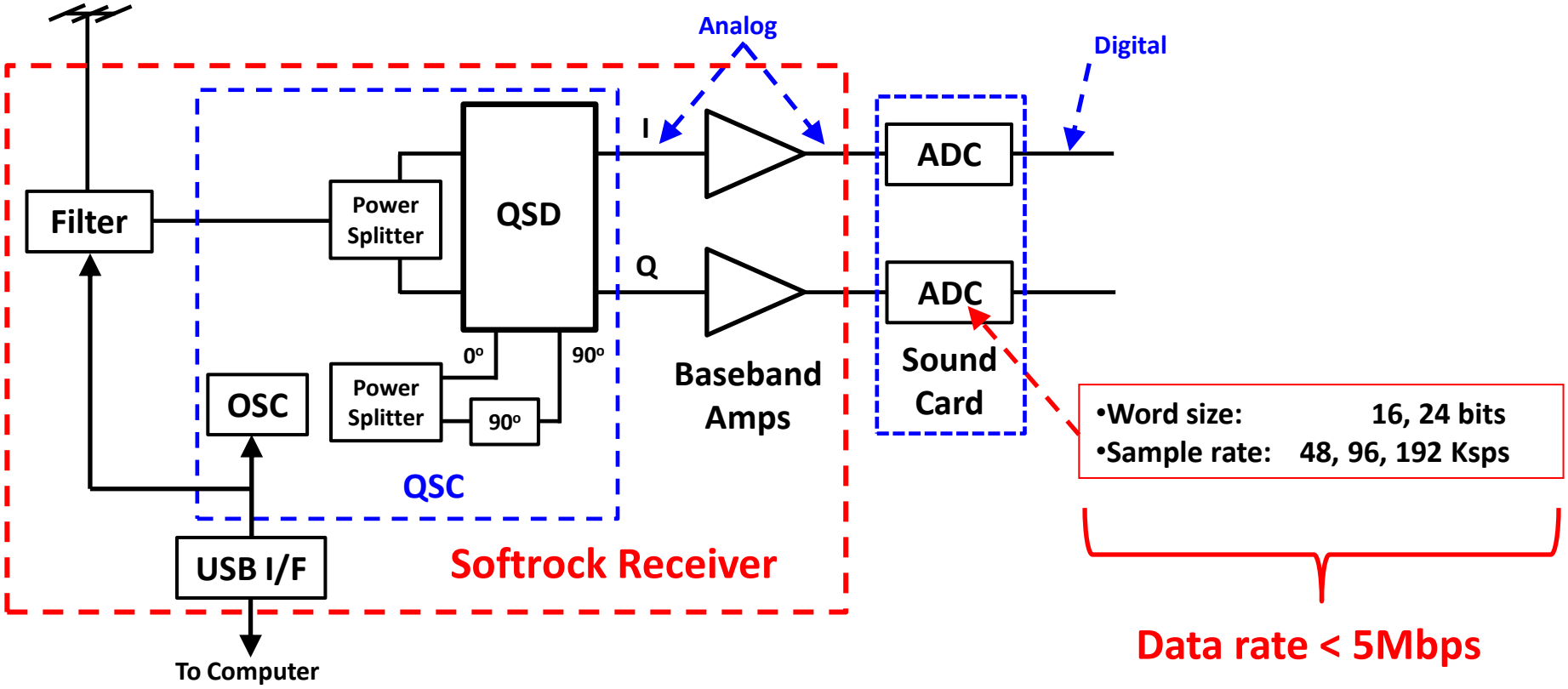


This is <u>not</u> a complete SDR receiver!

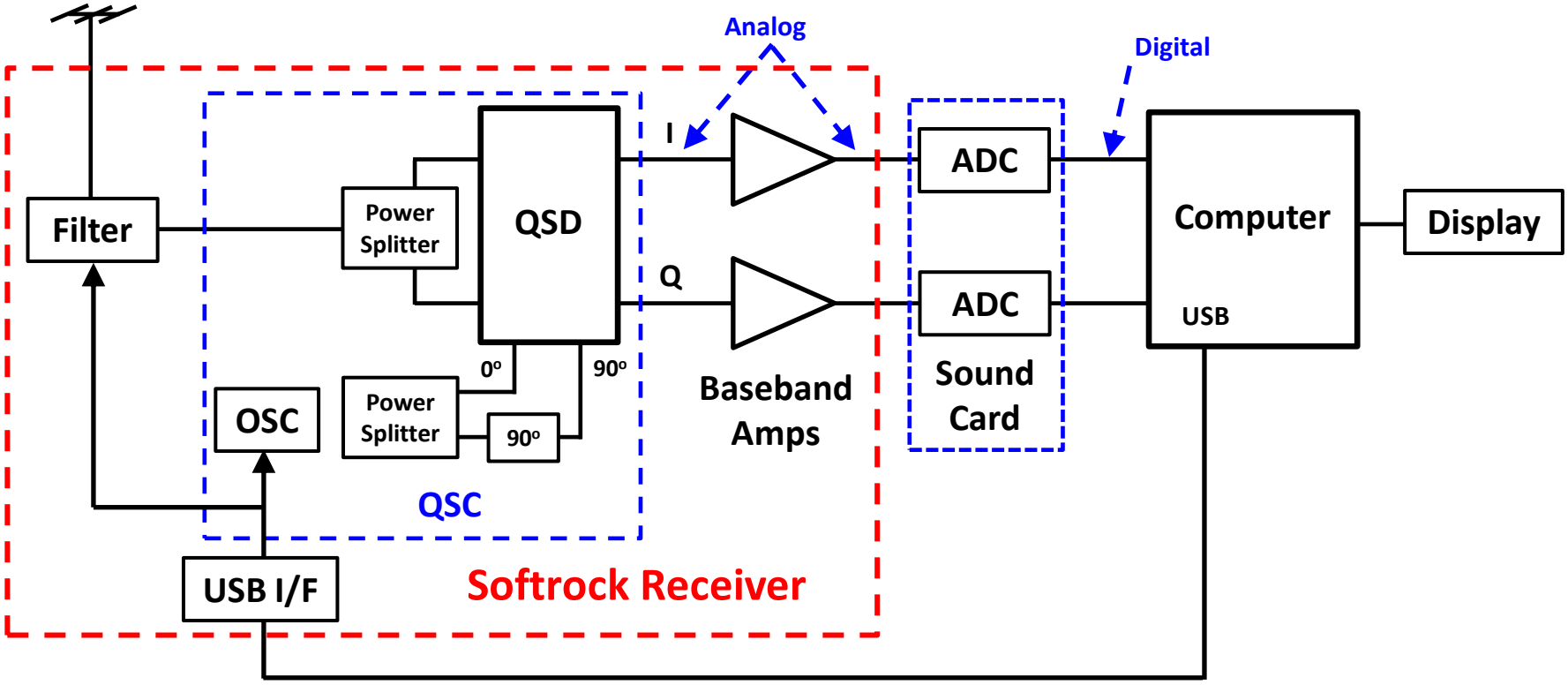
- ***Most of a SDR is in the software***
- ***All we have here is two analog, low gain, direct conversion receiver <u>front ends</u>***

"Softrock" Receiving System



Additional hardware required

"Softrock" Receiving System



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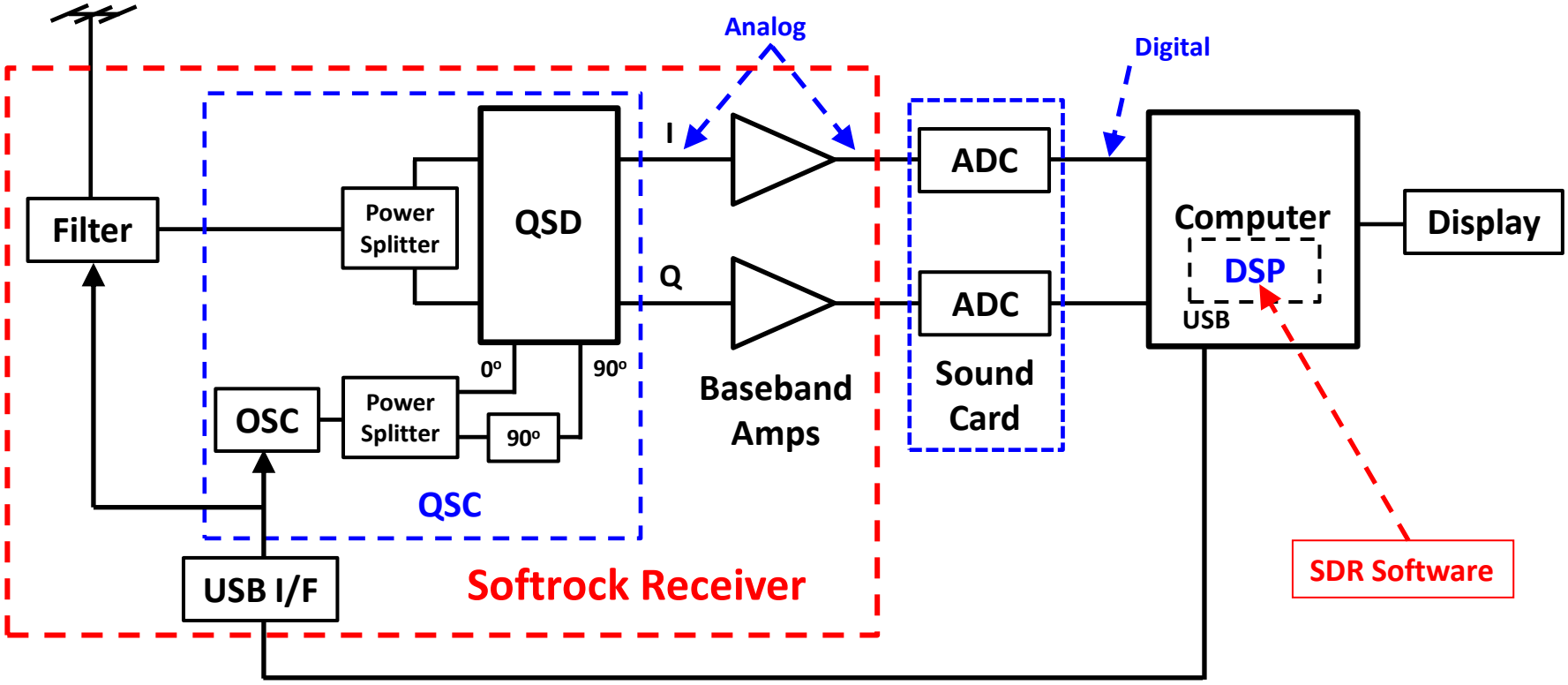
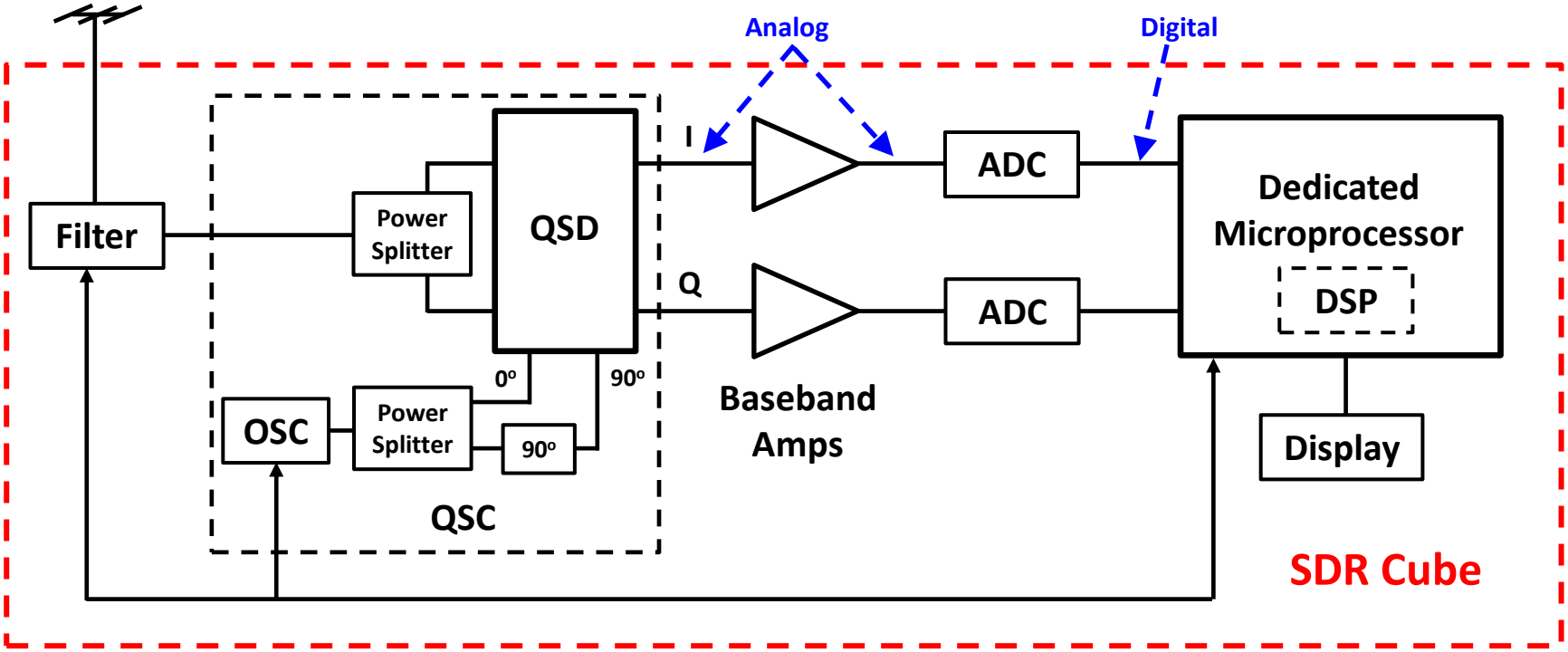


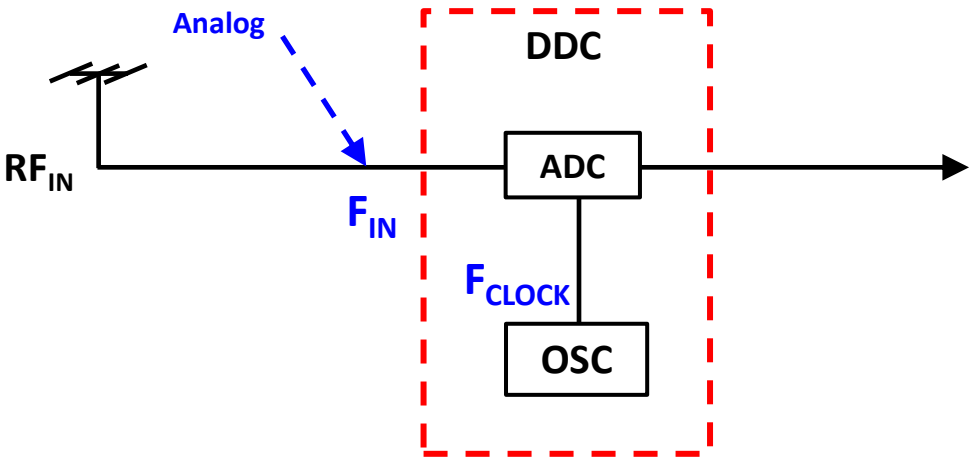
Additional software required

Quadrature Sampling SDR (SDR Cube)



No external computer, display or sound card required

Direct Digital Conversion (DDC)



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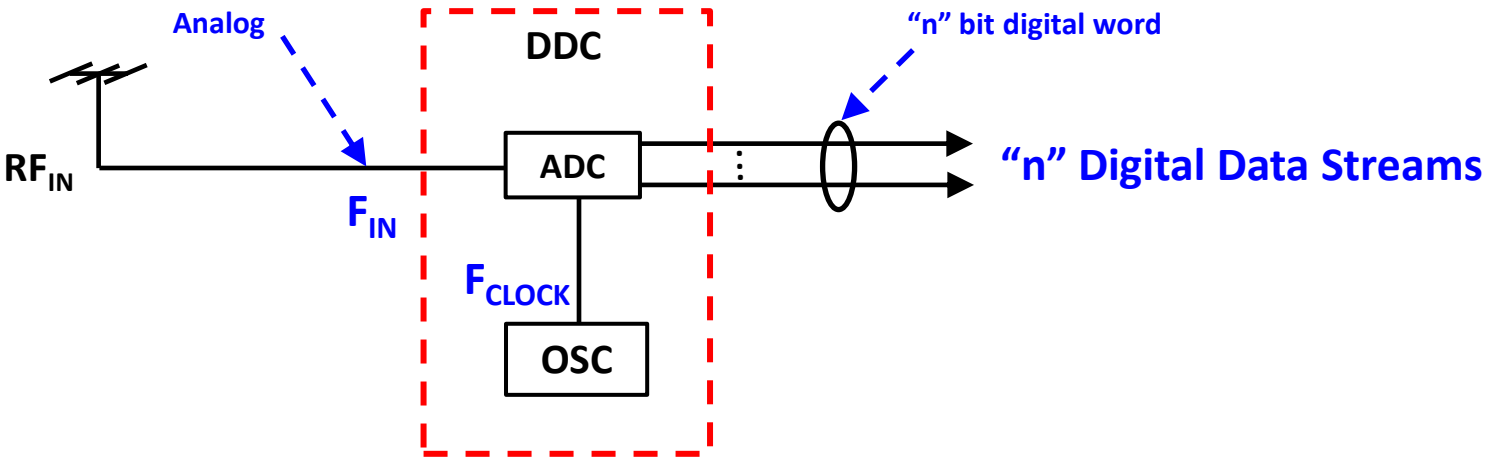
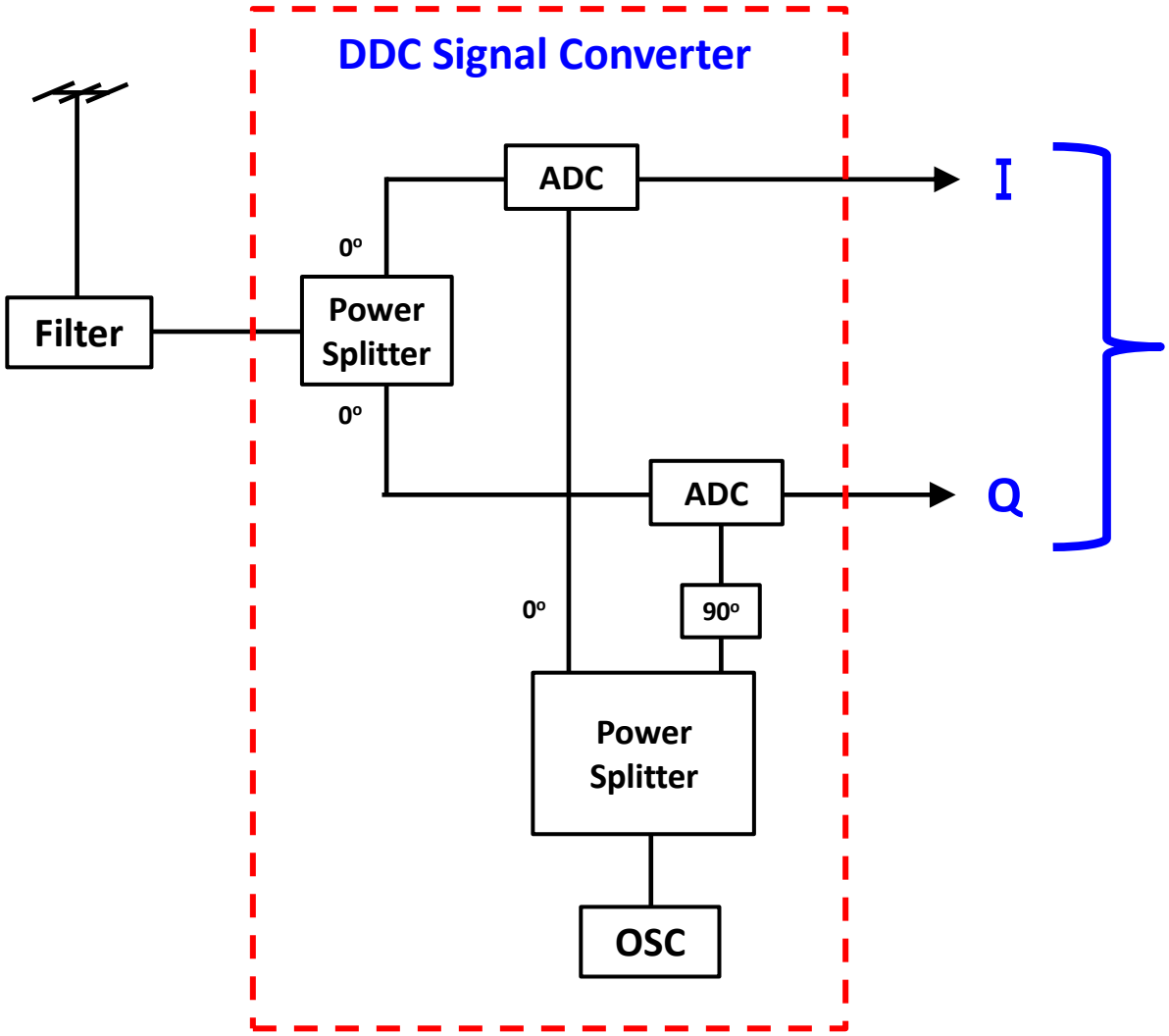


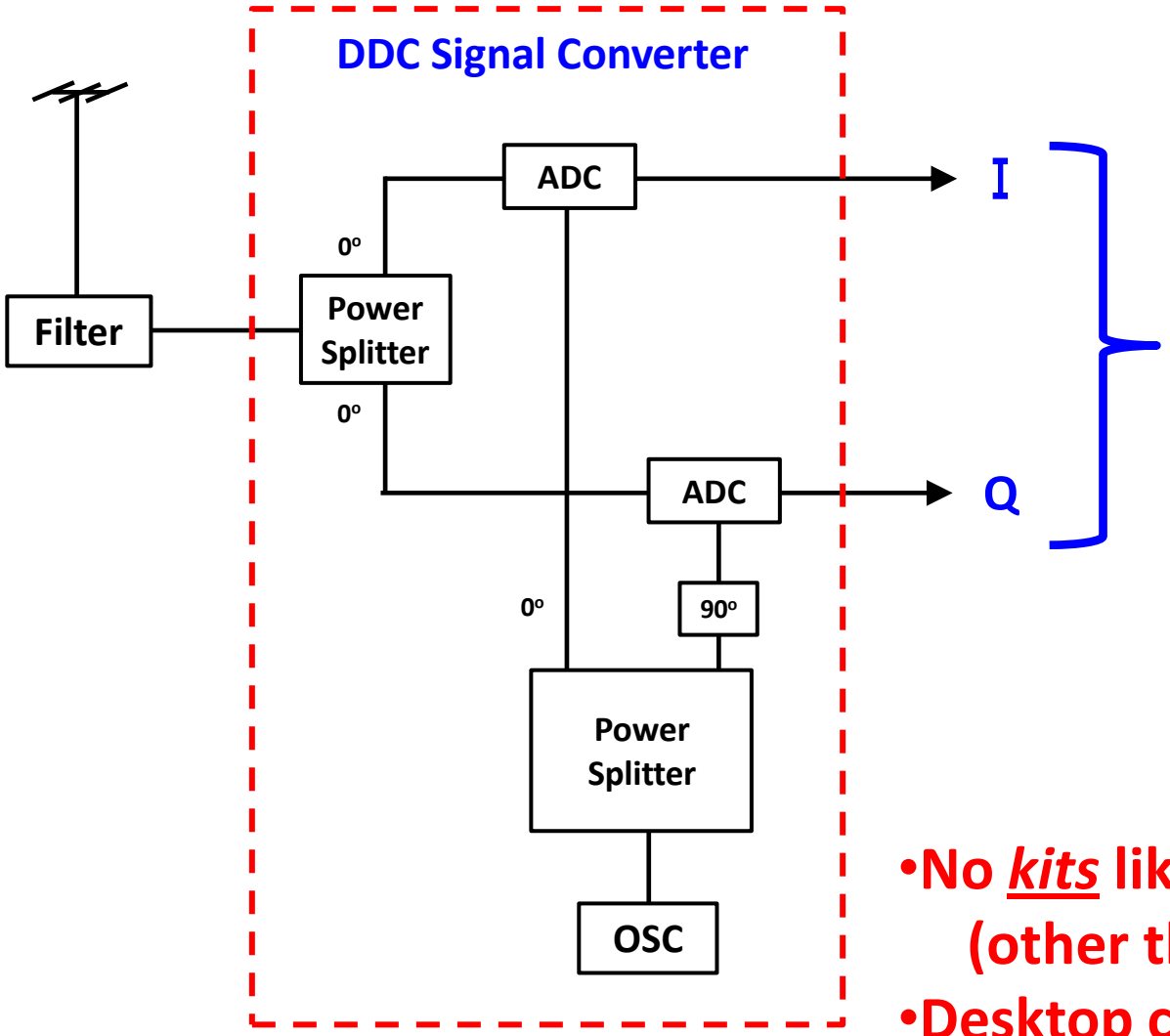
- F_{CLOCK} must be greater than 2 x F_{IN} (Nyquist criteria)
  - F_{CLOCK} is usually a fixed frequency
- ***Very high*** data rates
- Theoretically only one channel is needed
  - Two channels (I & Q) often used for implementation reasons

Typical Direct Digital Conversion (DDC)



- Two ***DIGITAL*** words
- 90 degrees out of phase
  - "Quadrature"

Typical Direct Digital Conversion (DDC)



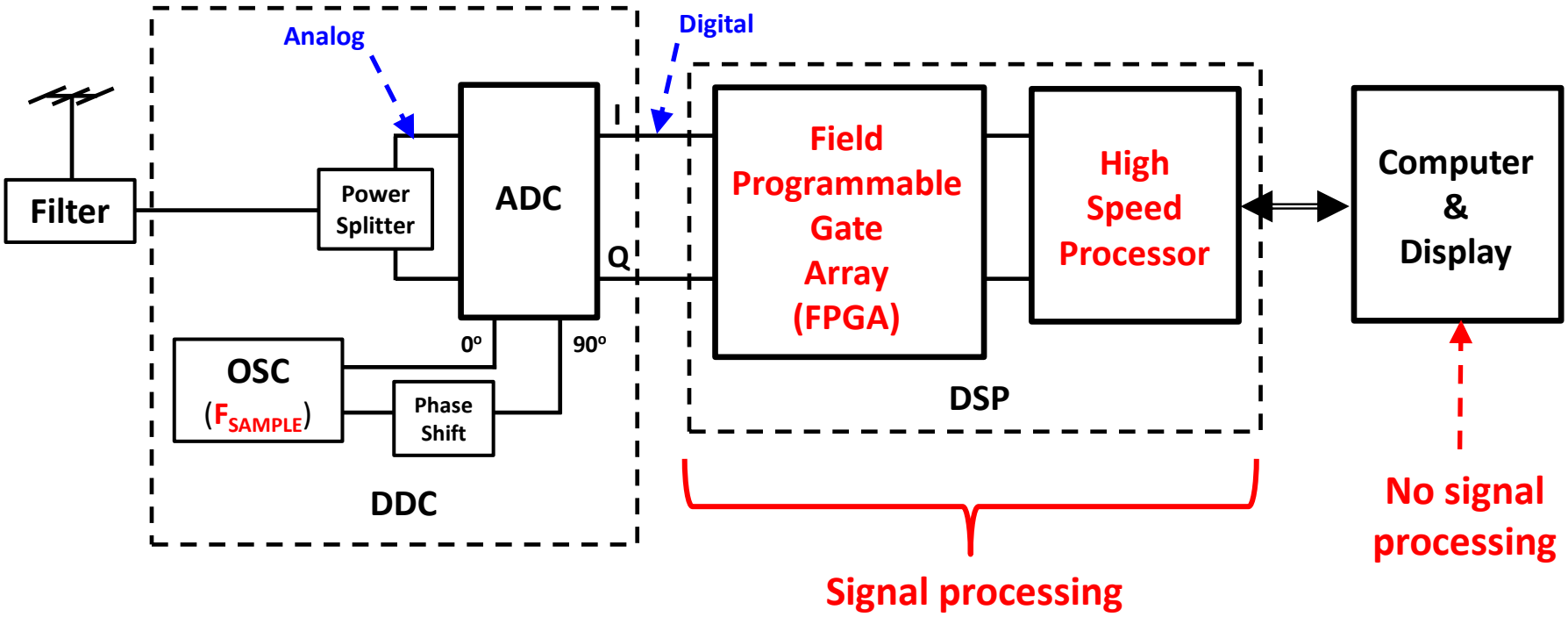
Perseus
- 14 bits
- 80 Msps
- Data rate ~ 2Gbps

- **QuickSilver QSR1**
- 16 bits
- 130 Msps
- Data rate ~ 4Gbps

Flex 6000
- 16 bits
- 490 Msps
- Data rate ~ 8Gbps

- No ***kits*** likely in the near future (other than HPSDR)
- Desktop computers won't work

Direct Digital Conversion (DDC) SDR



Flex 6xxx architecture

Some Important Considerations for SDR Projects

- **Computer Hardware Requirements:**
  - **Very important:**
    - **Processor speed**
    - **Dual or quad core processor**
    - **Amount of RAM**
    - **High speed (2.0) USB ports**
    - **Sound card interface**
- **Audio Amplifier(s)**
  - **Many kits require an external audio amp(s)**
    - Amplified computer speakers work well

Some Important Considerations for SDR Projects

- **Sound Cards:**
  - **Sound card interface**
    - PCI vs PCIe vs USB vs Firewire vs Ethernet?
  - What **sensitivity** is needed?
    - 16 bits (96dB DR) may be ok, but 24 bits (144dB DR) is best
  - What ***display*** bandwidth is needed?
    - Sample rate determines maximum achievable display bandwidth
      - 48, 96, 192 Ksps => 48, 96, 192 KHz
- **Recommendations from the Genesis reflector:**
  - Sound card choice depend on desired **Bandwidth** (sample rate) and **Sensitivity** (bits)
  - Asus Xonar DX series (cheap)
  - Asus Essence STX (expensive)
  - EMU 0202 or 0204 (USB external). Older cards can be bought very cheaply
  - Edirol FA-66 (expensive and Firewire may not work well)
  - All of these cards work fine for SDR applications in any supported Windows OS
  - How much to invest for Sensitivity depends on how "radio quiet" your location is ***and*** the quality of your PC components (power supply and motherboard are critical)
  - For beginners: try an older Audigy 2ZS (cheap 24bit/96KHz card)

Some Important Considerations for SDR Projects

- **Software:**
  - ***Free* SDR Applications:**
    - "Rocky"
    - Flex "Power SDR"
    - "WinRad"
    - "HDSDR" (not HPSDR)
    - "GSDR" (Genesis software based upon Flex "Power SDR")
      - ***Not*** based upon the latest version of Power SDR!
  - **Computer Operating Systems**
    - Windows:
      - **XP (good all around choice)**
      - Vista (no!)
      - 7 (be careful)
        - Early SDR applications designed for use with XP
          - They may, or may not work with W7
        - Run XP on W7 machine may be an option
    - Mac (be *very* careful)
    - Linux (be *very*, very careful)

Receiver Performance Comparisons

- **Dynamic Range:**
  - **Traditional Methods (ie, IMD) used for analog radios don't accurately represent digital radios**
    - **Hard limiting in A/D converters**
    - **Digital radios have spurious signals that don't occur in analog radios**
- **Unwanted image/sideband rejection:**
  - **DDC receivers have a *big* advantage**
- **QSD vs. DDC vs. Superhet Performance Comparison:**
  - ***https://sites.google.com/site/lofturj/comparison_of_sdr_vs_superhet***
  - Also has good discussion of 16 bit vs. 24 bit sound cards

Receiver Performance Comparisons

- **Rob Sherwood rankings (*http://www.sherweng.com/table.html)***
  - **Measured SDR receiver performance:**

Item		Blocking	LO	Filter	Dynamic Range	
Mfg	Model	dB	Noise (dBc/Hz)	Ultimate dB	Wide dB	Narrow dB
Elecraft	KX3	138	144	**110**	**105**	**104**
Yaesu	FTdx-5000D	127	135	90	104	101
Elecraft	K3	**140**	138	105	104	101
Perseus*	-	125	**147**	109	99	99
FlexRadio Systems	FLEX-5000A	123	123	98	96	96

***DDC architecture**

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Elecraft	K3	**140**	138	105	104	101
Perseus*	-	125	**147**	109	99	99
FlexRadio Systems	FLEX-5000A	123	123	98	96	96

  - **Predicted receiver performance:**

FlexRadio Systems	FLEX-6xxx*	-	**147**	-	-	**110**

***DDC architecture**

SDR Kits

- **Softrock:** *http://kb9yig.com/*
- **Genesis:** *http://www.genesisradio.com.au/*
- **Lazy Dog:** *http://www.lazydogengineering.com*
- **Crosscountry Wireless:** *www.crosscountrywireless.net/*
- **SDR CUBE:** *http://www.sdr-cube.com/*
- **HPSDR:** *http://openhpsdr.org/*
- **PM-SDR (Italy):** *http://www.iw3aut.altervista.org/*
- **?**
- **?**
- **?**

SDR Kits – cont'd

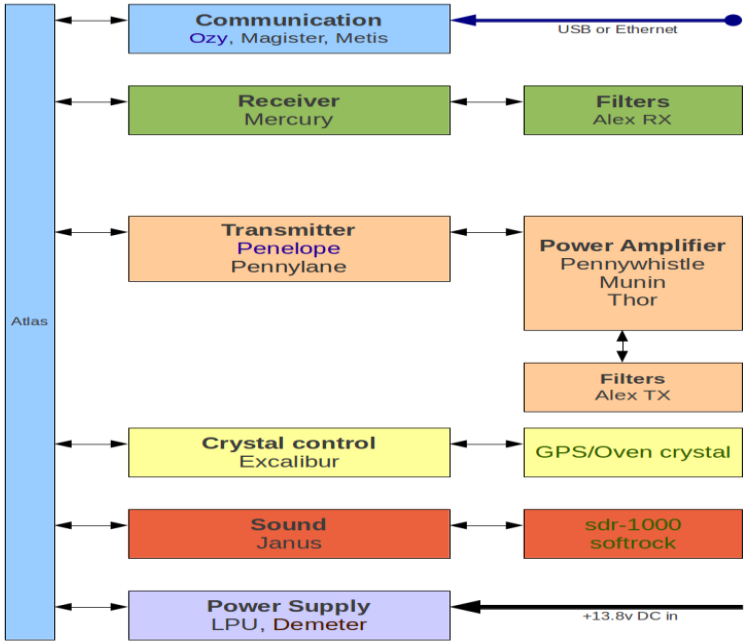
- **Beginner:**
  - **Tiny SDR** (*http://www.qrz.lt/ly1gp/SDR/Intermediate)*:
    - Very simple hardware (receiver only) but ***not a kit***
      - All parts must be procured individually
  - **Softrock:**
    - Excellent choice for first time SDR builder
    - Some (~25) surface mount components
    - Runs on any of several SDR software applications:
      - Power SDR (Flex software)
      - Rocky
      - **HDSDR**
    - Over 12,000 sold worldwide
    - Good website based support
    - May have to wait to purchase one

SDR Kits – cont'd

- **Intermediate Experience:**
  - **SDR Cube:**
    - Integrated architecture
      - Embedded DSP processor
      - No external computer required
      - No external display required
    - Single band HF transceiver
    - Built around a Softrock RF front end
    - **Mostly SMT components**
  - **Genesis:**
    - High performance transceivers
      - G59 (no longer offered)
      - **G11**
      - G6 (Direct Digital Sample - Fall of 2012)
        - Fully assembled (not a kit and ~$1000)
    - Good website based support

SDR Kits – cont'd

- ***Highly*** **Experienced:**
  - **HPSDR**



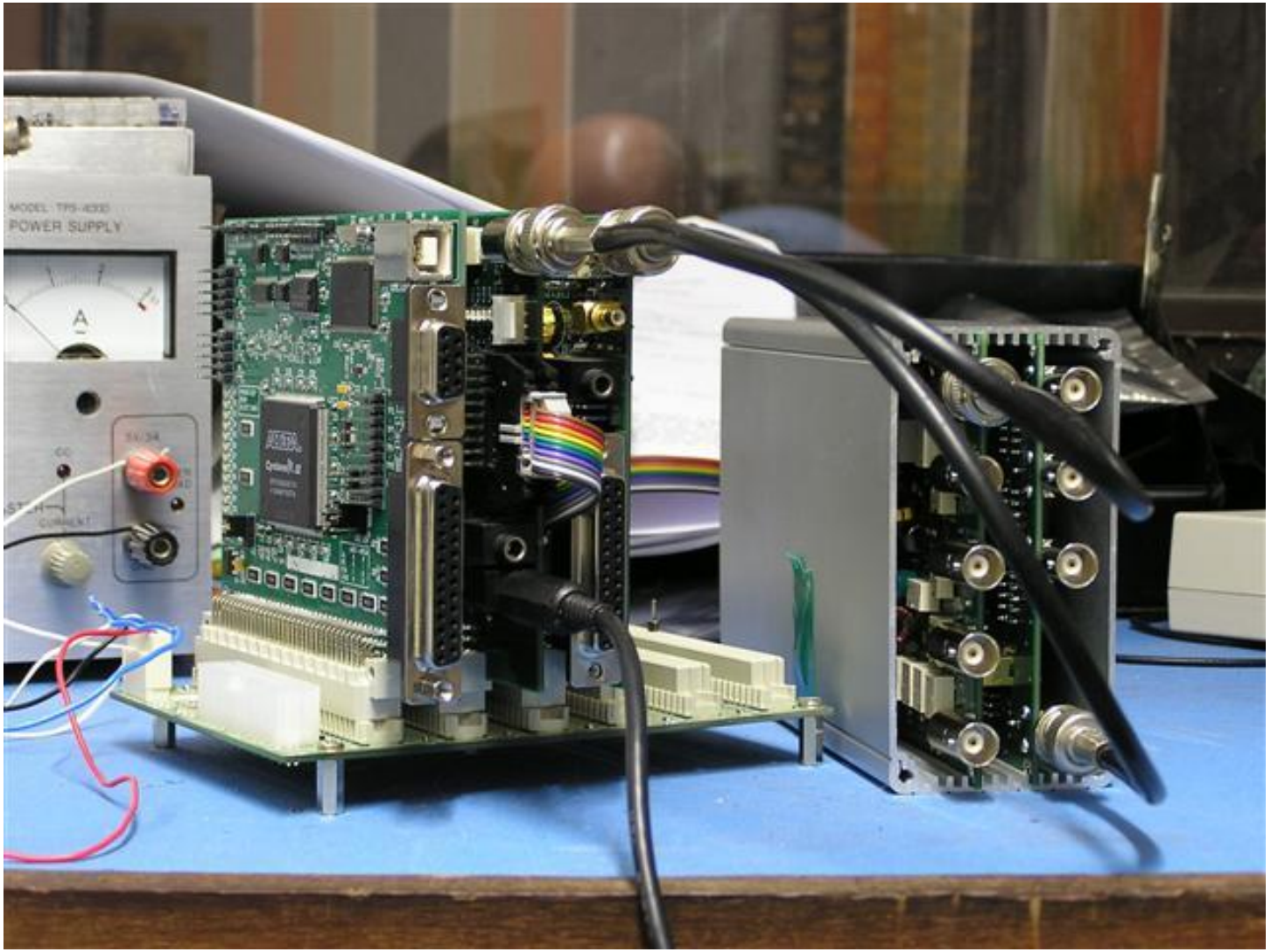
http://openhpsdr.org/

13-16 Different **Subsystems:**

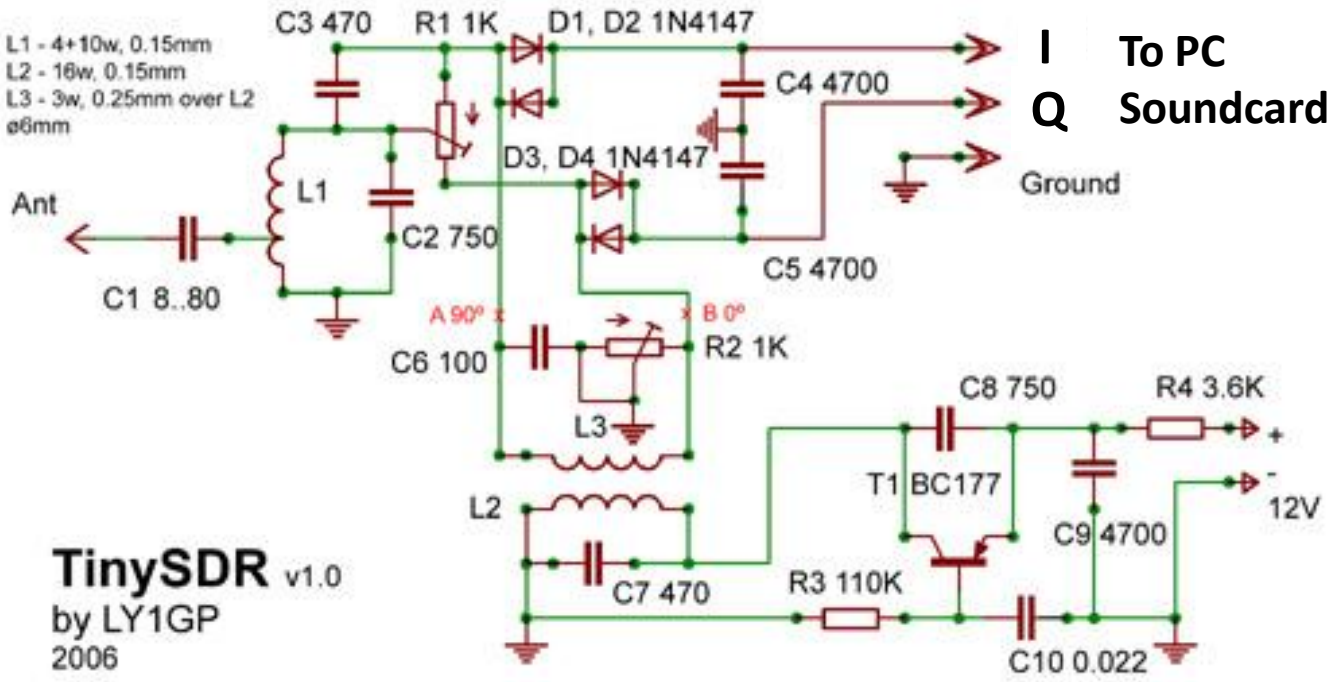
- **Atlas**
- **Ozy**
- **Mercury**
- **Alex**
- **Penelope**
- **Pennywhistle**
- **Alex**
- **Excalibur**
- **Janus**
- **LPU**
- **Alexiares**
- **Metis**
- **Hercules**

HPSDR Architecture

- **Built around a six slot Backplane (ATLAS)**



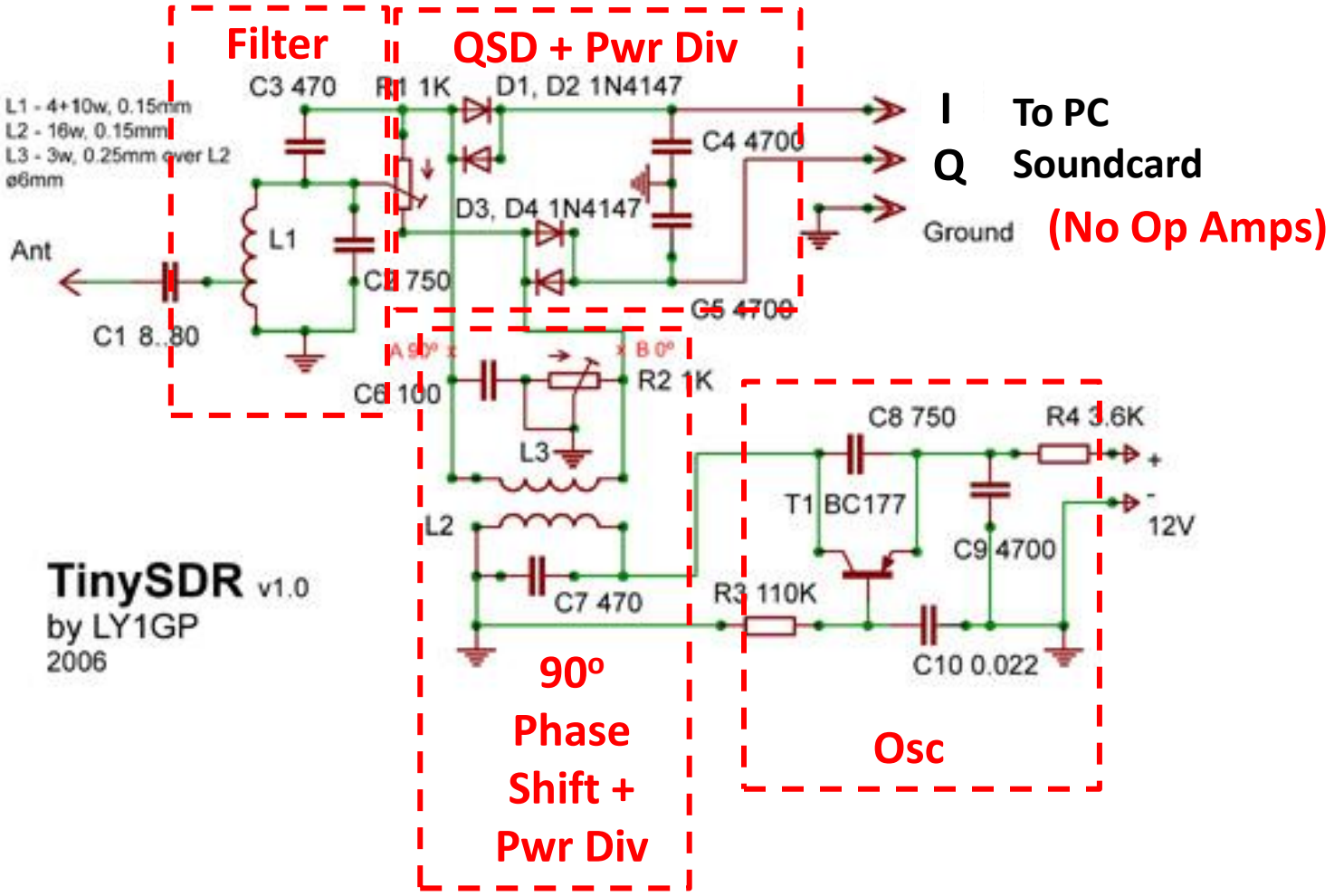
Tiny SDR



Only 20 components!

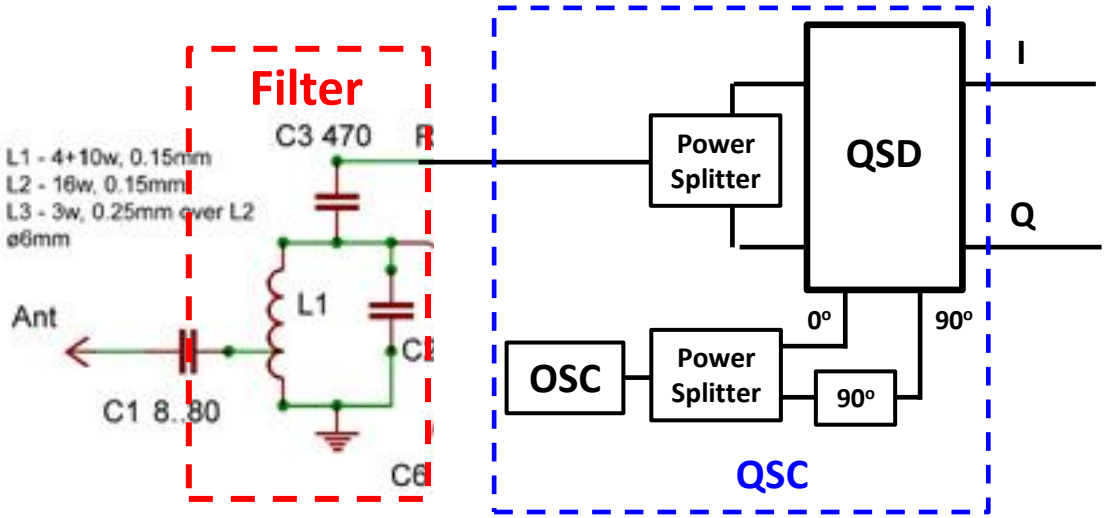
http://www.qrz.lt/ly1gp/SDR/Intermediate

Tiny SDR



http://www.qrz.lt/ly1gp/SDR/Intermediate

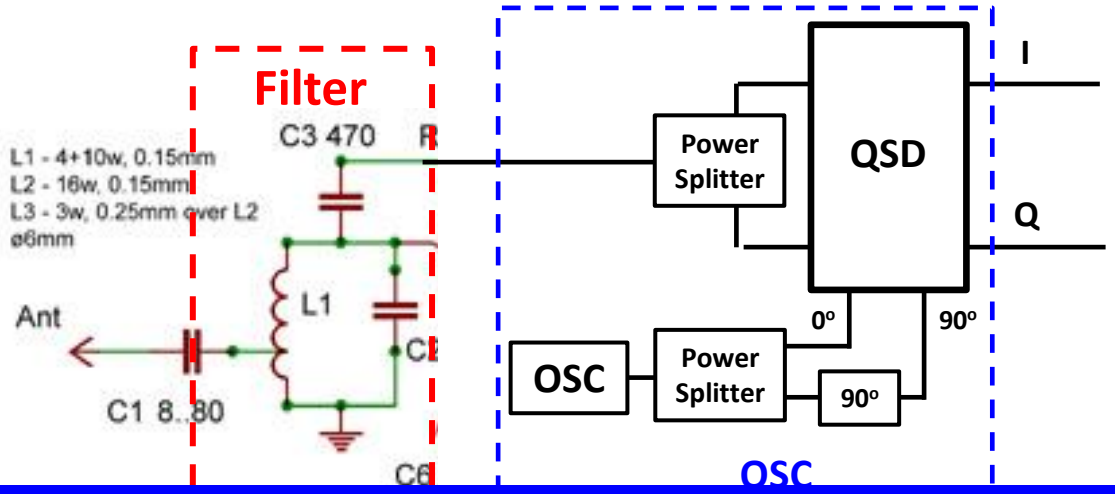
Tiny SDR



TinySDR v1.0
by LY1GP
2006

http://www.qrz.lt/ly1gp/SDR/Intermediate

Tiny SDR



Note: No amplifiers in signal path

TinySDR v1.0
by LY1GP
2006

http://www.qrz.lt/ly1gp/SDR/Intermediate

What is a "Softrock"?

"Softrock" is a term for a software defined radio (SDR) which consists of three major building blocks:

- The **SDR hardware** (e.g., one of the Softrock kits) offered by **Tony Parks (KB9YIG)**: *http://kb9yig.com/*

- A **PC** running SDR software , and

- **Stereo soundcard(s)**
  - One stereo input ("Line IN") for RX, and
  - A second stereo output ("Line OUT") for TX

Documentation: found at *http://www.wb5rvz.com/sdr/*
- Robby Robson (WB5RVZ)

Softrock Kits

- SoftRock_**40_R** receiver kit **$21.00 each**

SoftRock **HF** Receiver Kit **$67.00 each**

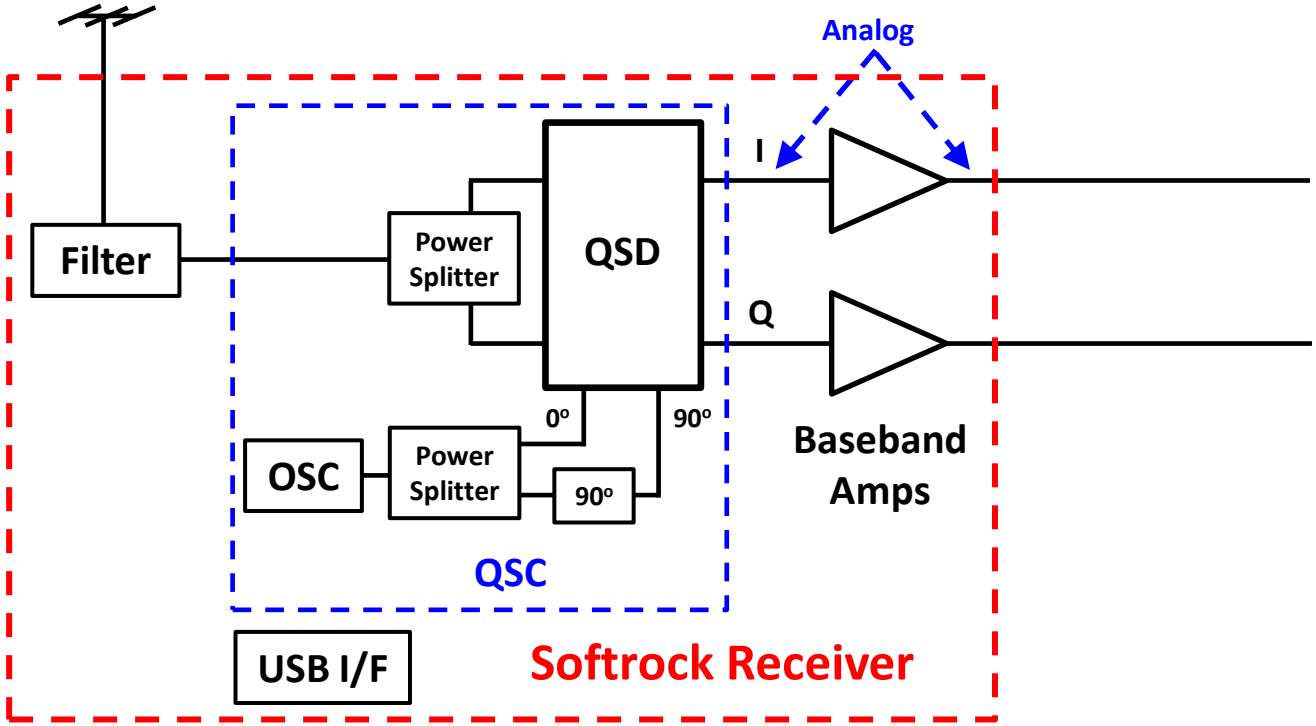
- SoftRock **6m/4m/2m RX Ensemble** Receiver Kit **$68.00 each**

- SoftRock **RXTX Ensemble** Transceiver Kit **$89.00 each**
  - The SoftRock RXTX Ensemble Transceiver Kit provides a 1 watt SDR transceiver that can be built for one of the following four band groups: 160m, 80m/40m, 30m/20m/17m or 15m/12m/10m
- ***When kits do become available, they can sell out within 24-48 hours***

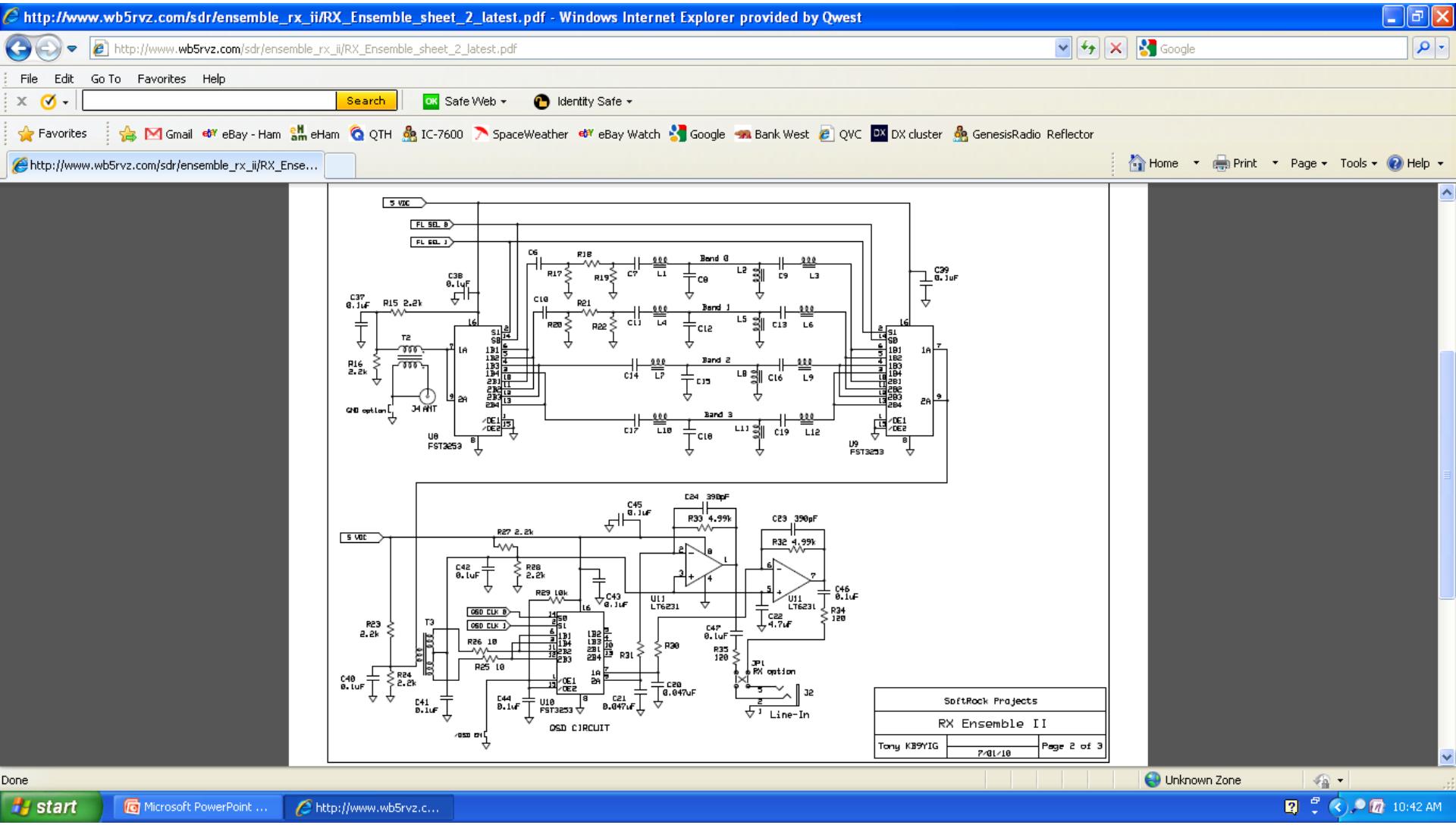
Softrock "Ensemble II"

- **"Ensemble II" RX Specs:**
  - Coverage in 4 bands:
    - **HF:**
      - Band 0: 160M - Continuous coverage from 1.8 to 4.0 MHz
      - Band 1: 80M and 40M- Continuous coverage from 4.0 to 8.0 MHz
      - Band 2: 30M, 20M, and 17M - Continuous coverage from 8.0 to 16 MHz
      - Band 3: 15M, 12M, and 10M - Continuous coverage from 16 to 30 MHz
    - **LF:**
      - 180 KHz to 3.0 MHz in four bands
  - All parts needed for either HF or LF option are supplied in kit
  - Runs on external 12 VDC supply (not supplied)
  - Good sensitivity
  - Front end easily overloaded
  - Makes an excellent Panadapter
  - HDSDR can run on a small Laptop or Netbook that has ***stereo*** "Line IN"
    - Many older Laptops do not have stereo
- **A TX/RX version is also available**

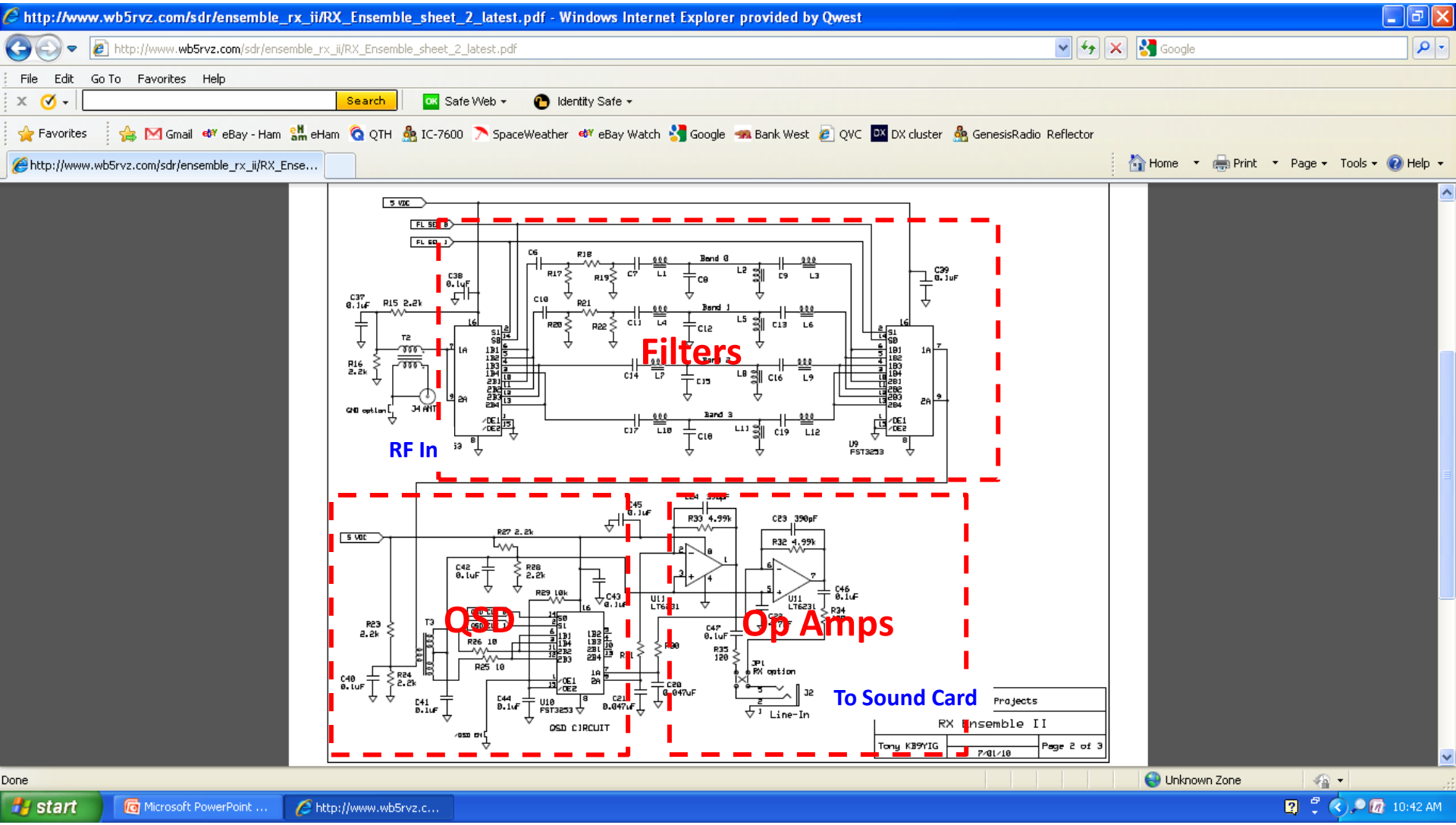
Softrock "Ensemble II" – cont'd



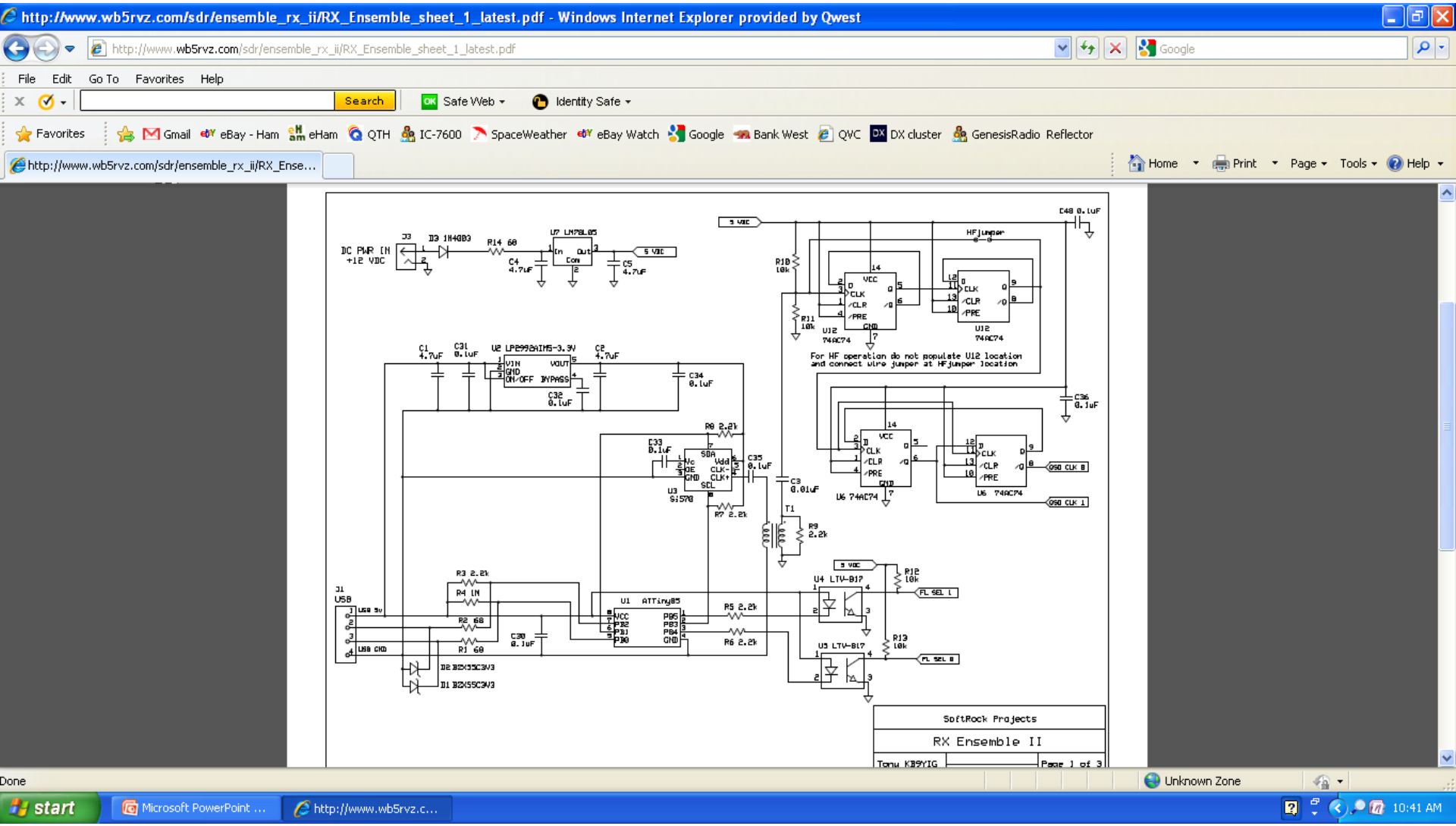
Softrock "Ensemble II" – cont'd



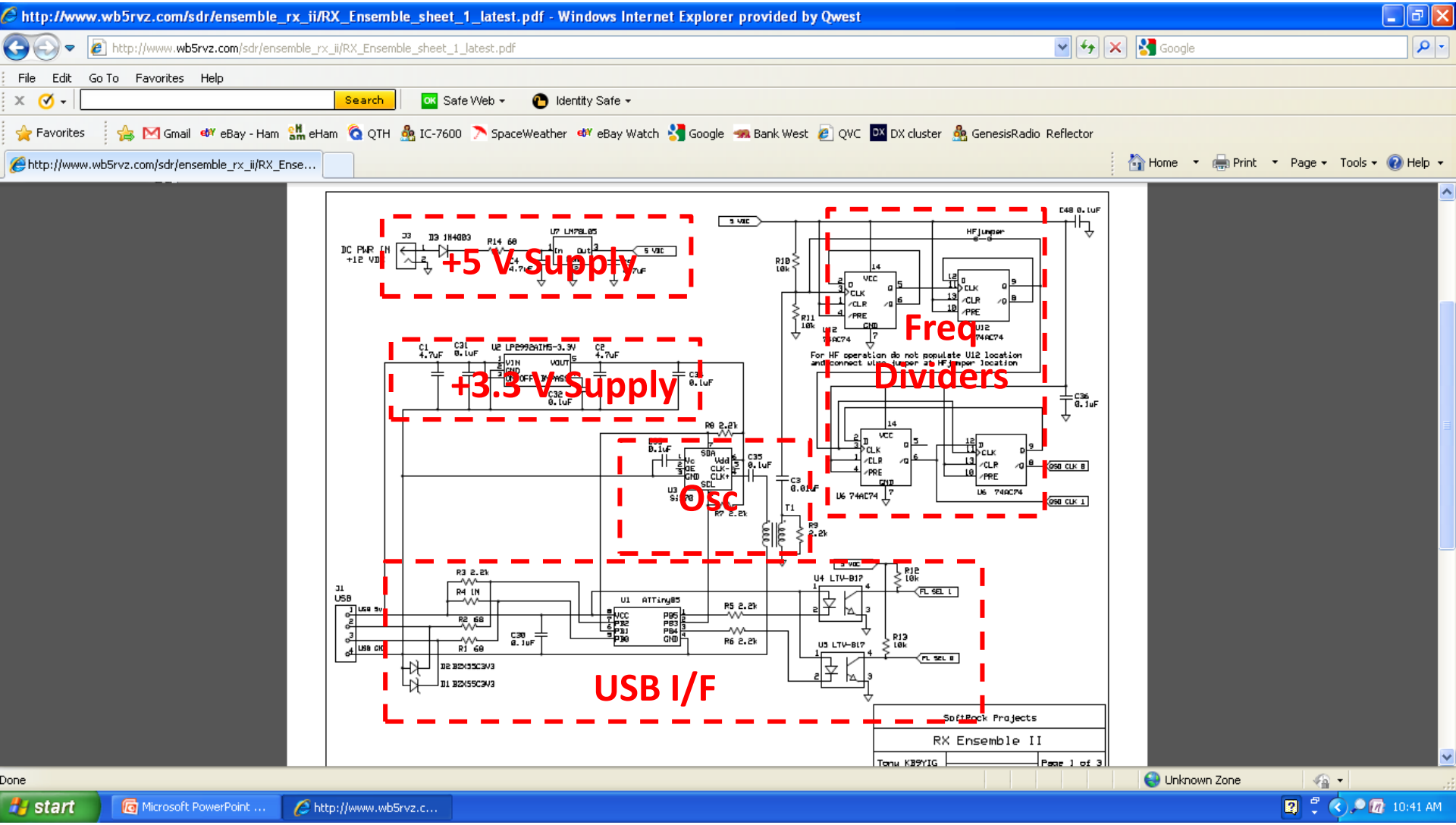
Softrock "Ensemble II" – cont'd



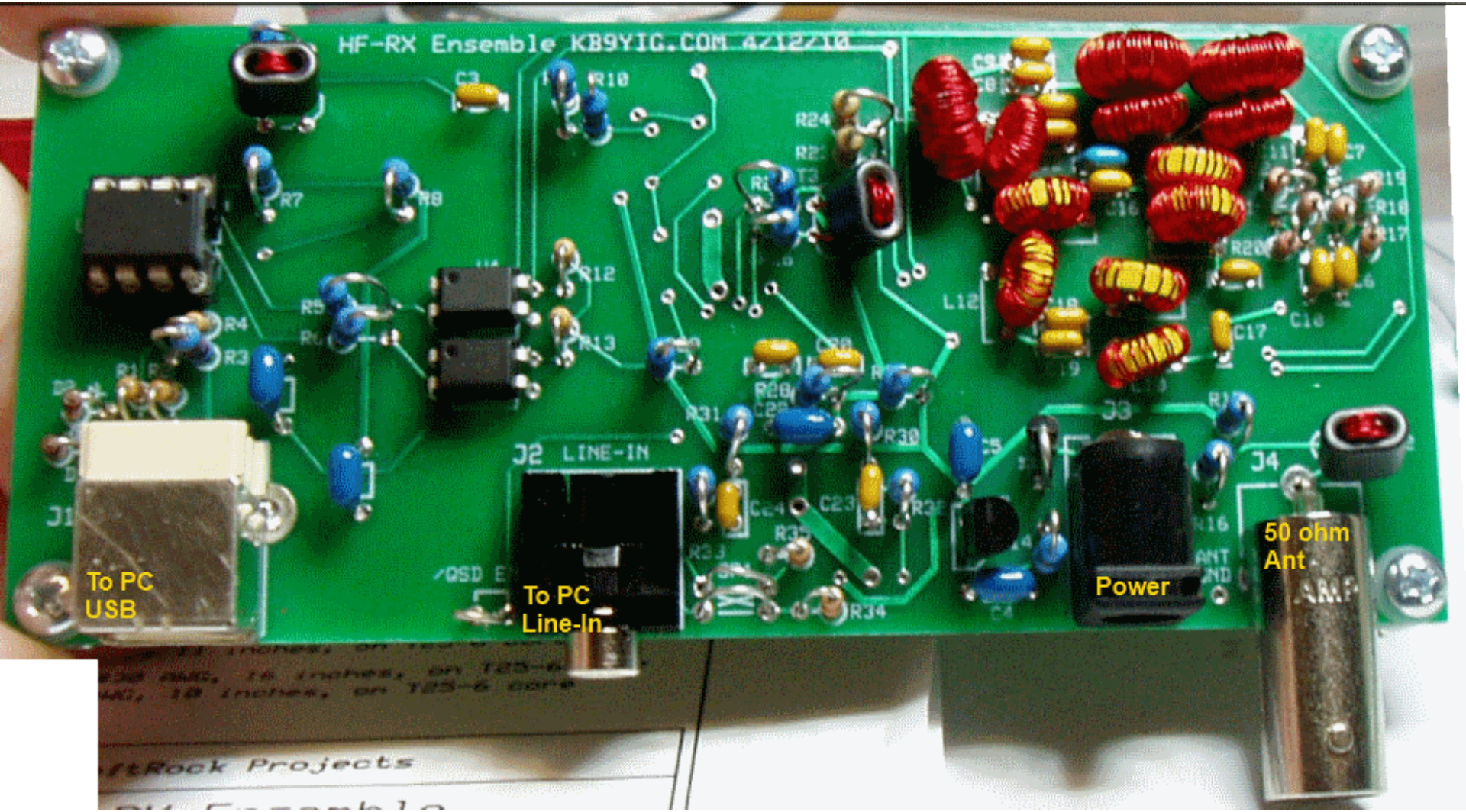
Softrock "Ensemble II" – cont'd



Softrock "Ensemble II" – cont'd

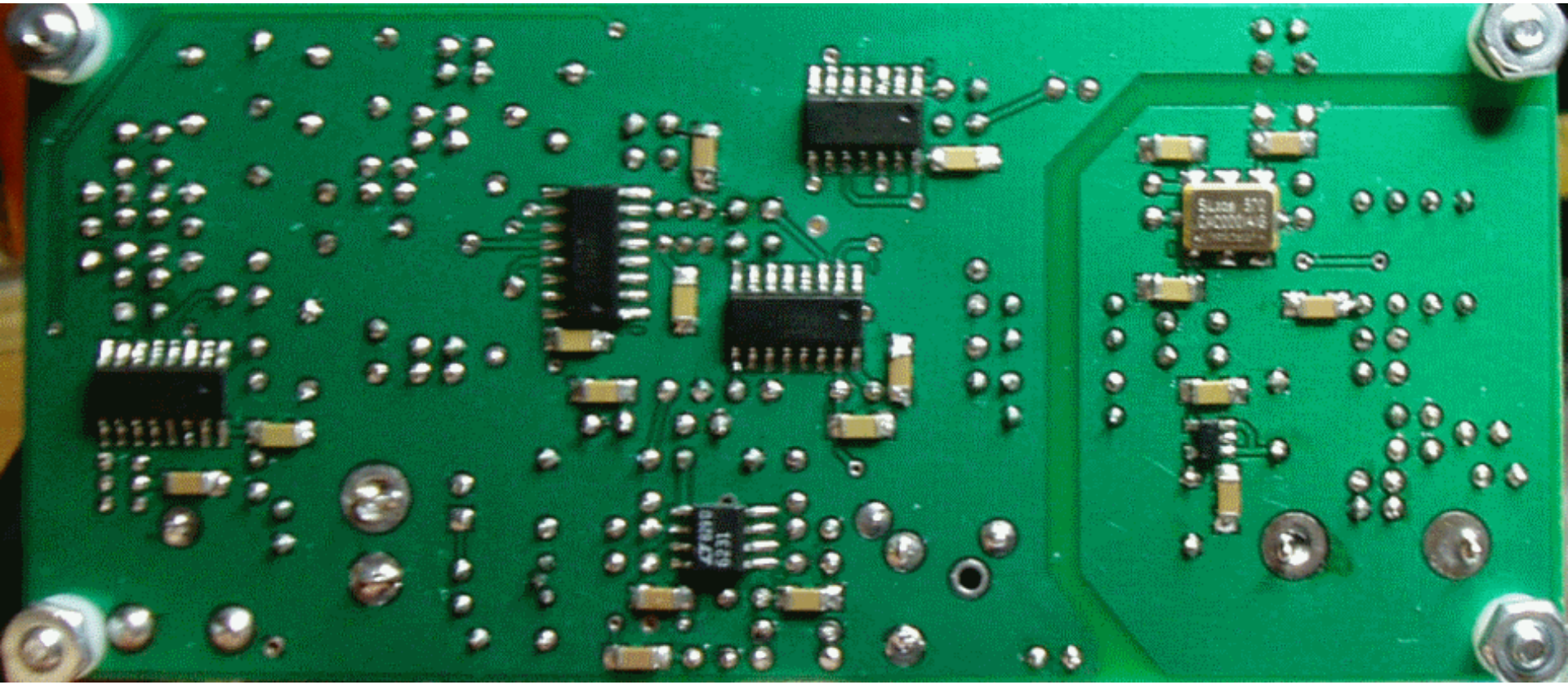


Softrock "Ensemble II" Receiver

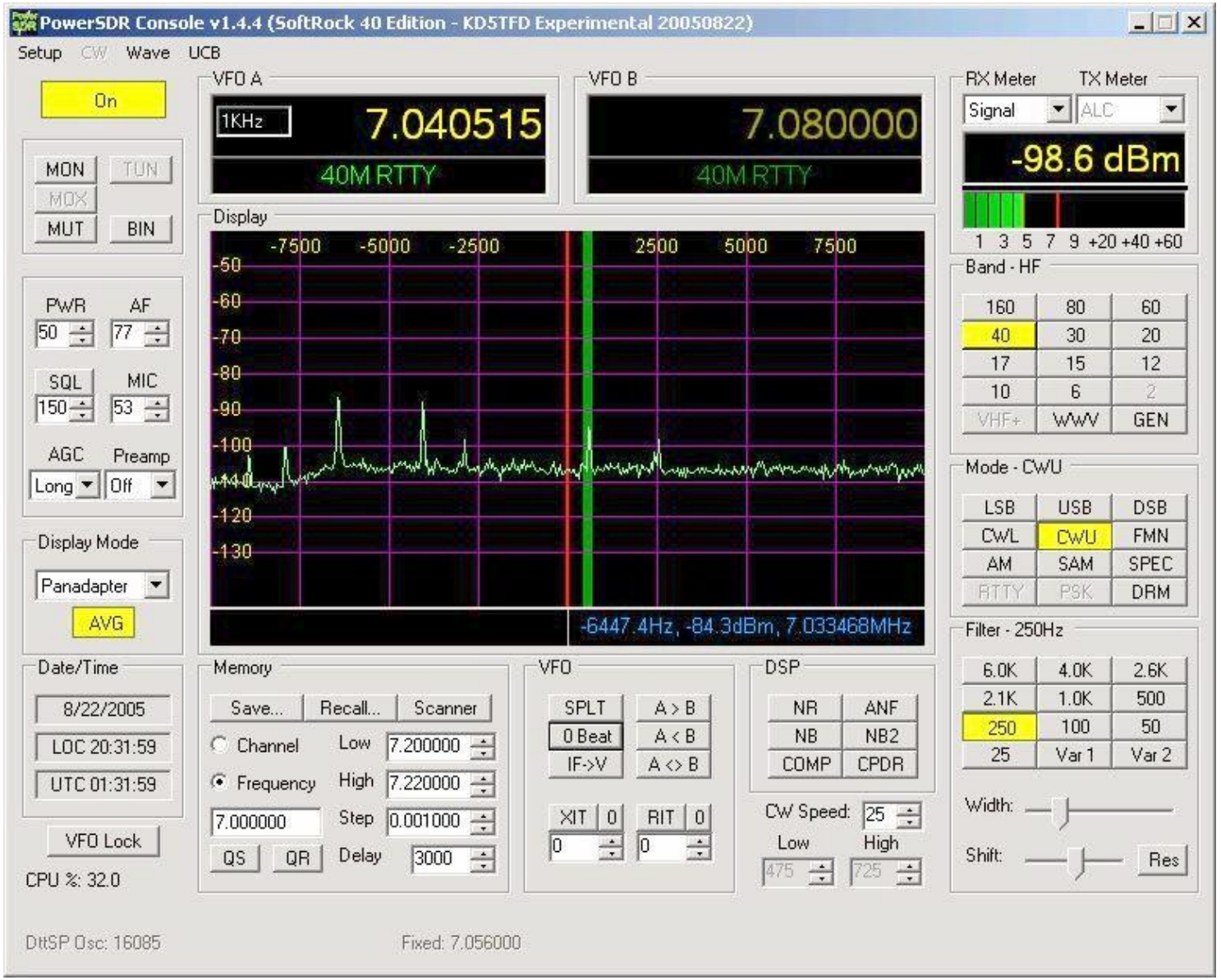


Softrock "Ensemble II" Receiver – cont'd

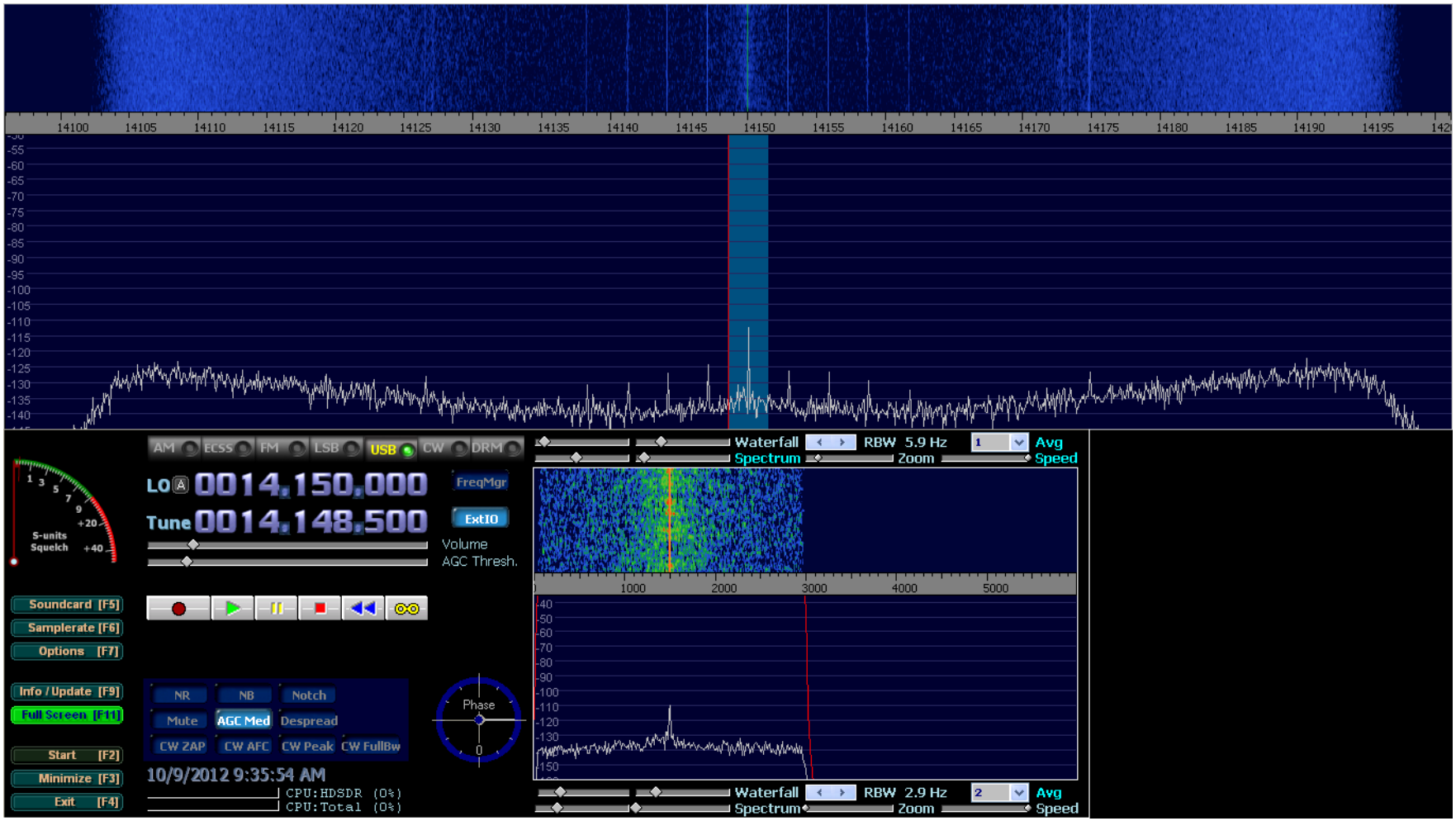
~25 Surface Mount (SMD) Parts



Softrock "Ensemble II" Display (Power SDR)



Softrock "Ensemble II“ Display (HDSDR)

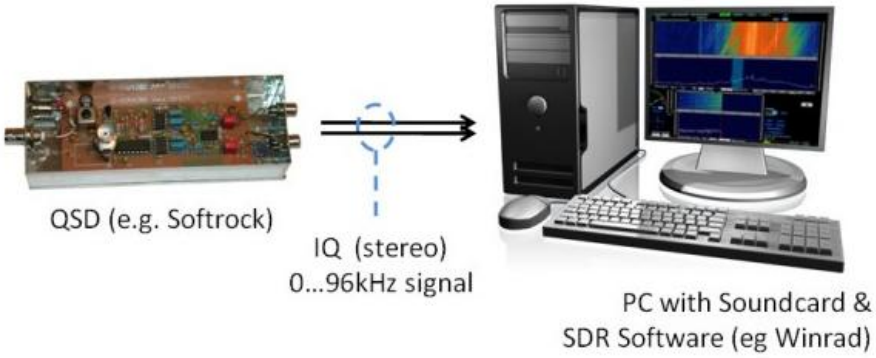


SDR Cube Transceiver

- ***Single band*** HF transceiver
- Built around a Softrock RF front end
- All DSP processing is accomplished by an ***embedded*** DSP processor
  - No external computer or display required
- LCD display ***with Bandscope*** (+/- 4 KHz bandwidth)
- Transmit output power **?** (5 watts?)
- $434 US (Kit) ($293 w/o Softrock Tx/Rx)

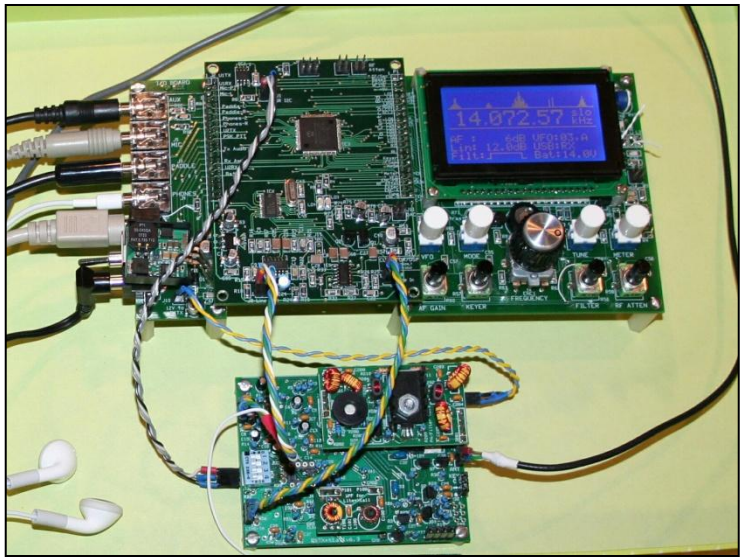
SDR Cube Transceiver – cont'd

Instead of this …



The SDR Cube Does THIS

Embedded DSP



Graphic User Interface

Softrock RXTX 6.3

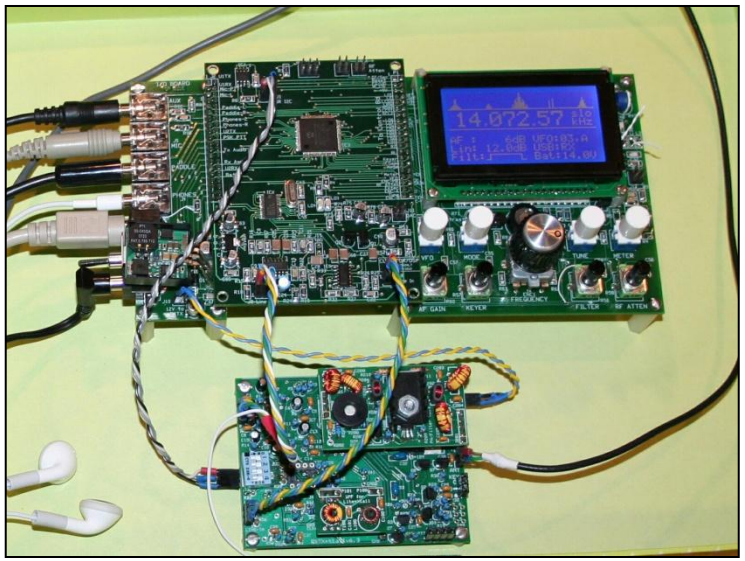
SDR Cube Transceiver – cont'd

Instead of this …

"We don't need no stinkin' PC!"

The SDR Cube Does THIS

Embedded DSP

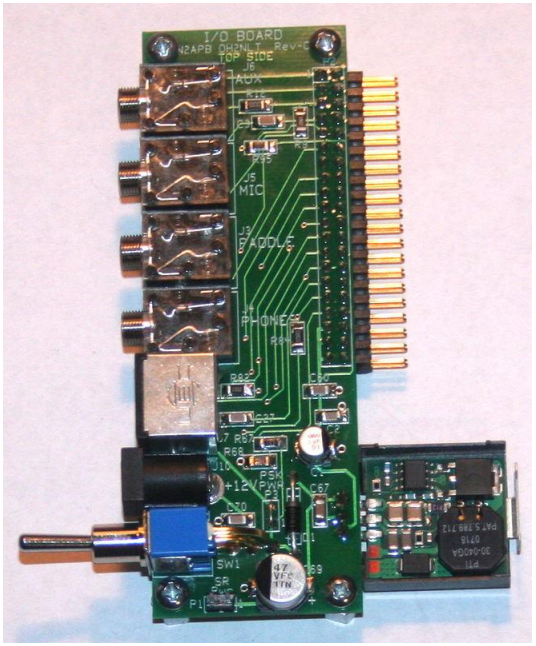


Graphic User Interface

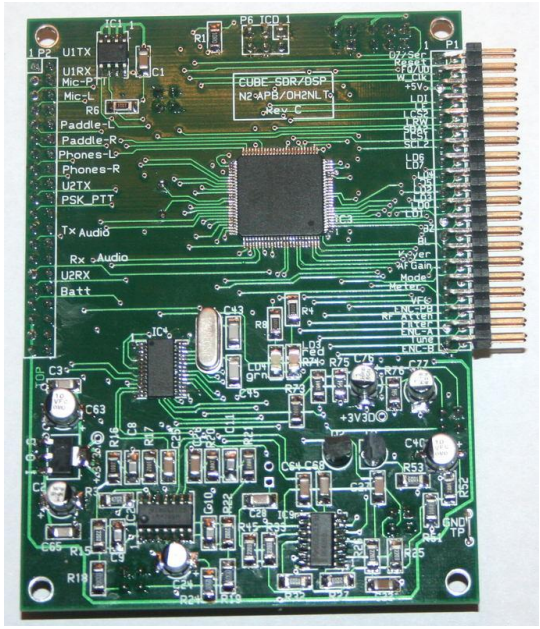
Softrock RXTX 6.3

SDR Cube Transceiver – cont'd

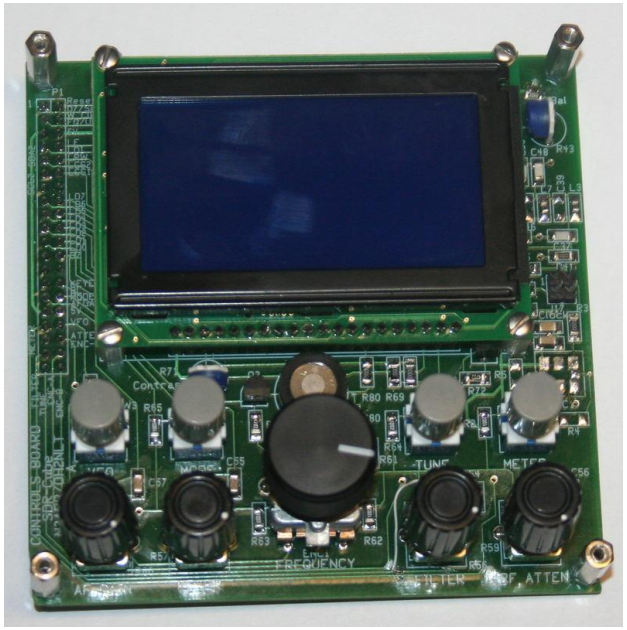
3-PCB BOARD SET



I/O Board



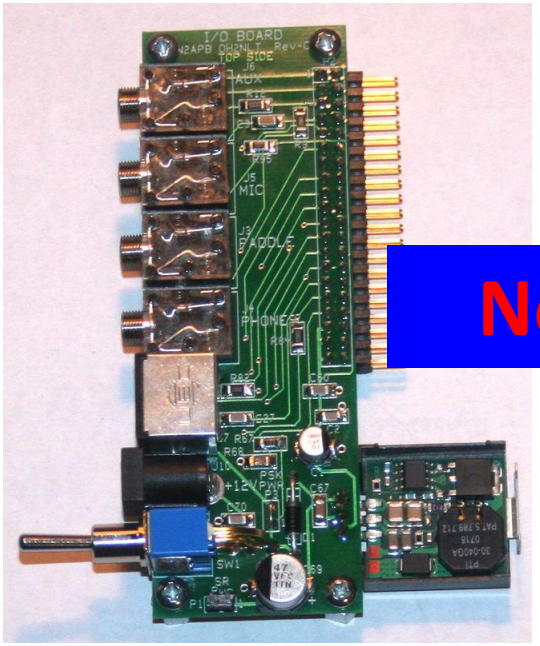
DSP Board

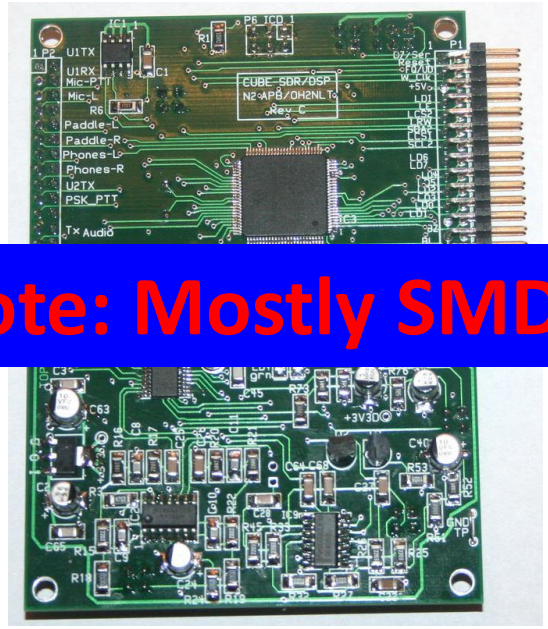


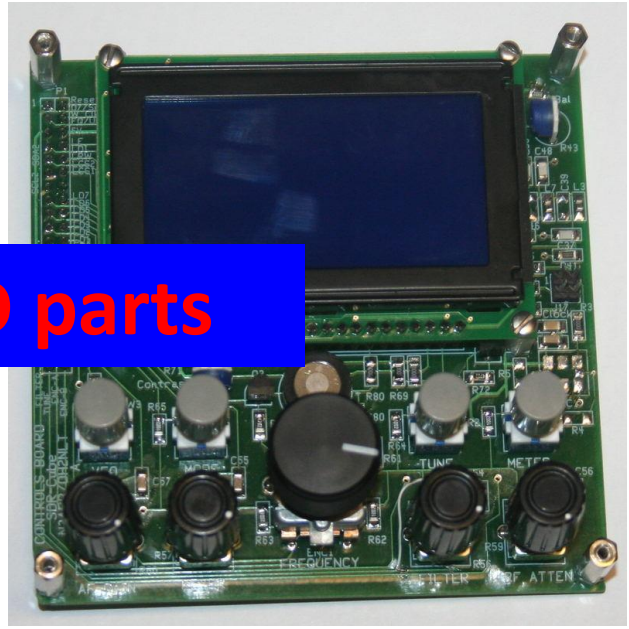
Controls Board

SDR Cube Transceiver – cont'd

3-PCB BOARD SET







Note: Mostly SMD parts

I/O Board

DSP Board

Controls Board

SDR Cube Transceiver – cont'd

HARDWARE ARCHITECTURE

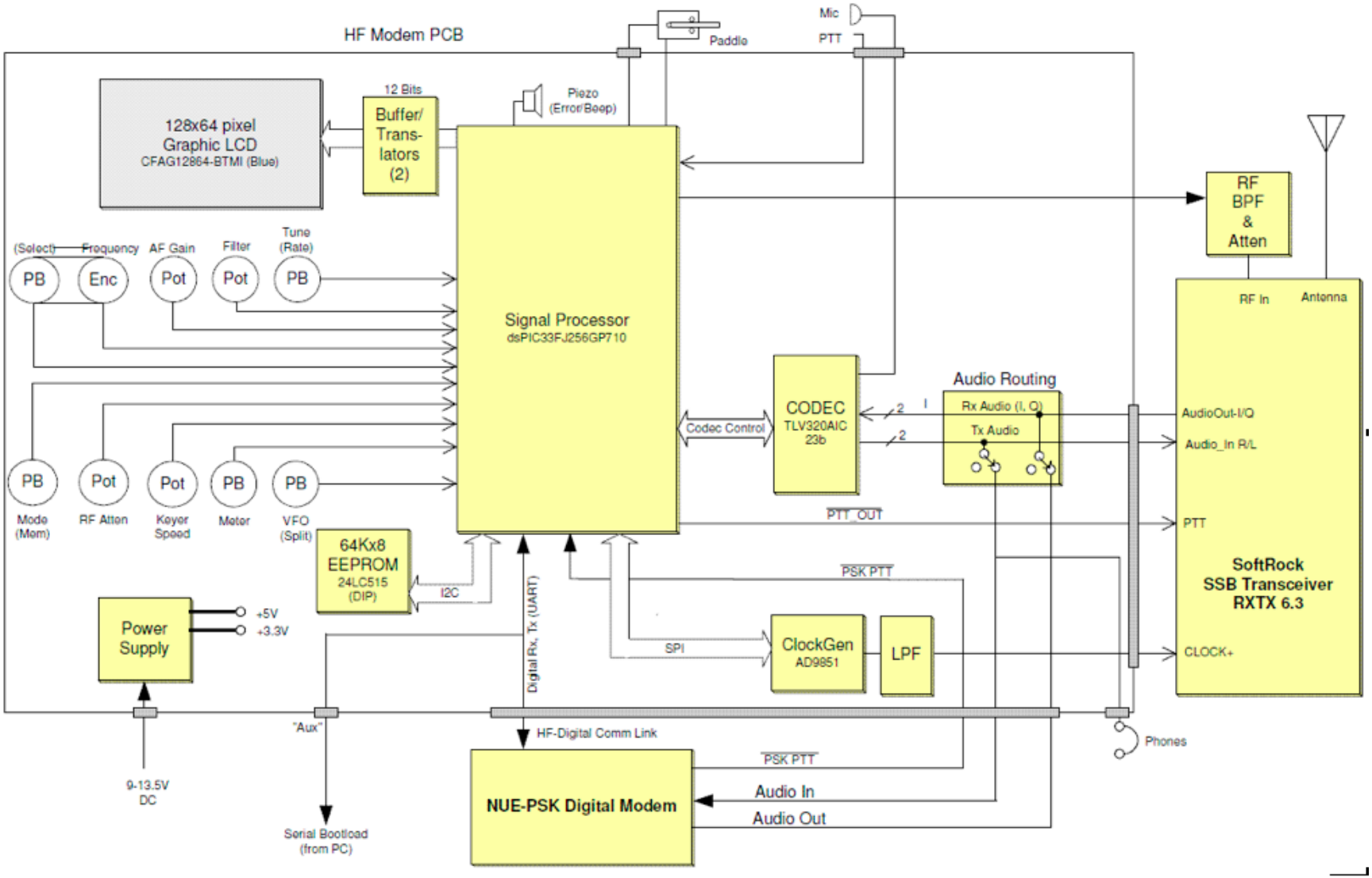
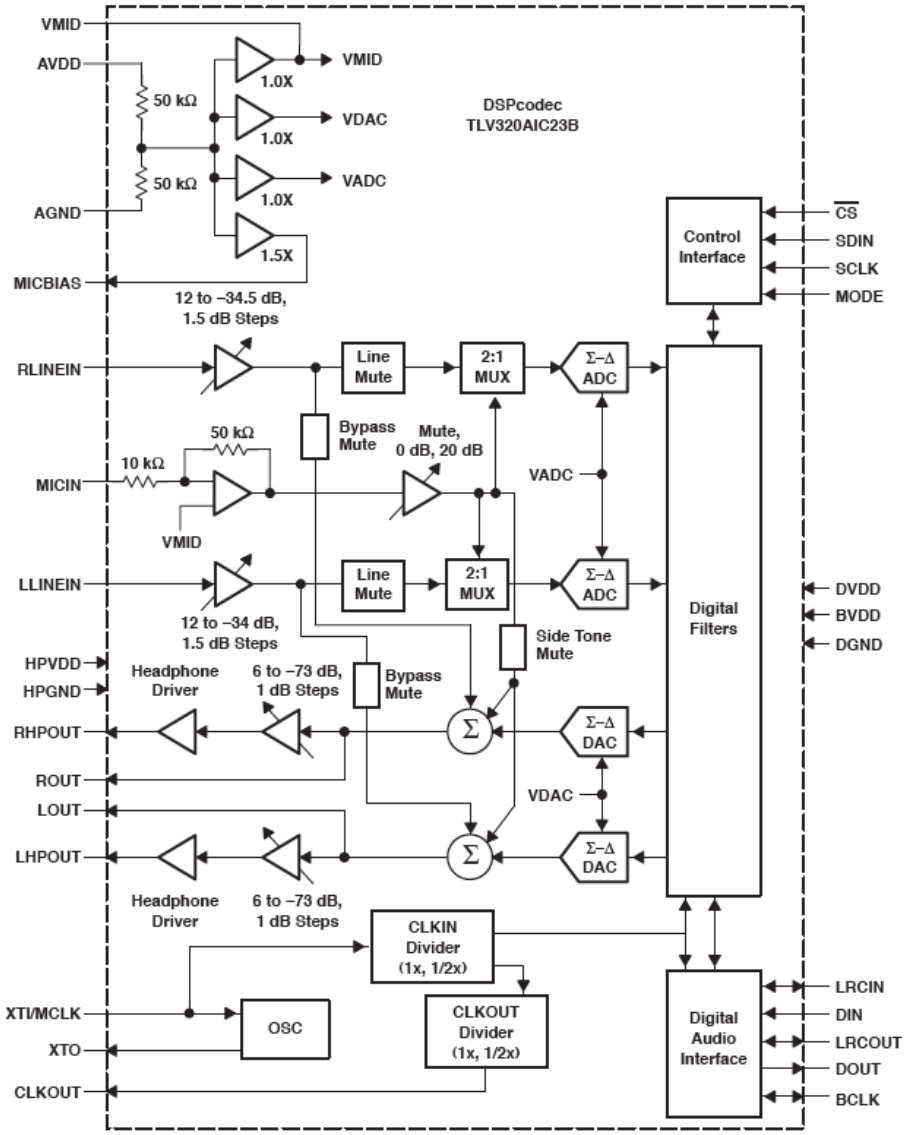


Figure 3: SDR Cube Hardware Architecture

Illustrates designed-in controls, graphic display, and tight integration with NUE-PSK Digital Modem

SDR Cube Transceiver – cont'd



TLV320AIC23B Codec

The TLV320AIC23B is a relatively old codec. The main reason we used this particular part was the accumulated SW experiences how to control it. The TLV320AIC23B also provides handy adjustable input amplifiers, mic amplifier and head phone amplifiers. Most part of the audio signal routing is done with the codec mux block and codec driver sw. Only the PSK modem audio needed external switching.

The TLV320AIC23B provides 24-bit ADC output. Our processing happens in 16-bit resolution but we can benefit from the 24 bits by selecting the magnitude that we use from it. If we start from bit 22 instead of bit 23 we get 6dB gain and so on. S/N ratio gets worse on every bit reduction. Practical numbers are 1 to 3 bits. More can be used, yielding 6 to 18dB of "free gain".

SDR Cube Transceiver – cont'd

Genesis

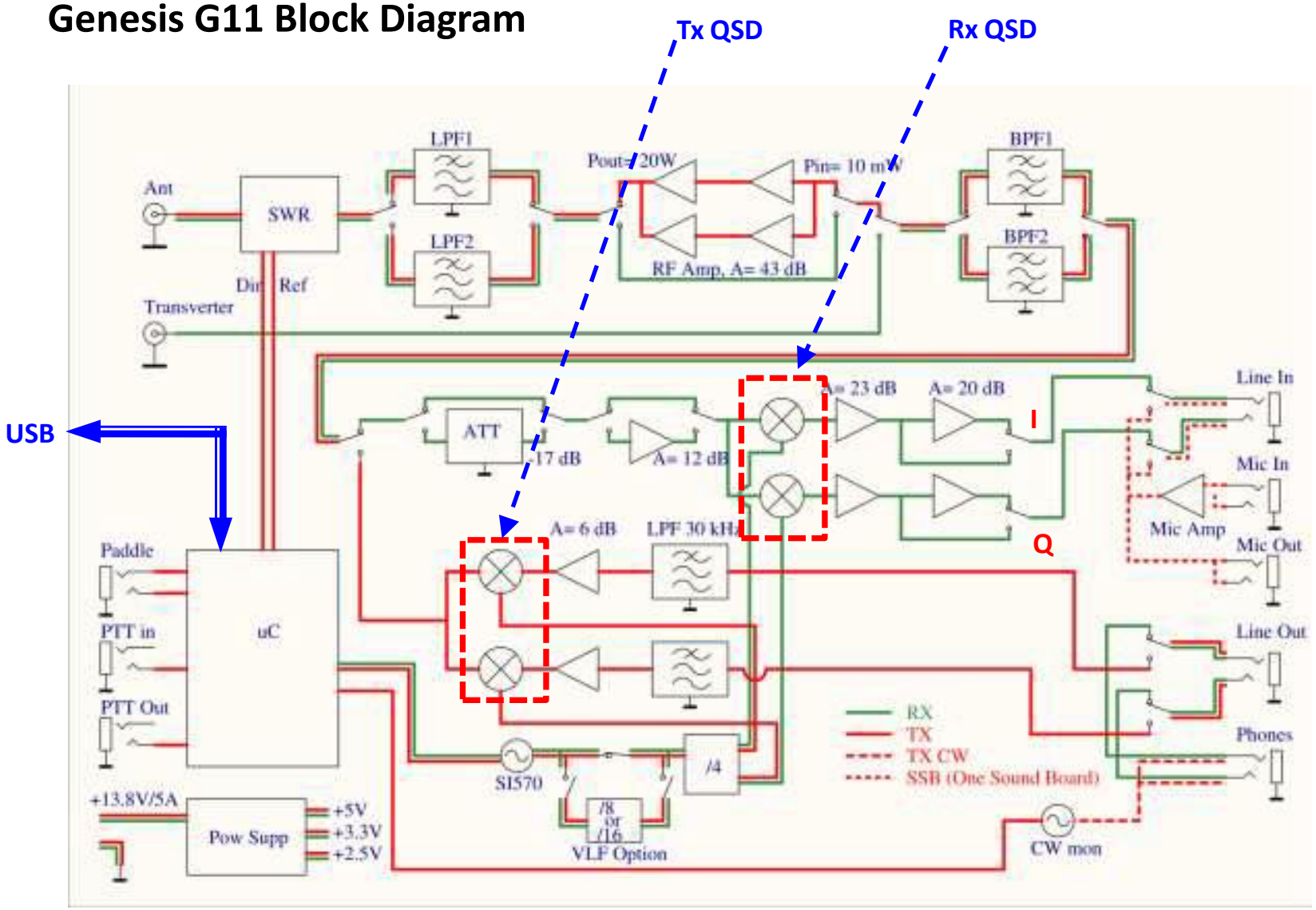
- **What is Genesis?**
  - **Small group (~4) of hams that sell high performance SDR kits**
    - Bus Mgr, H/W Engr, S/W Engr, Tech Support
- **Kits offered:**
  - **G59 HF Transceiver** (no longer offered)
    - GPA-10: 10 watt power amp for 160-6 M (no longer offered)
  - **G11 HF Transceiver**
  - **G6 HF Transceiver (*available Fall 2012*)**
    - Direct Digital Sample
    - ***Not a kit*** (fully assembled)
    - Key features:
      - band coverage: 138KHz-450MHz
      - A/D and D/A convertors built in
      - 32 bit CPU
      - USB 2.0 connection
      - 10W output power
      - SMD technology
  - Kits are periodically built in batches and ***can sell out quickly***
- **Websites:**
  - Home: **http://www.genesisradio.com.au/**
  - Order: **http://www.greenmountainradio.com/G11/order.html**
  - Yahoo Reflector: **http://groups.yahoo.com/group/GenesisRadio/**

Genesis – cont'd

- **G11 Transceiver Kit:**
  - All SMT parts (600+) are ***factory installed***
    - Thru-hole parts (~50) need to be installed by purchaser
    - Average assembly time ~8 hrs
  - Operates all modes on 5 user selected bands
    - Option for 160-6 M available ($139)
  - 10 watt RF output power
  - Schematics can be downloaded from website
    - ***No charge***
  - Build instructions can be downloaded from website
    - ***No charge***
  - GSDR software can be downloaded from website
    - Based on Flex Power SDR
    - ***No charge***
  - Cost: $299 US

Genesis G11 – cont'd

Genesis G11 Block Diagram



Genesis G11 – cont'd

Genesis G11 Specifications:

1. **LF version**: 137 KHz or 500 KHz (RX 50KHz – 2MHz)
   HF version: covers up to **5 HF bands (1.8-30 MHz),** depending on BP/LP filters selection
   160 M monoband
   6 M monoband
2. Min synthesizer step: **1Hz,** adjustable
3. All-mode **CW/SSB/FM/ DIGITAL** *
4. **IIP3 30-32dBm** *
5. **MDS** is -116 to -122dBm * **RF preamplifier** on: MDS is from -**130 to -133dBm***
6. Image rejection: -35 to -60 dB [hardware], better than 60dB [software]
7. **RX sensitivity: 0.15-0.2uV for 10 dB S/N ratio**. Max S/N measured: 70dB.
8. SFDR (Spurious free dynamic range) is 93-100dB these results are with signals spaced 5 kHz or more.
9. Receiver 1dB compression point is + 5dBm
10. **Second antenna RX2 input**
11. **Support for transverter** with split RX input
12. Transmitter output power is **10W min** (5W on 6m) and it is adjustable in software to almost 0W
    - Transmission is possible only on amateur bands
13. TX carrier suppression: 45-60dBc [hardware]
14. Image rejection: -35dBc to -50dBc [hardware], 60dB with GSDR SDR software
15. Built in microphone preamplifier with adjustable 2 position gain to enable operation with single-input sound card [LINE IN or MIC in]
16. **Built in IAMBIC CW keyer with independent CW monitor**
17. Control circuit for keying RF linear power amplifier
18. Power requirements: +12V to +14V @3.5A
19. Specified operating temperature range is from 0C to +55deg C
20. Dimensions 240 x 240 x 88mm weight 1.5kg
21. Kit assembly: 5-8 hours **
22. G11 control via USB connection with GSDR software running on XP, Vista or WIN7 OS

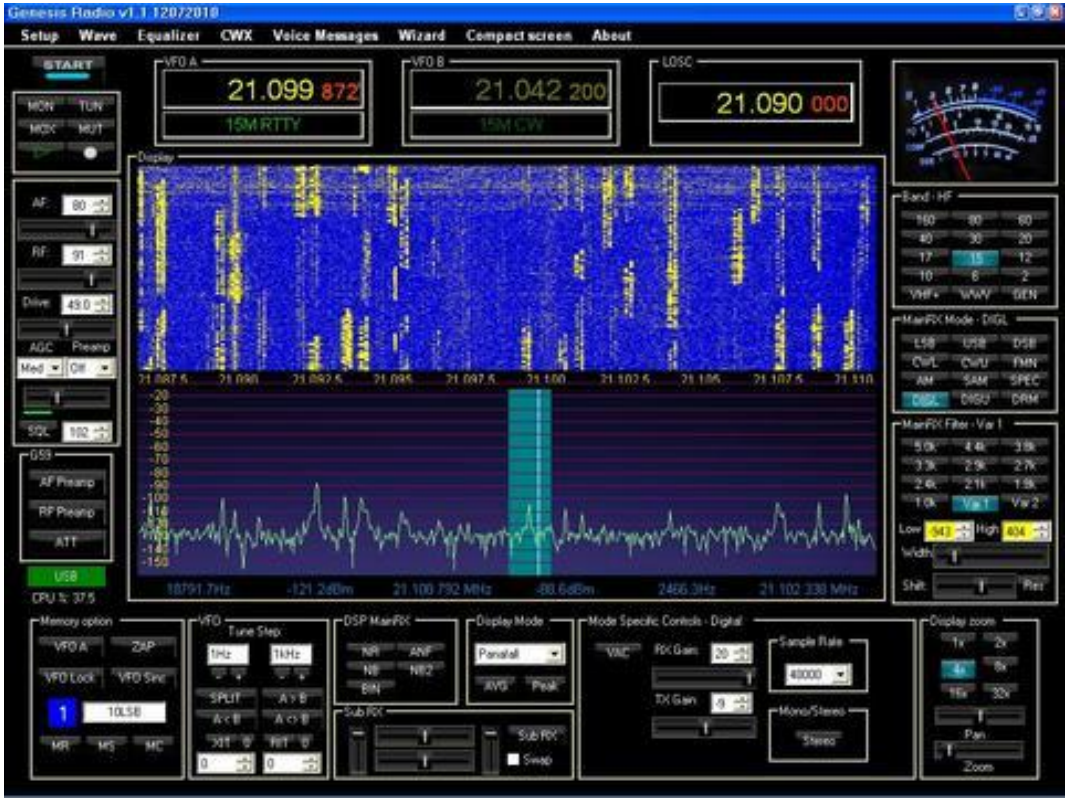
* Software or sound card dependant/related

** enclosure, power supply, sound card and PC supplied by owner!

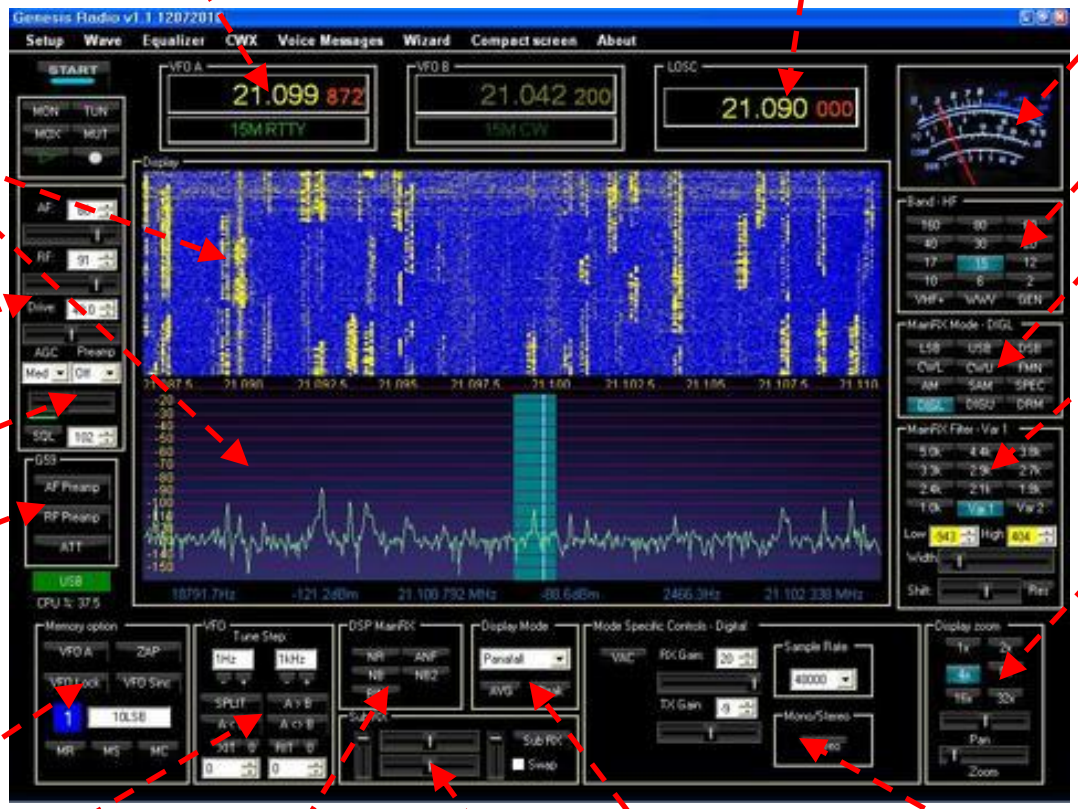
Genesis G11 – cont'd

- The G11 enclosure is ready for board installation
- All holes punched & labeled
- $60

Genesis GSDR Display



Genesis GSDR Display



Main RX

TX

Analog or Digital S Meter

•Waterfall
•Spectrum
•Oscilloscope

Bands Select

Modes Select

Gain Controls

AGC

Bandwidth select

•RF Amp
•AF Amp
•Attenuator

Display Zoom (up to x32)

Memory

VFOs

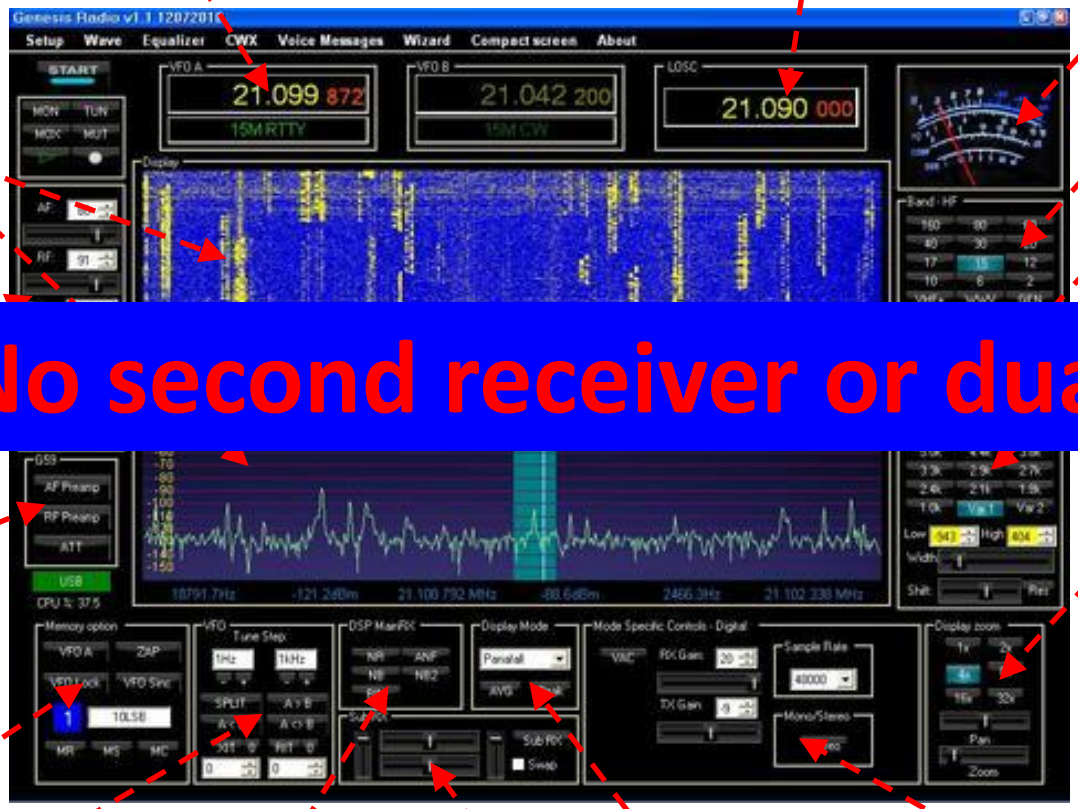
•Noise Reduction
•Auto Notch
•Noise Blankers (2)

Sub RX

Display Control

Digital Modes

Genesis GSDR Display



Main RX

TX

Analog or Digital S Meter

- Waterfall
- Spectrum
- Oscilloscope

Bands Select

Modes Select

Note: No second receiver or dual watch

- RF Amp
- AF Amp
- Attenuator

Display Zoom (up to x32)

Memory

VFOs

- Noise Reduction
- Auto Notch
- Noise Blankers (2)

Sub RX

Display Control

Digital Modes

Panadapter Displays

14.150 MHz
-70 dBm (S9+3dB)
100% AM @ 1KHz

GSDR (96 Ksps)

IC-7600

Wide

Narrow

Panadapter Displays

14.150 MHz
-70 dBm (S9+3dB)
100% AM @ 1KHz

GSDR (96 Ksps)

IC-7600

Wide

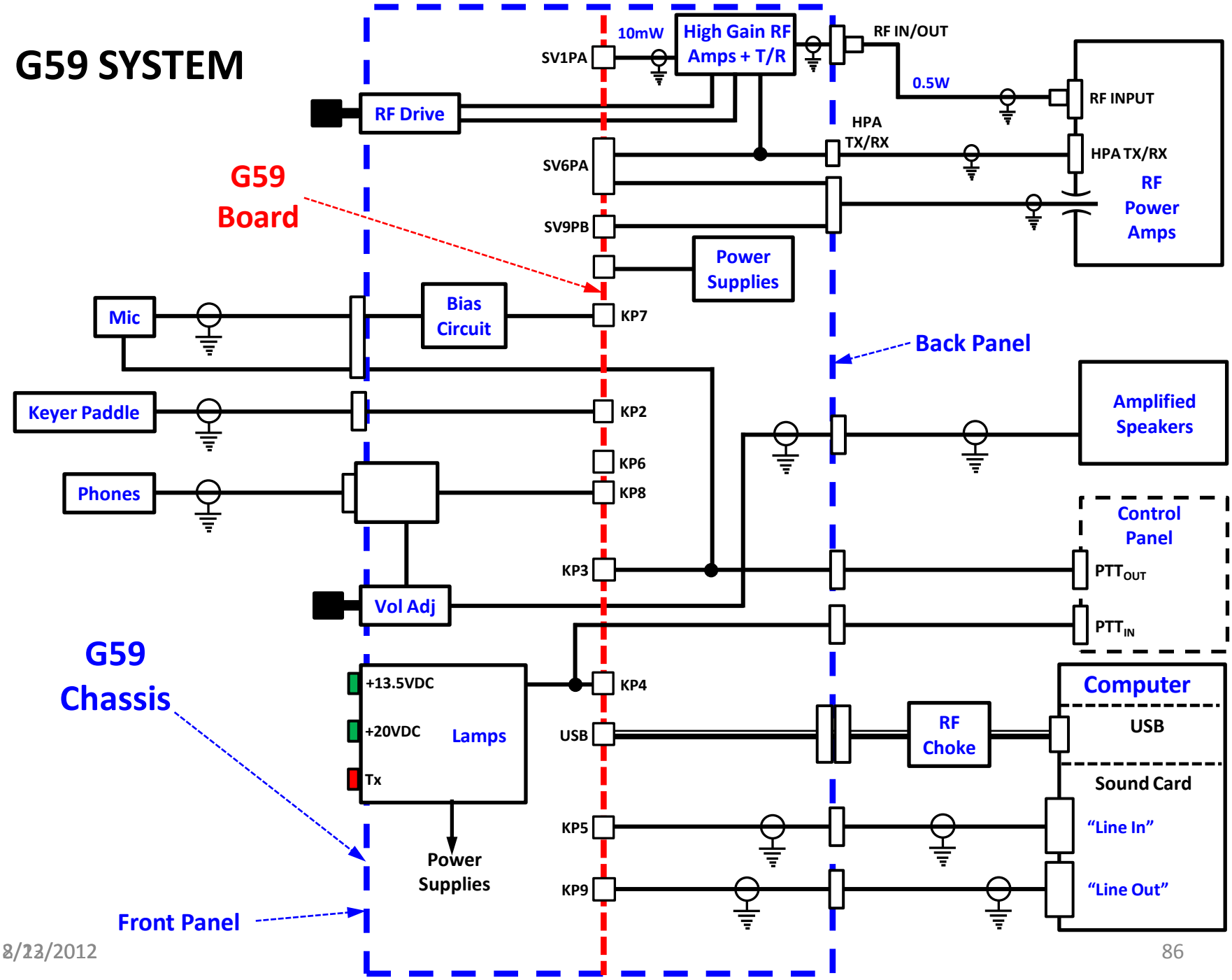
The 7600 can display up to 500 KHz

Narrow

Genesis G59 Transceiver

Genesis G59 Project

- **Goals:**
  - Build a high performance 100 watt SDR transceiver for *daily ops*
- **Approach:**
  - Use parts from junk box as much as possible
  - Packaging: Ease of servicing more important than small size
  - Use Genesis G59 transceiver as the core
  - Use an EM-U 1212 sound card (24 bits & 192 Ksps)
  - Build HF power amp capable of 100 watts continuous duty
  - 7 Bands: 160M, 80M, 40M, 20M, 15, 17M, 10M
  - Separate into two chassis:
    - **Chassis 1**: G59 SDR Transceiver + High Gain RF Amps
      - Don't want high sensitivity circuits in same chassis with 200 watt power amp
      - Use linear power supplies
    - **Chassis 2**: RF Driver Amp + High Power RF Amp
      - Use IRF-510 FETs for driver amp
        - Input 0.5 watt for 20 watts out
      - Use CCI 200 watt kit for final amp
      - Add SWR & Thermal protection circuits
      - Use self contained switching power supply
    - Use "**RF tight**" enclosures for both chassis

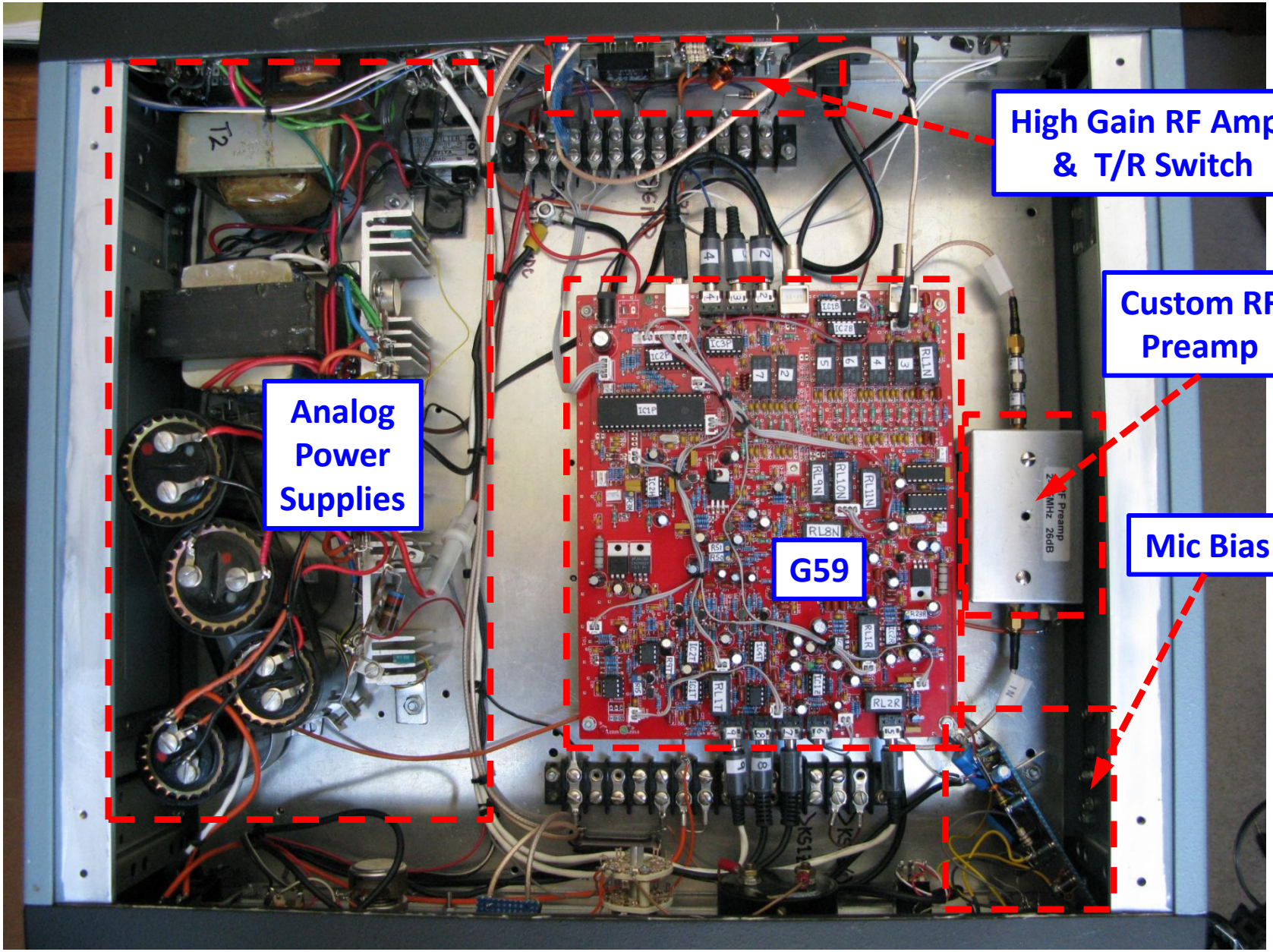

G59 SYSTEM
G59 Board
G59 Chassis
Front Panel
Back Panel
10mW
High Gain RF Amps + T/R
SV1PA
RF IN/OUT
0.5W
RF INPUT
RF Drive
HPA TX/RX
HPA TX/RX
SV6PA
RF Power Amps
SV9PB
Power Supplies
Mic
Bias Circuit
KP7
Keyer Paddle
KP2
KP6
Phones
KP8
Amplified Speakers
Control Panel
KP3
PTT OUT
Vol Adj
PTT IN
+13.5VDC
+20VDC
Tx
Lamps
KP4
Computer
USB
RF Choke
USB
Sound Card
KP5
"Line In"
Power Supplies
KP9
"Line Out"

Genesis G59 Project

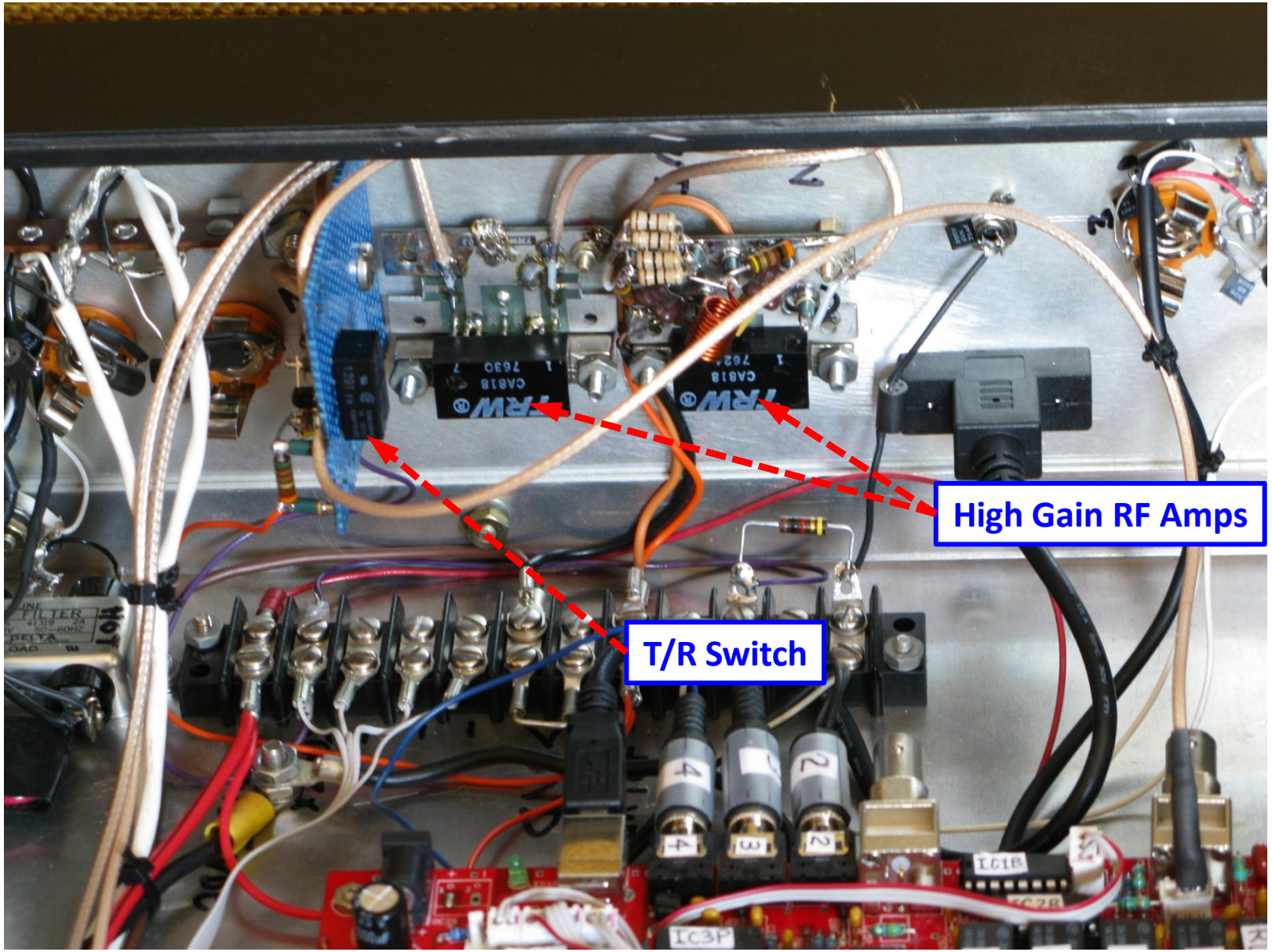
Genesis G59 Project

G59 & RF Power Amp Front Panels

G59 Chassis


High Gain RF Amps & T/R Switch
Custom RF Preamp
Analog Power Supplies
G59
Mic Bias

G59 High Gain RF Amps & T/R Switch



Knobs

Flex 5000

Knobs

Flex 5000

"We don't need no stinkin' knobs!"

Knobs

"I do need those stinkin' knobs !"

(... and meters, and switches, and lights, and ...)

G59 Panel Layouts

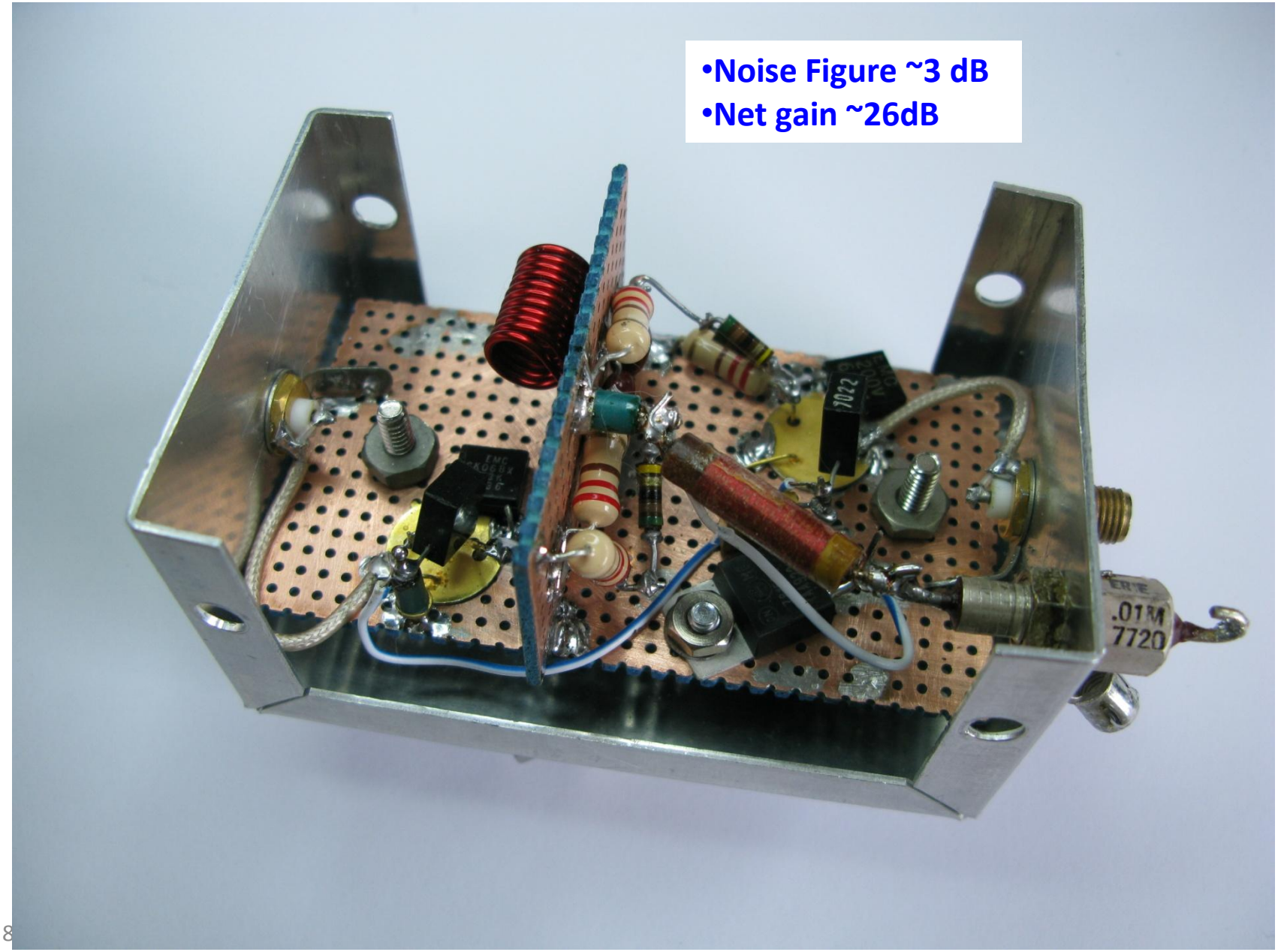
Receiver Performance - Sensitivity

	Estimated **Sensitivity[1]**
IC-7600	**0.15 uV (= -123 dBm = S1)[2]**
TS-930S	**0.2 uV (= -121 dBm = S1)**
G59	**~0.8 uV (= -109 dBm = S2)[3]**
G59	**<0.1 uV (< -127 dBm < S1)[4]**
Ensemble II	**~2 uV (= -101 dBm = S4)[5]**

Notes:

1: ~10 dB output (S+N)/N using maximum RF preamp gain (BW=2.4KHz)
2: Measurements made with Preamp 2 ON (spec = 0.15 uV)
3: Preamp OFF
4: Using custom RF Preamp
5: Has *no* RF Preamp

G59 Custom RF Preamp



Receiver Performance – Dynamic Range

- Dynamic Range is hard to measure for digital receivers
  - Traditional methods such as IP3 can be inaccurate and mis-leading
  - Digital radios can have unwanted spurs even at low signal levels that analog radios do not have
  - Overloading the ADC causes ***serious*** problems
    - Example: G59 Overload (RF Preamp OFF)

0 dBm

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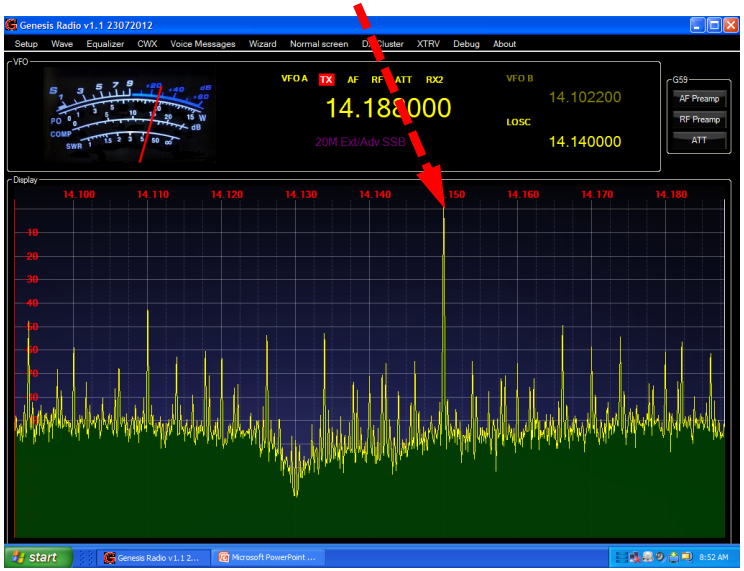
0 dBm

1 dBm



Receiver Performance – Dynamic Range

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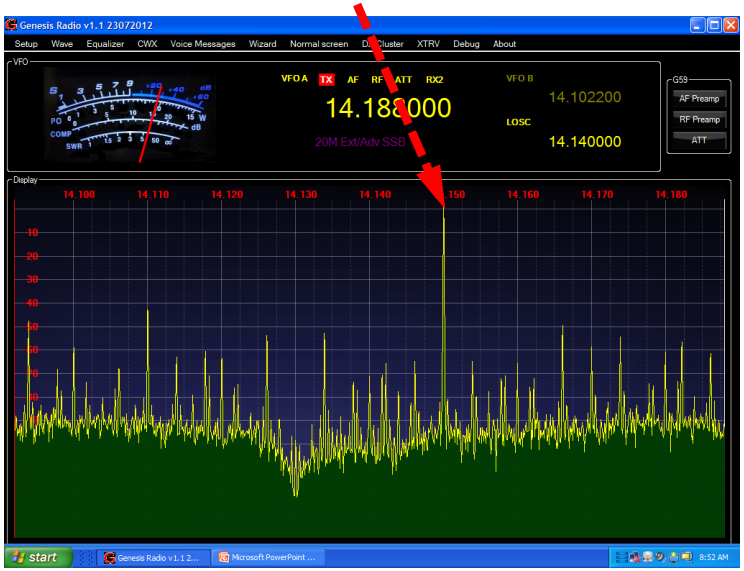
  - Traditional methods such as IP3 can be inaccurate and mis-leading
  - Digital radios have unwanted spurs even at low signal

Note: +1 dBm = S9 + 74 dB

- Example: G59 Overload (RF Preamp OFF)

0 dBm

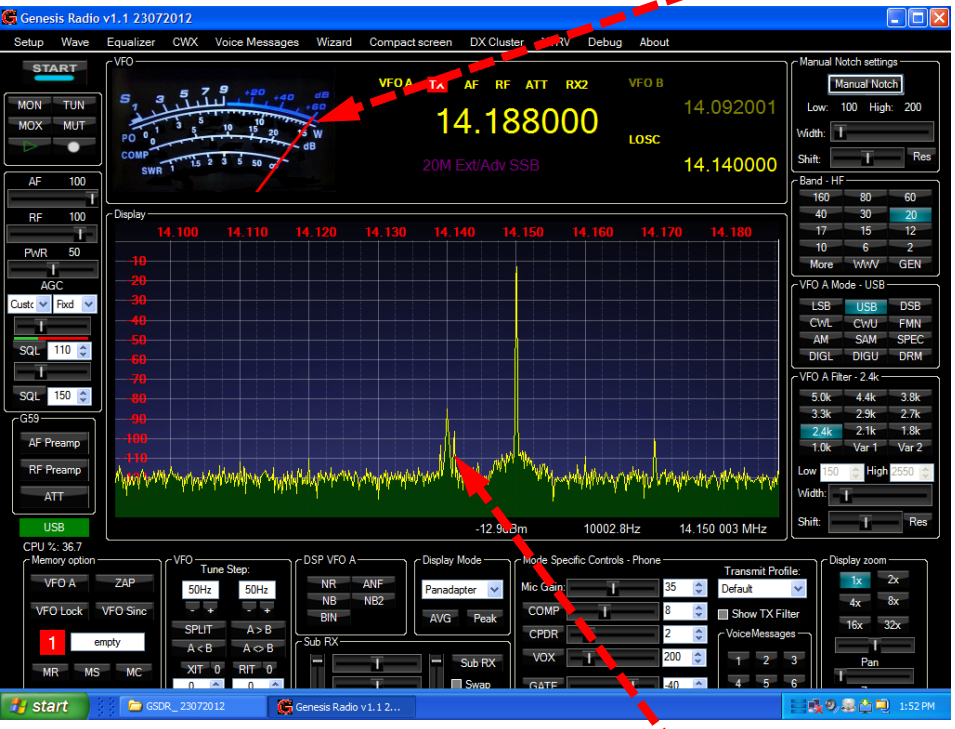
1 dBm



Receiver Performance – Dynamic Range

S9+60 dB

G59



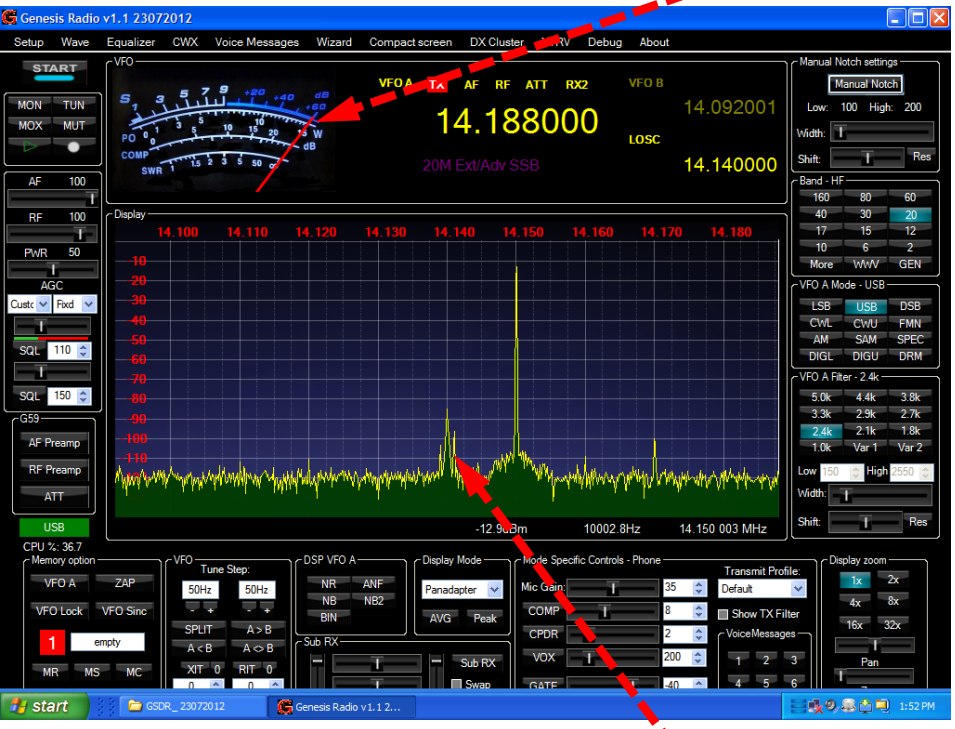
Not a spur (common with Direct Conversion Receivers)

Receiver Performance – Dynamic Range

- The IC-7600 does not exhibit hard limiting
  - It has a <u>hardware</u> AGC that the G59 does not have

S9+60 dB

G59



IC-7600

Not a spur (common with Direct Conversion Receivers)

Receiver Performance – Dynamic Range

- The IC-7600 does not exhibit hard limiting
  - It has a <u>hardware</u> AGC that the G59 does not have

S9+60 dB

G59

IC-7600

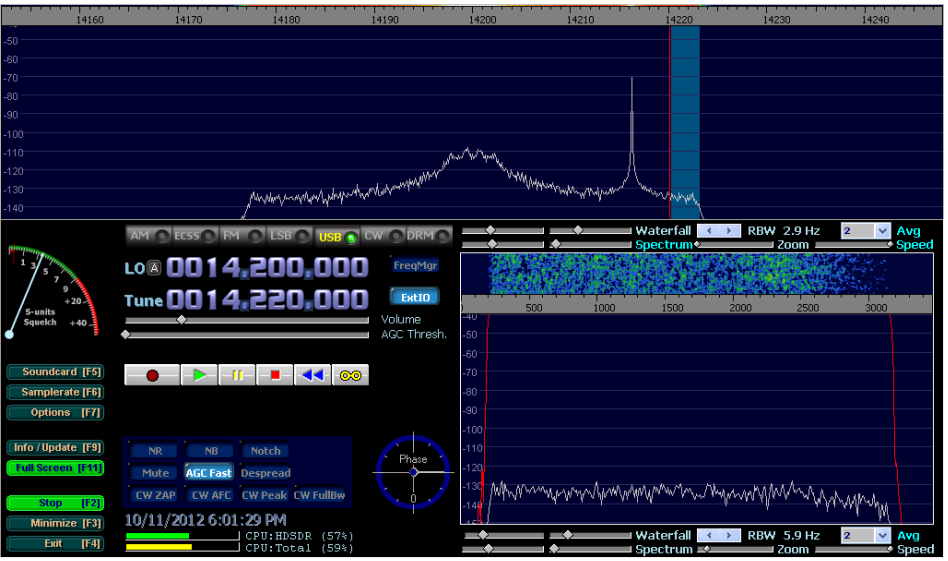
Which receiver is better???

Not a spur (common with Direct Conversion Receivers)

Receiver Performance – Dynamic Range

- **The Ensemble II/ACER Notebook *combination* overload:**

S9+13 dB



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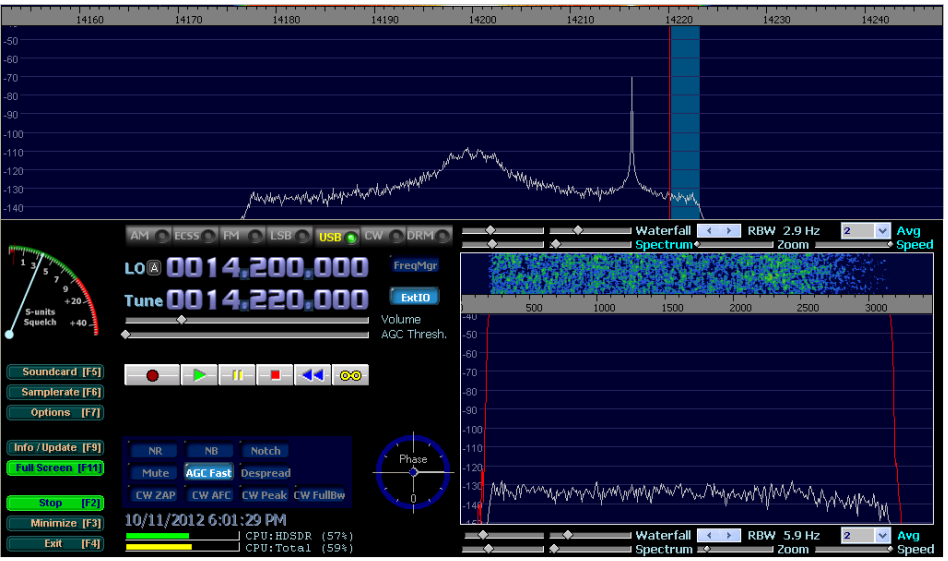
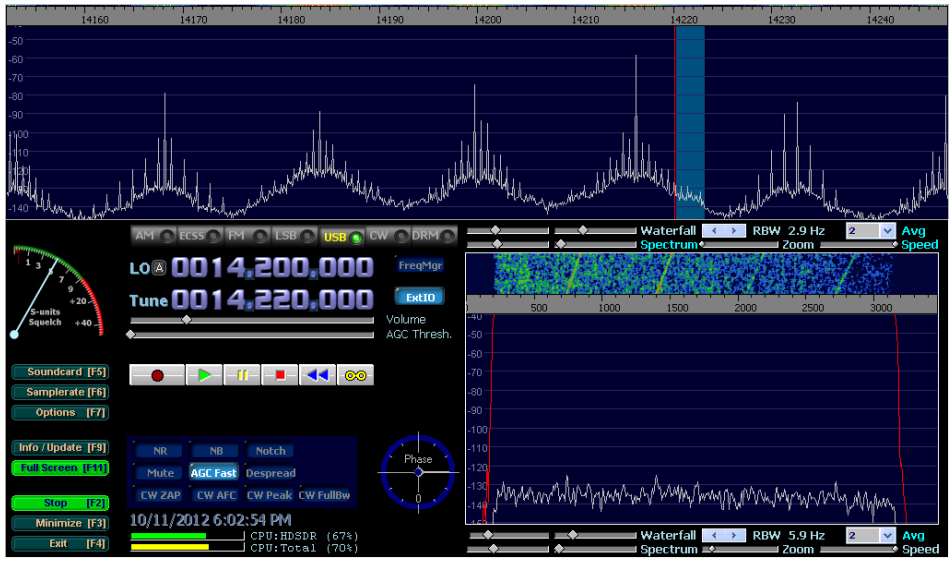


S9+14 dB



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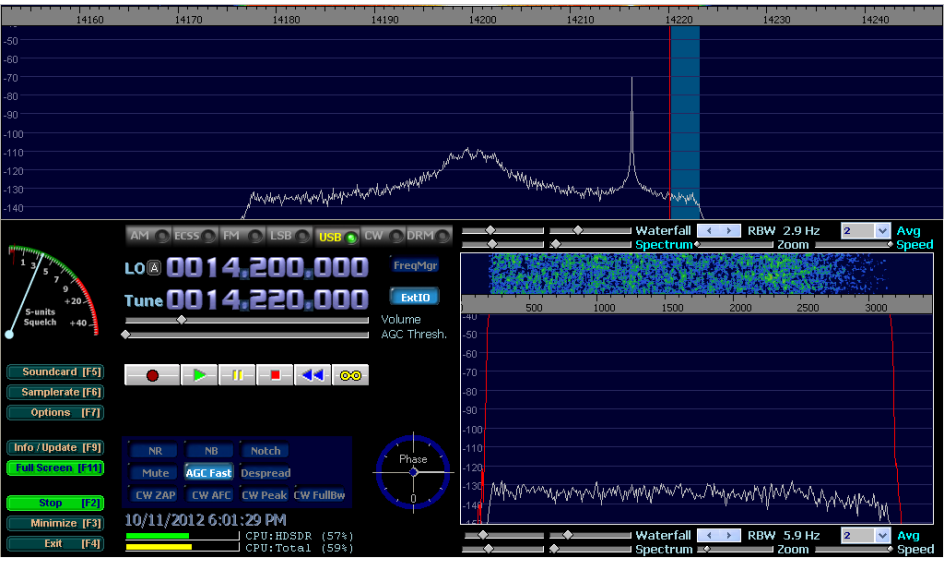
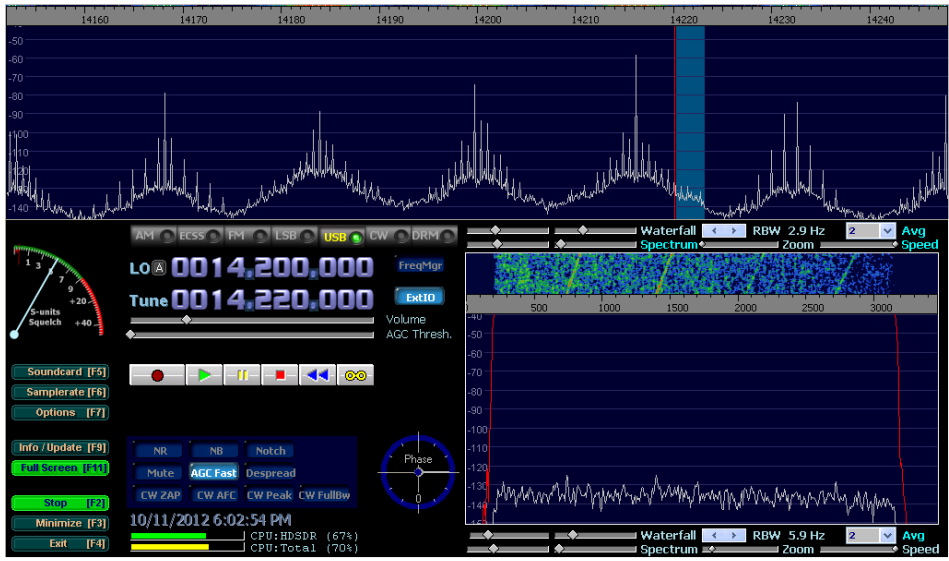


S9+14 dB



- **The Ensemble II looks good up to -15 dBm (S9+58 dB)**

Receiver Performance – Dynamic Range

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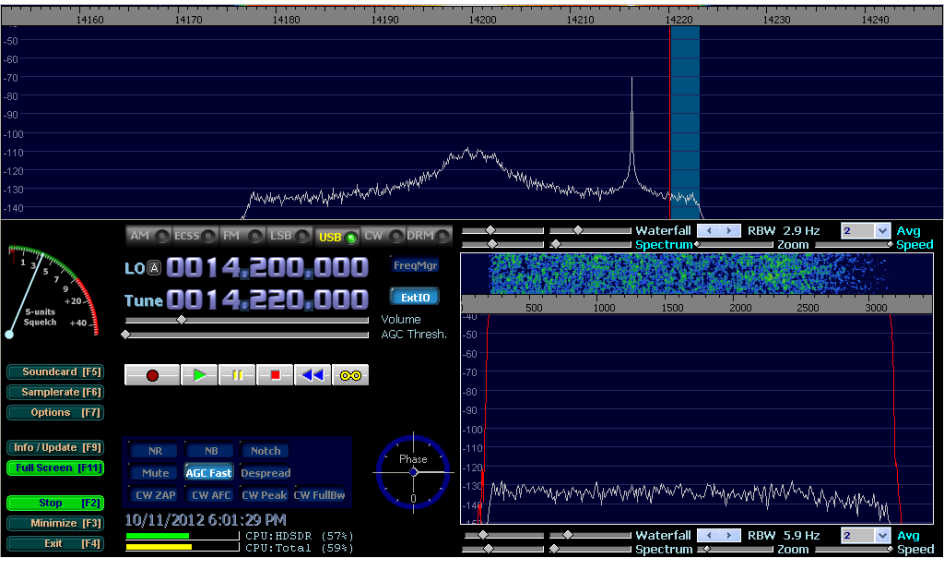
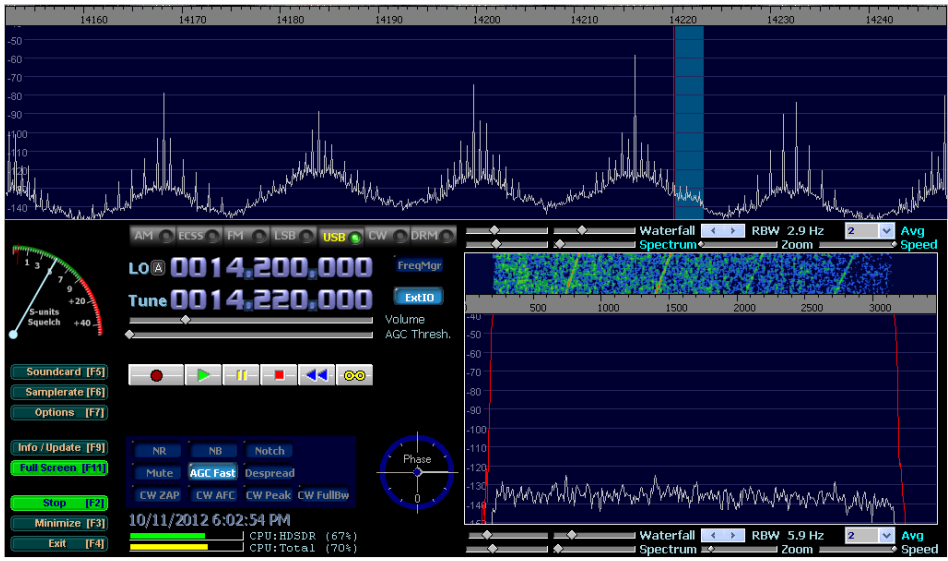


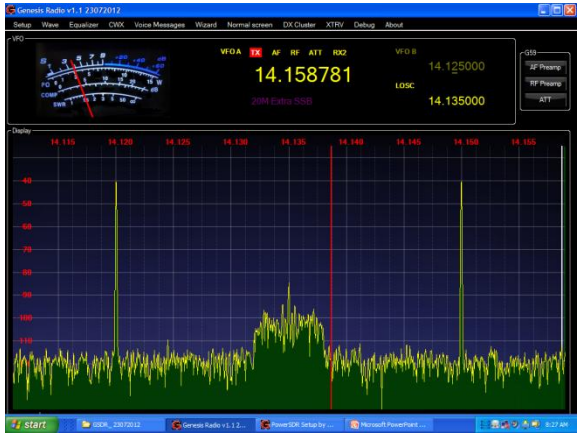
S9+14 dB



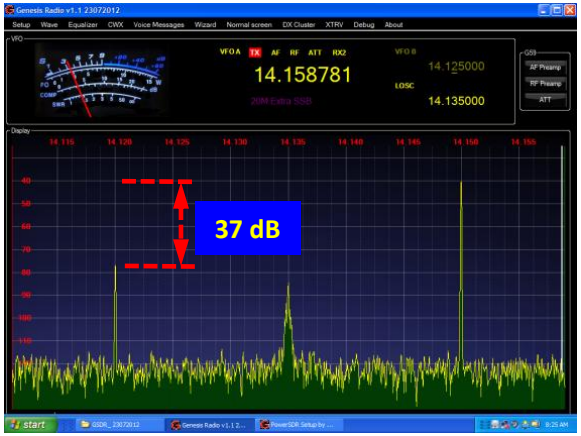
- **The Ensemble II looks good up to -15 dBm (S9+58 dB)**
- **This overload problem is in the ACER Netbook**

Receiver Performance – G59 Image Rejection

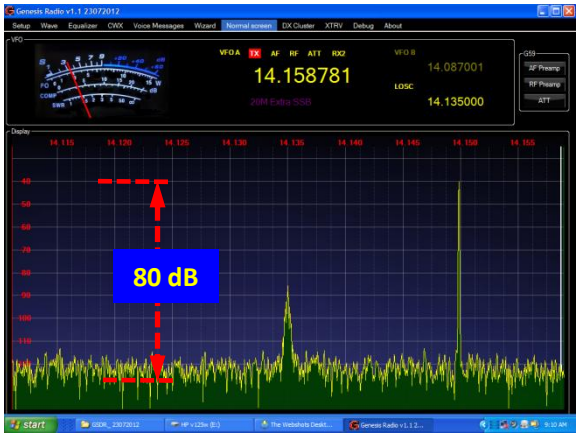
No Rejection



H/W Only Rejection

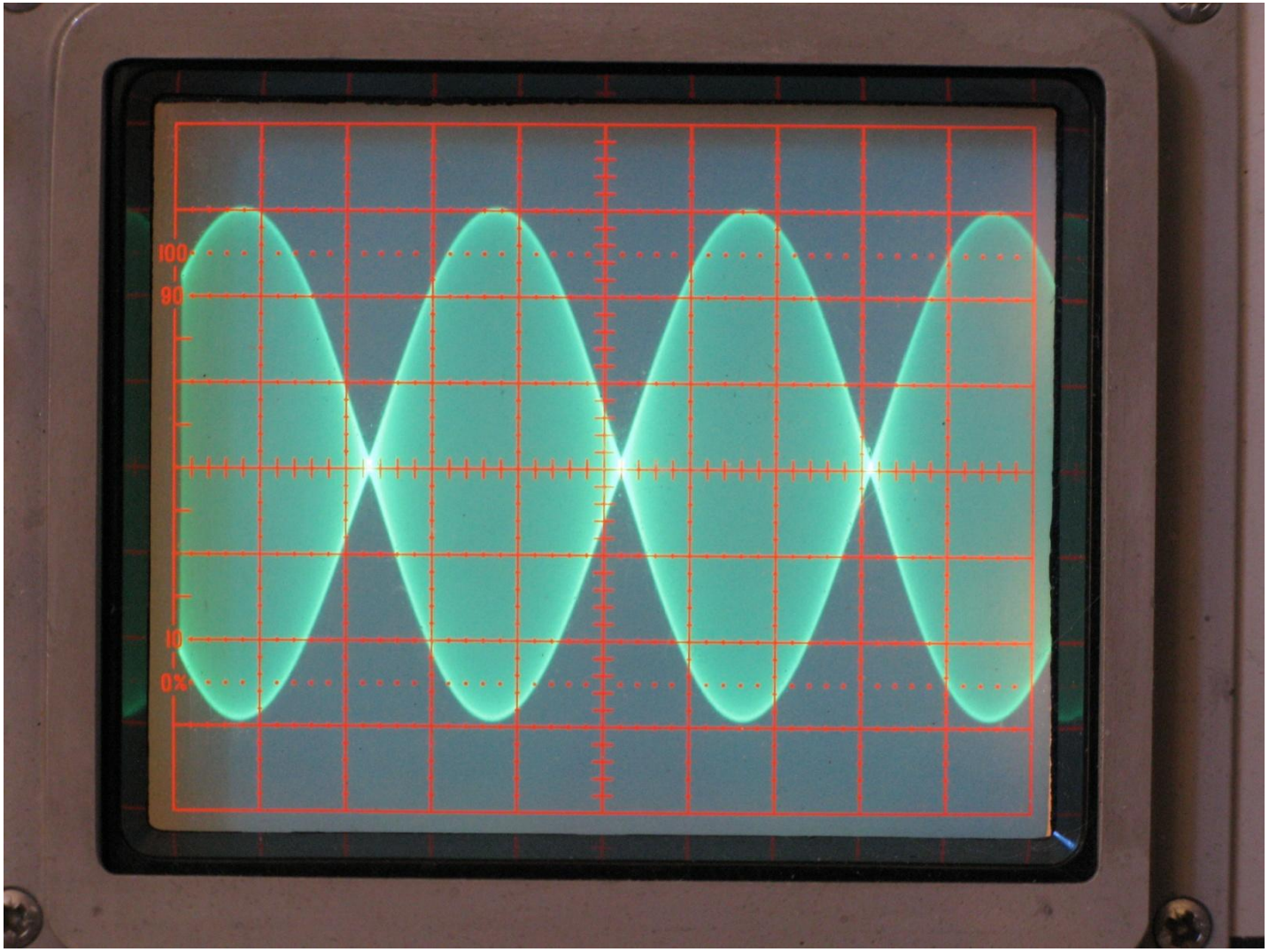


H/W + S/W Rejection



G59 Transmitter Performance

- **Image (unwanted sideband) Rejection at G59 Output:**



G59 Transmitter Performance

- **Image (unwanted sideband) Rejection at G59 Output:**

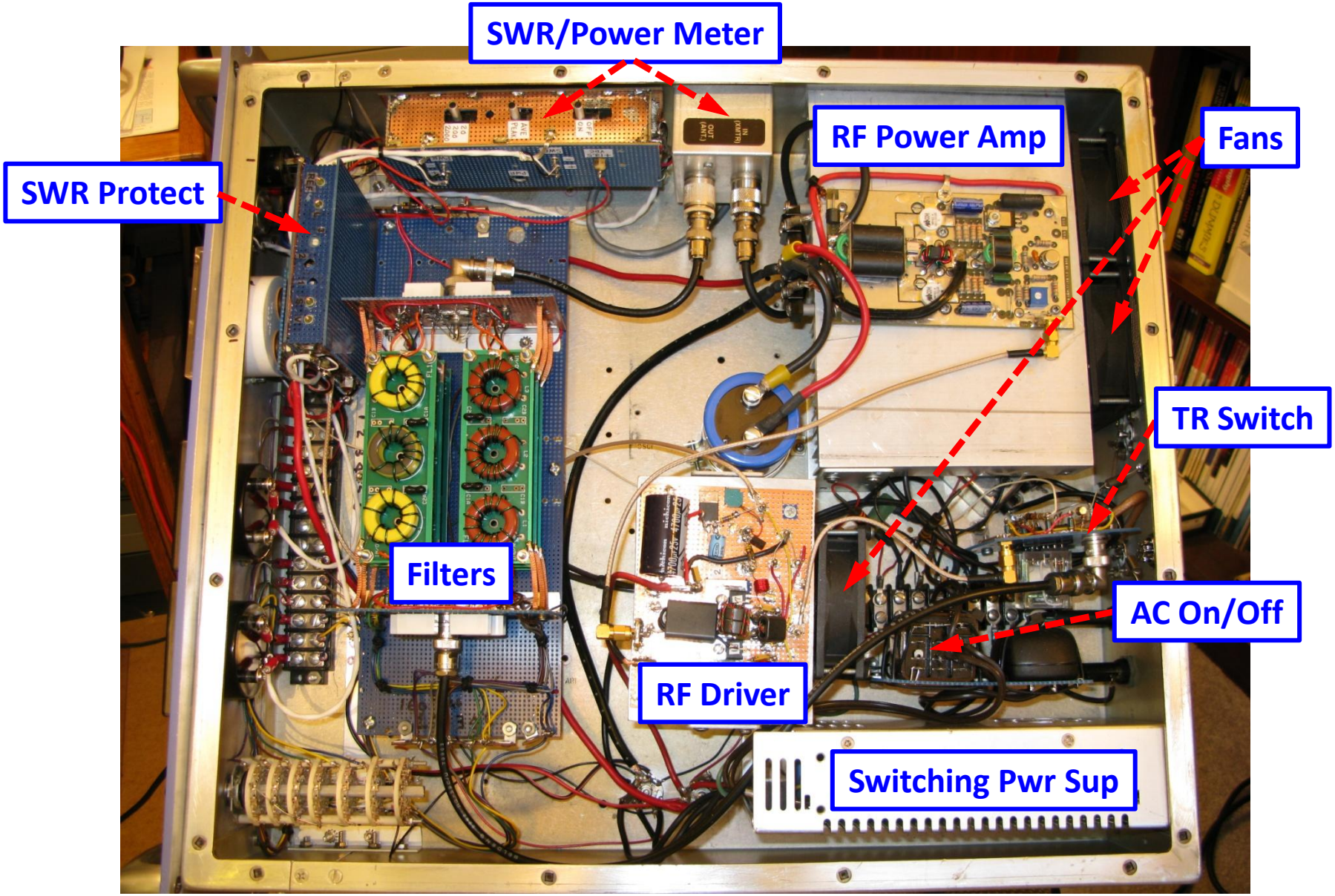
All unwanted spurious down >60 dB

Transmitter (RF Power Amplifiers)

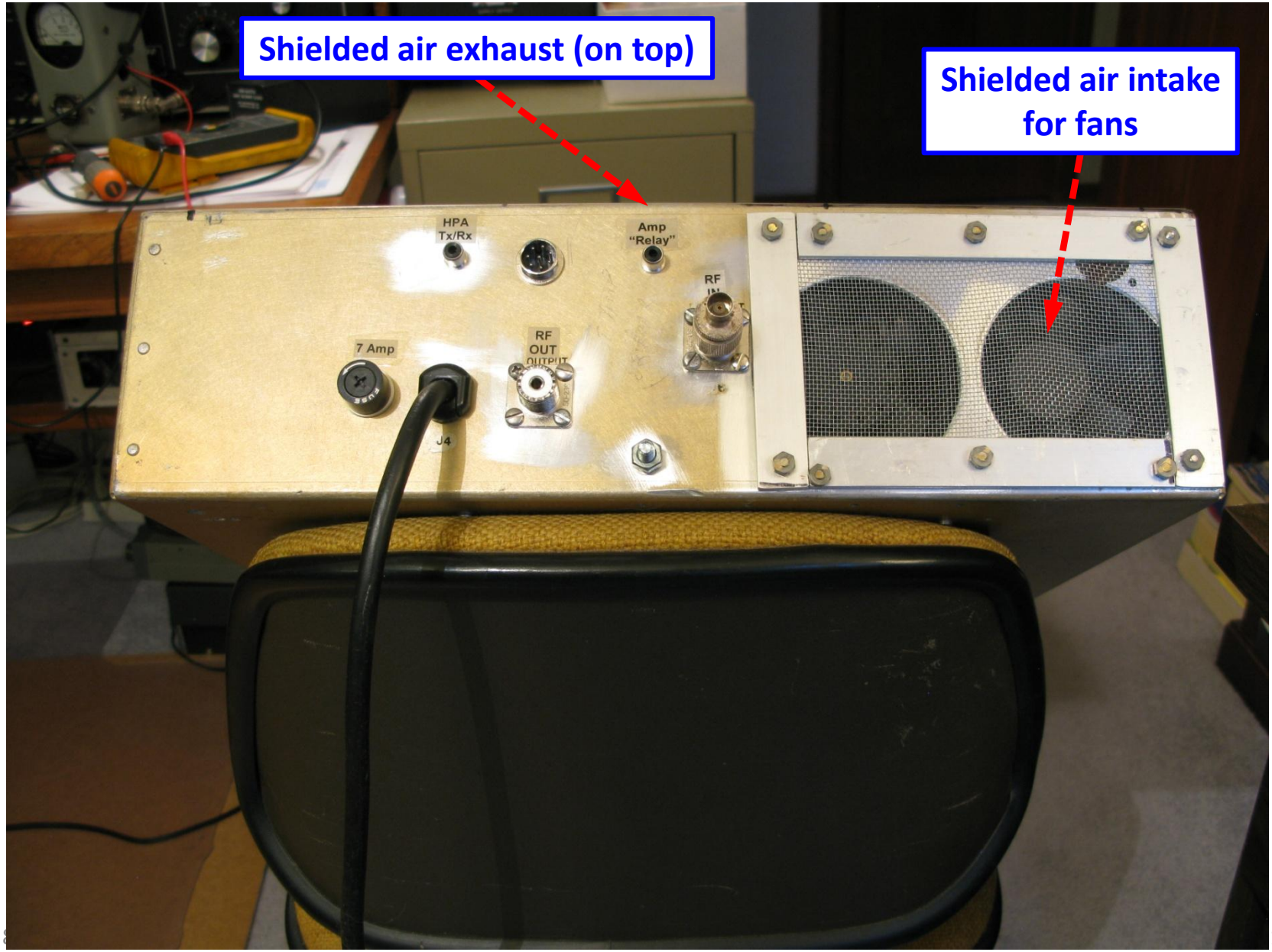
Goals:

- **Gain ≥ 43 dB (0.01 watt to 200 watts)**
  - **Split into 20 dB & 23 dB => separate enclosures**
- **Bands: 160M, 80M, 40M, 20M, 15/17M, 10M**
  - **Dedicated filter for each band**
  - **Auto filter select via G59**
- **Adequate filtering to meet FCC harmonics requirements**
  - **>40 dB second harmonic rejection**
- **IMD down >30 dB**
- **Two stage SWR protection**
  - **Fast response (ie, ALC based upon Reflected Power)**
  - **Latch after 1 sec delay**
  - **Front panel Threshold Adjust and Reset**
- **Thermal**
  - **Design for full 100% duty cycle at 100 watts output**
  - **Over Temp protection**

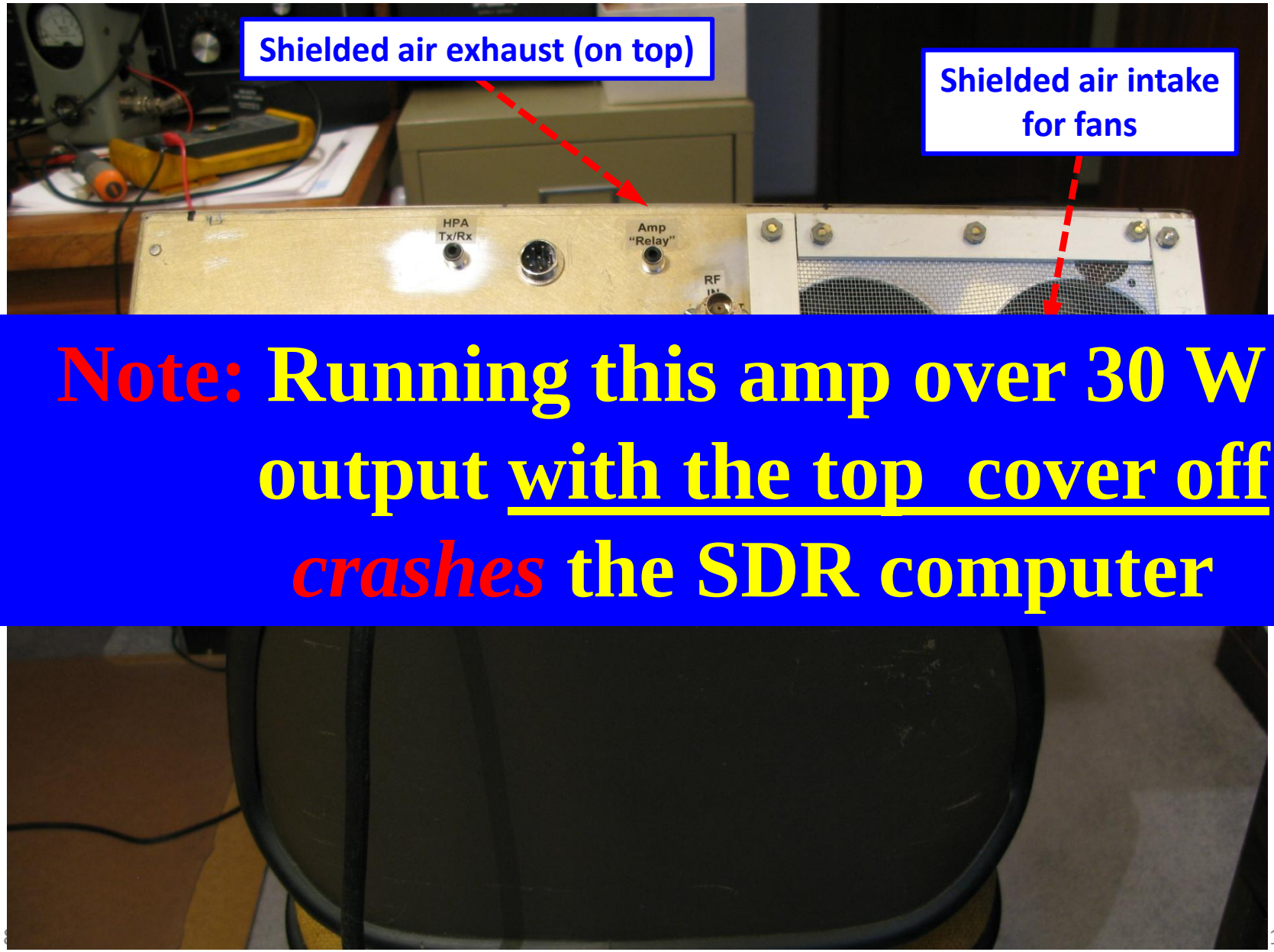
RF Power Amplifier Chassis



RF Power Amplifier Back Panel



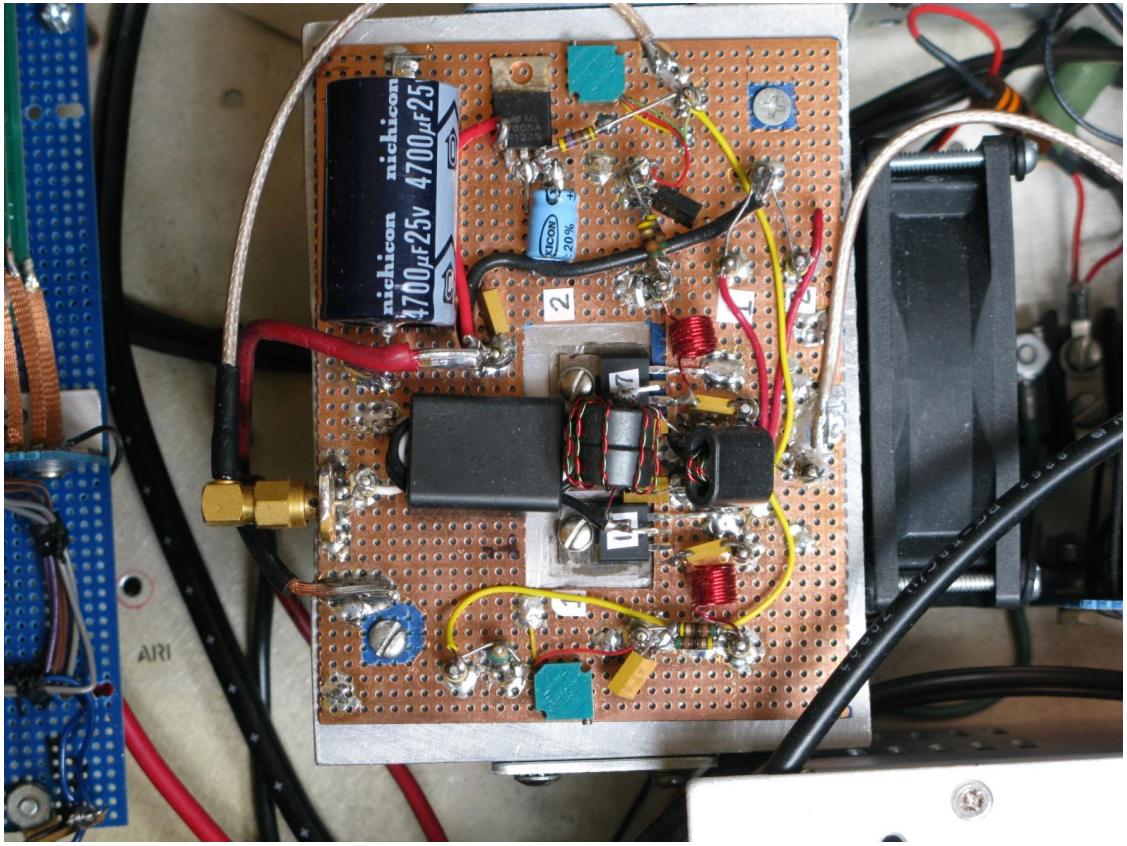
RF Power Amplifier Back Panel



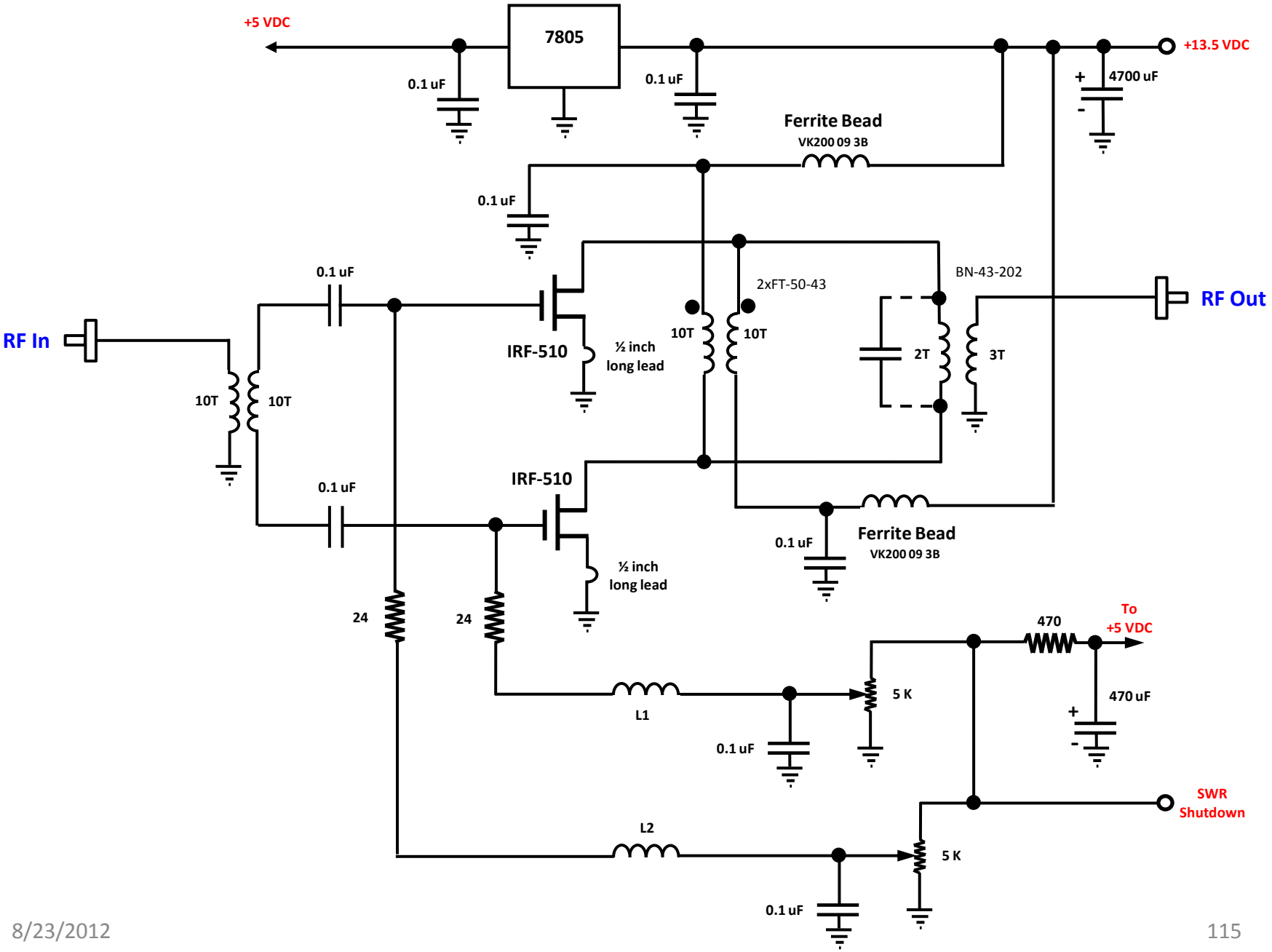
Note: Running this amp over 30 W output <u>with the top cover off</u> *crashes* the SDR computer

RF Driver Amp

- **Design: "*A Broadband HF Amplifier Using Low-Cost Power MOSFETs*"**
  By Mike Kossor, WA2EBY March 1999 QST
- **Uses two inexpensive ($0.70 ea) IRF-510 switching FETs in push-pull**
  - **Easy to burn out FETs at high SWR**
- **P_{IN} > 30 watts (P_{IN}= 1W) from 2-30 MHz**



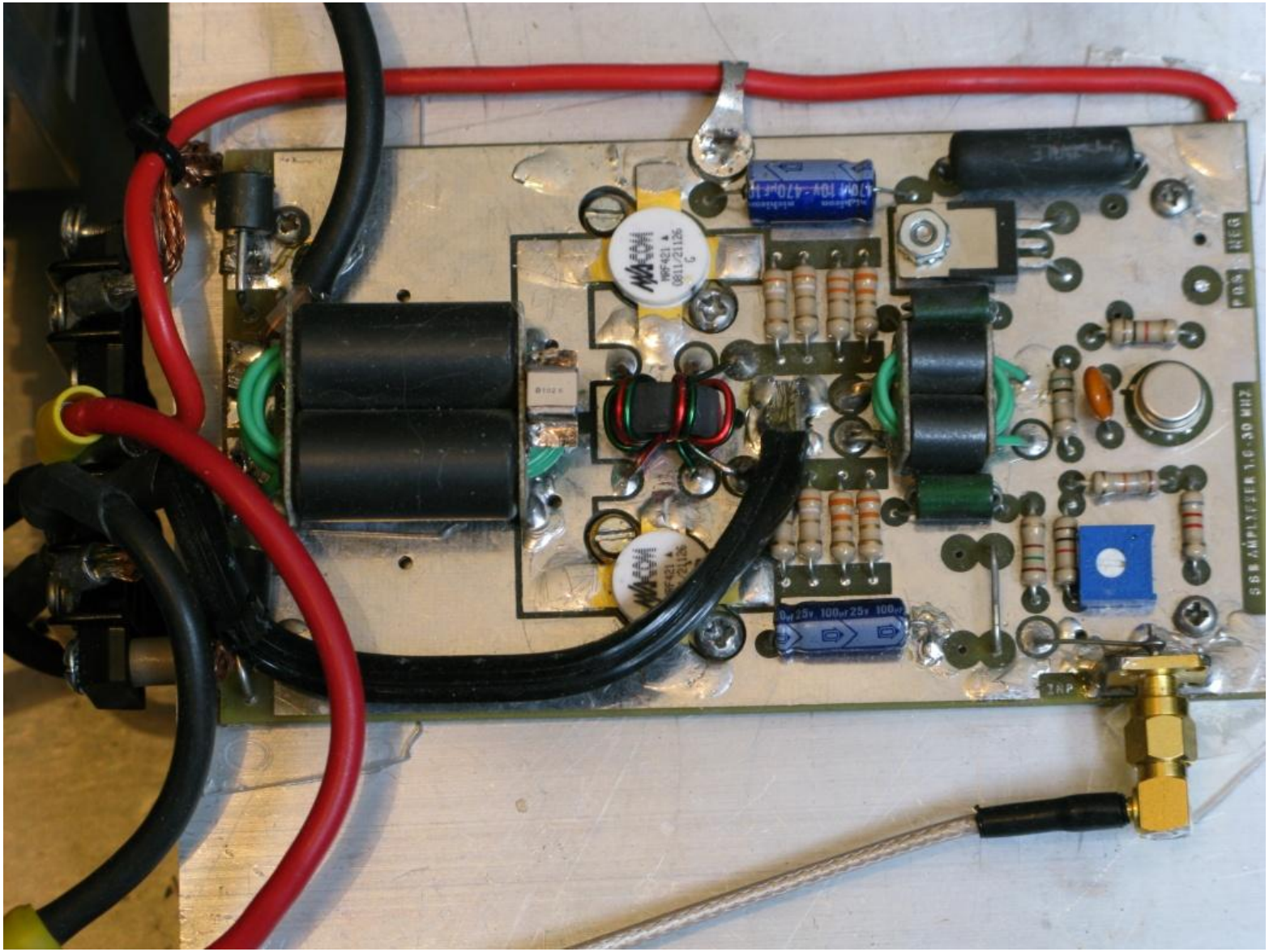
RF Driver Amp Schematic



Final Amp

- Based upon Motorola App Note AN-762
  - Parts and documentation available from:
    - Communications Concepts Inc
      - http://www.communication-concepts.com/
      - Solid state amplifier kits for 20 W to 1 KW power levels
  - 2-30 MHz
  - Uses two MRF-421 bipolar transistors in push-pull
  - 180 watt output with 15 watt input

Final Amp

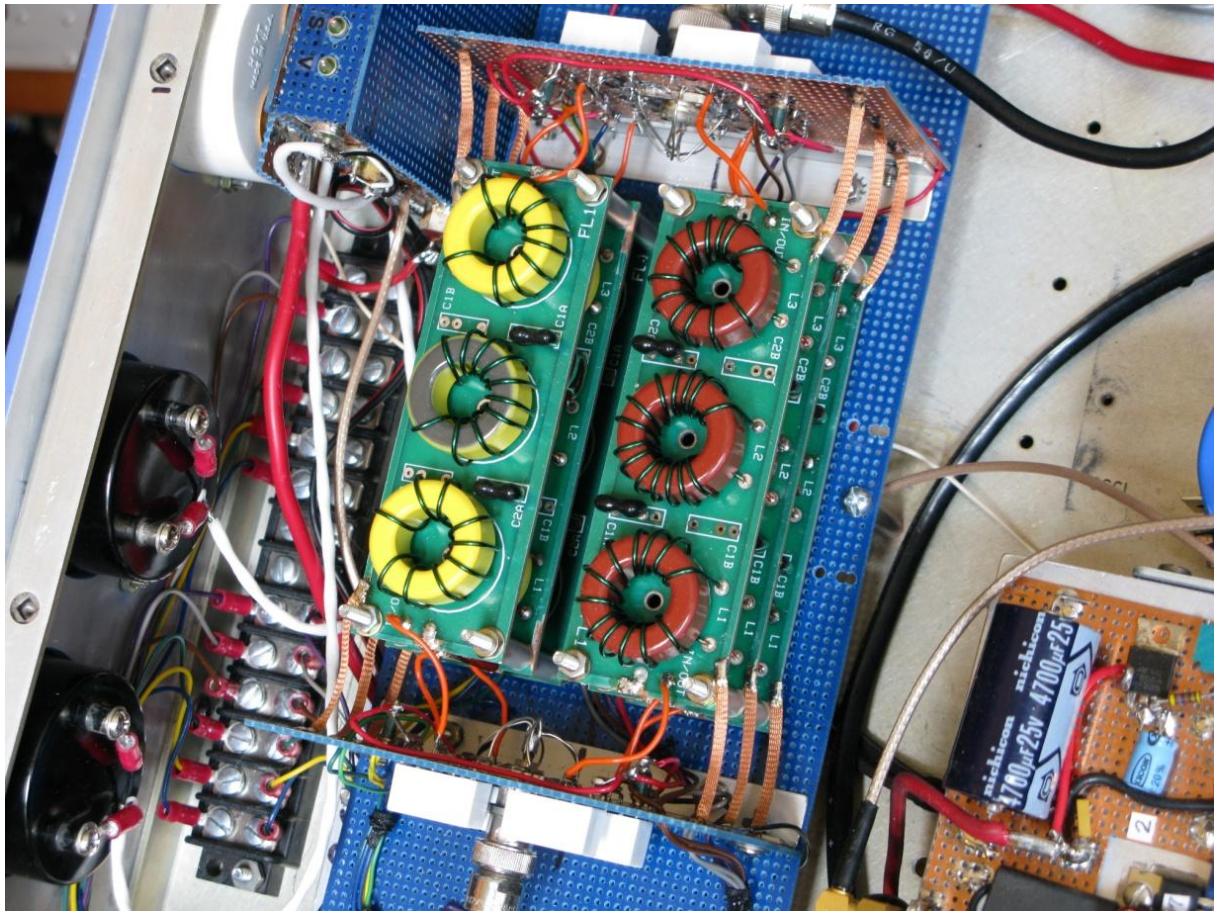


Transmitter Performance Summary

- **Tests done at 14.15 MHz**
- **G59 Final Amplifier:**
  - **Output Power:**
    - 100 watts with 10 watts input
    - Capable of ~200 watts with 20 watts input
- **IMD Performance Comparison at 100 watts:**
  - **G59: -30 dB**
    - **Bipolar** transistors
    - Motorola predicted -30 dB
  - **7600: -25 dB**
    - **FET** transistors
    - *Not spec'd*

Output Filters

- FCC requires all harmonics to be ≥ 40 dB below the PEP output
- Started with Comm Concepts Inc lowpass filter kits
  - Some needed tuning to center operating bandwidth
  - One (15/17M) needed to be re-designed to cover two bands:



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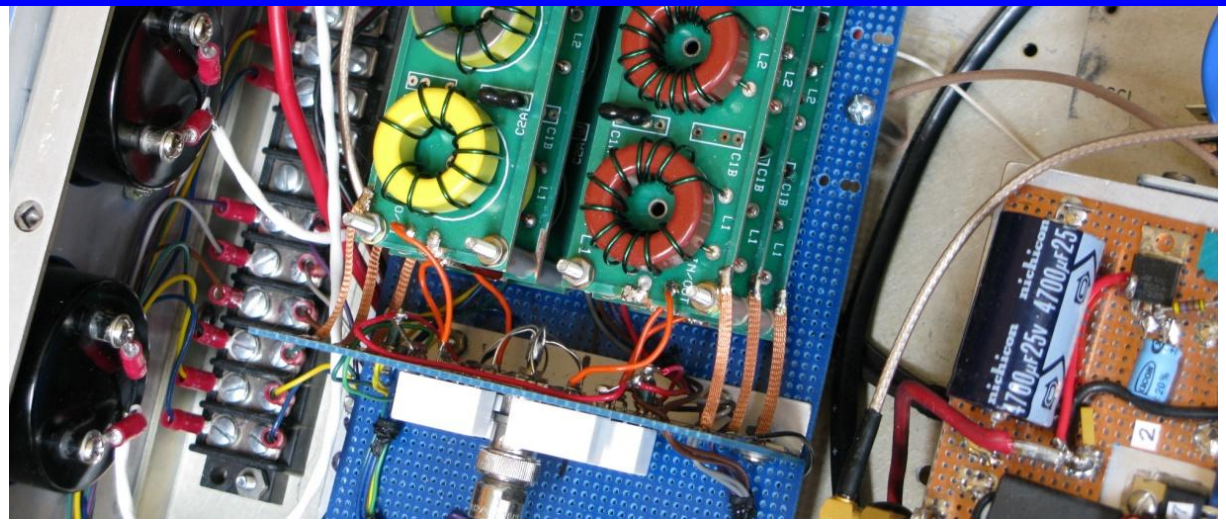
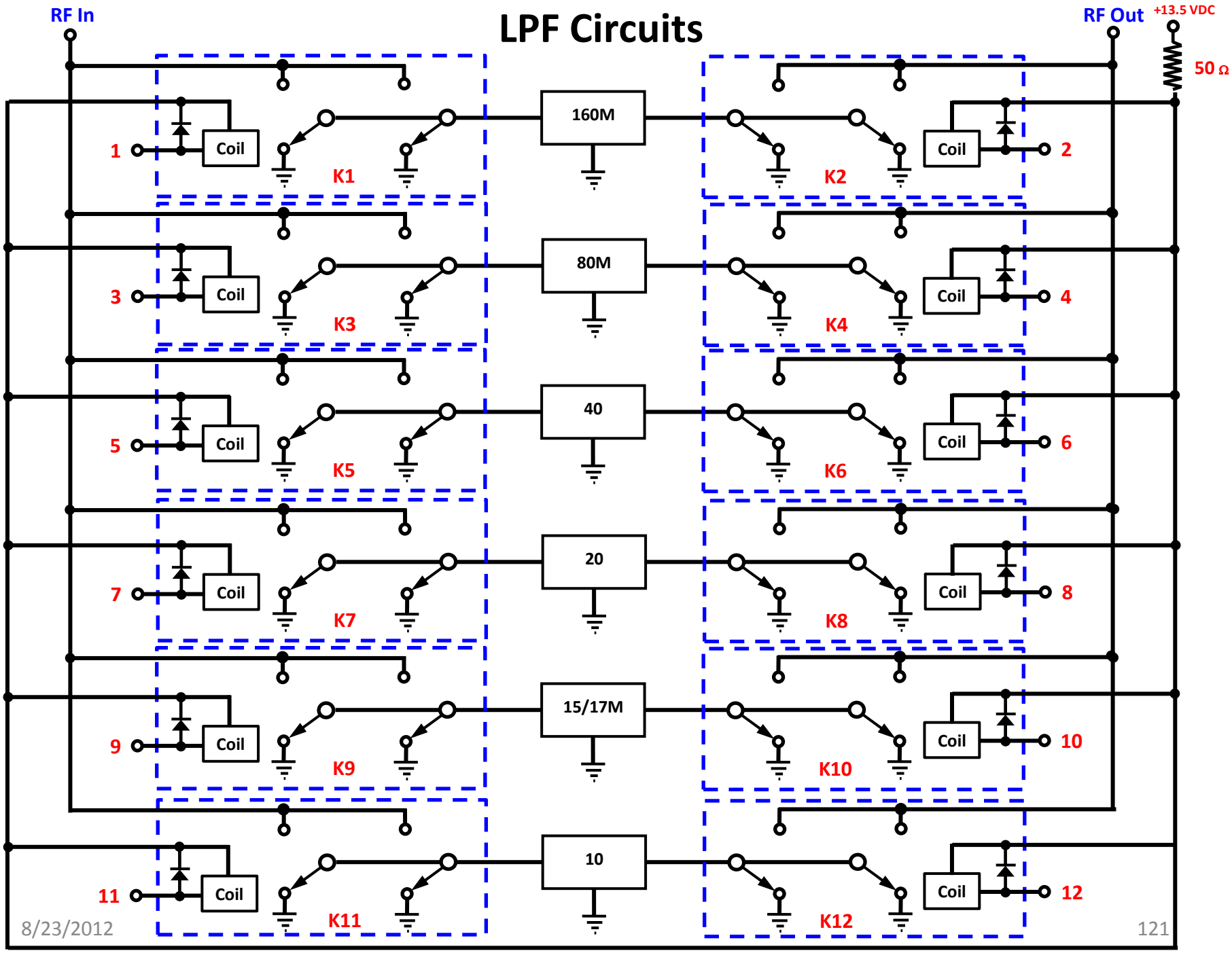
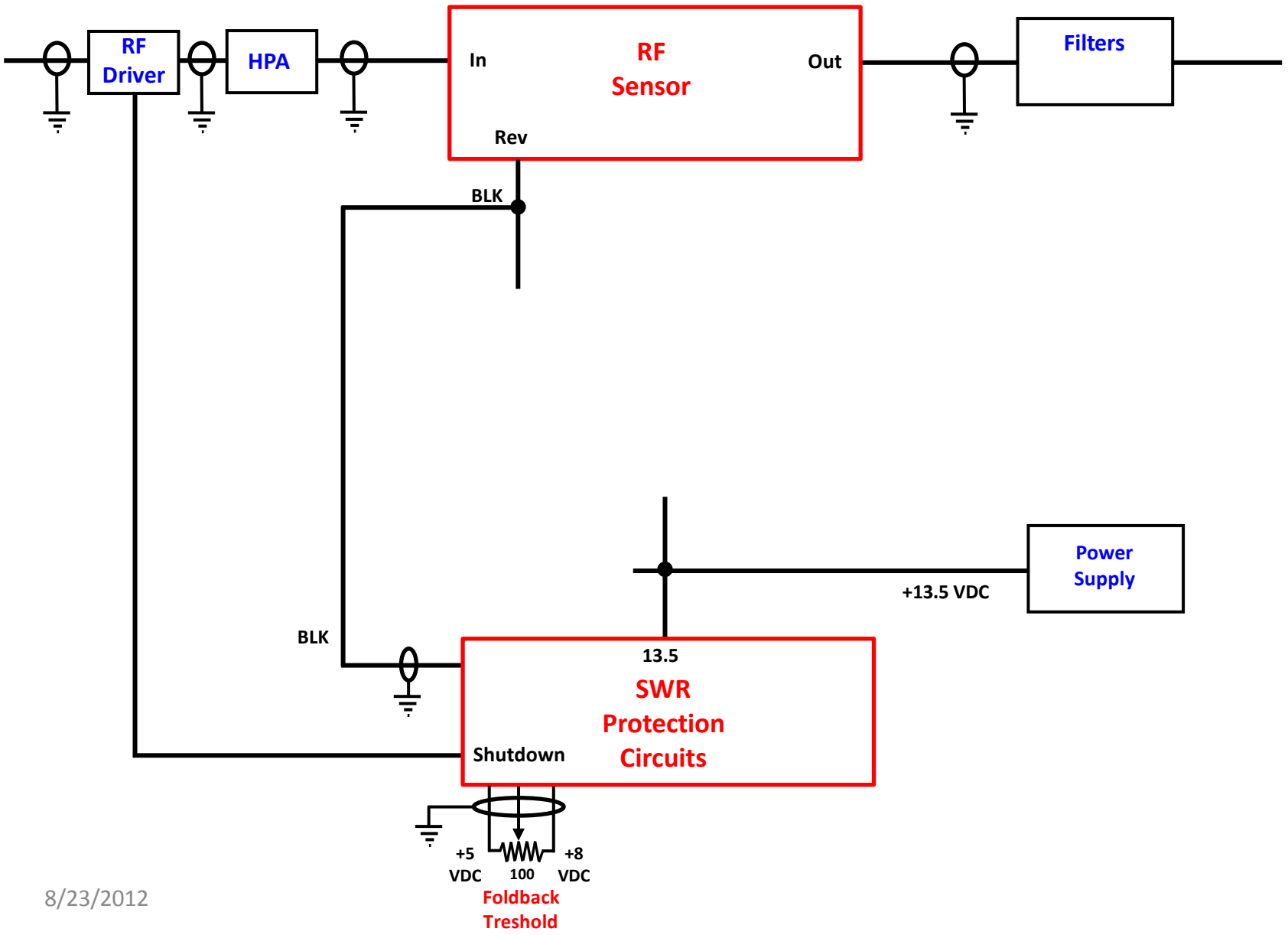
These filters can take a great deal of time & effort!



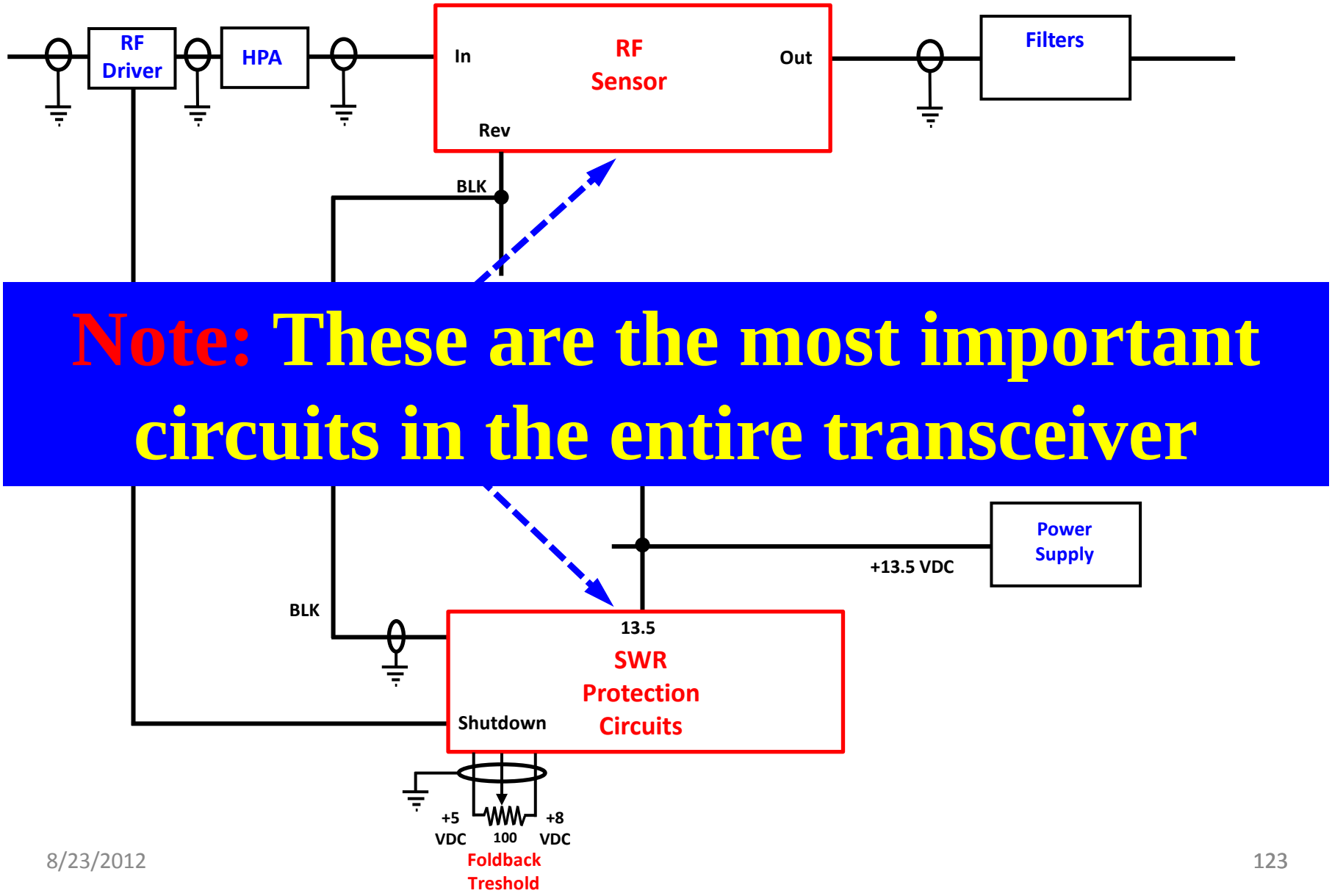
LPF Circuits



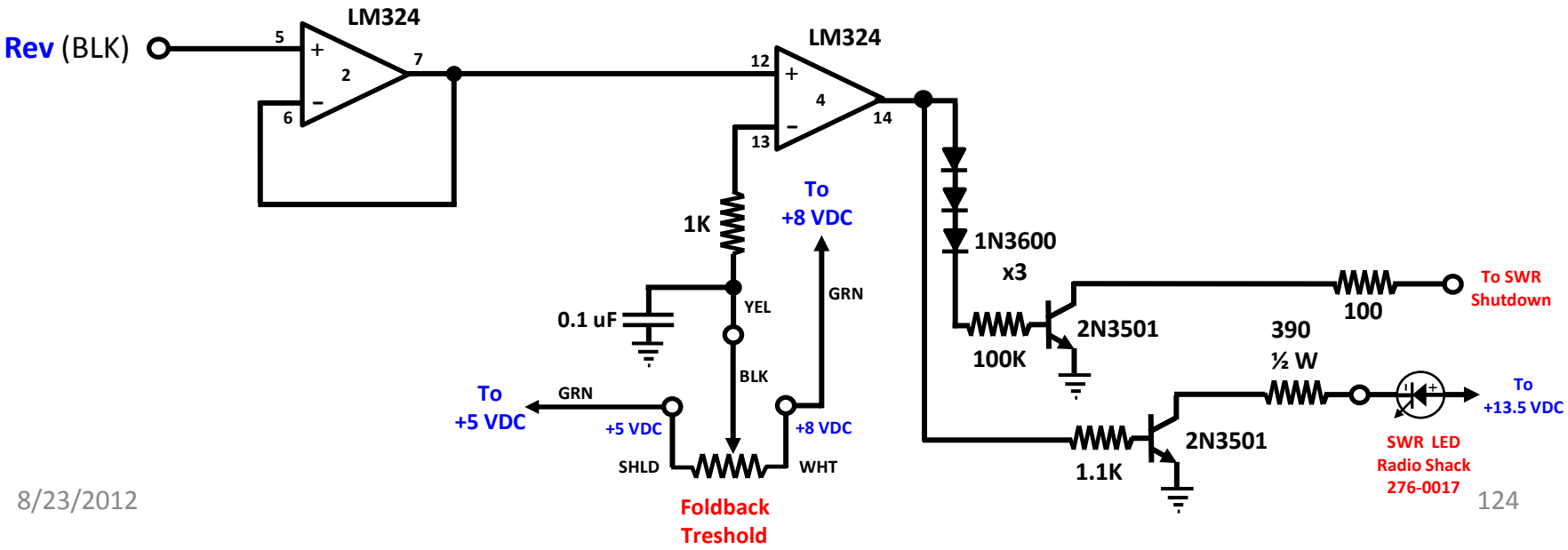
SWR Protection



SWR Protection

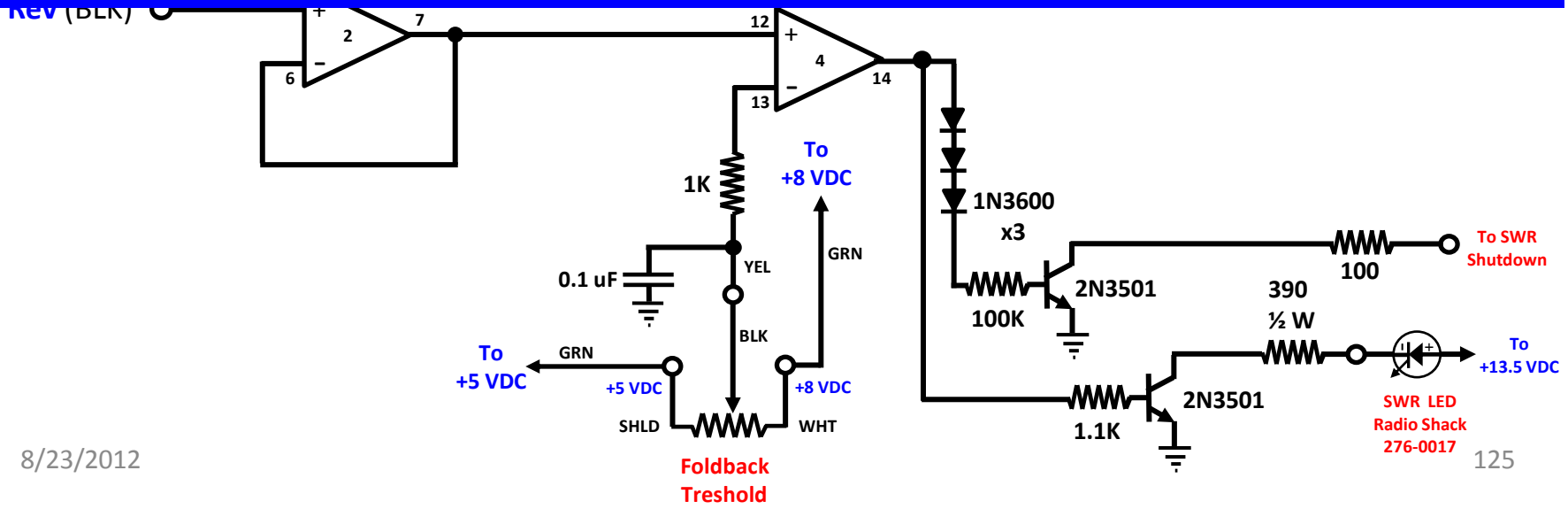


Basic SWR Protection Circuit

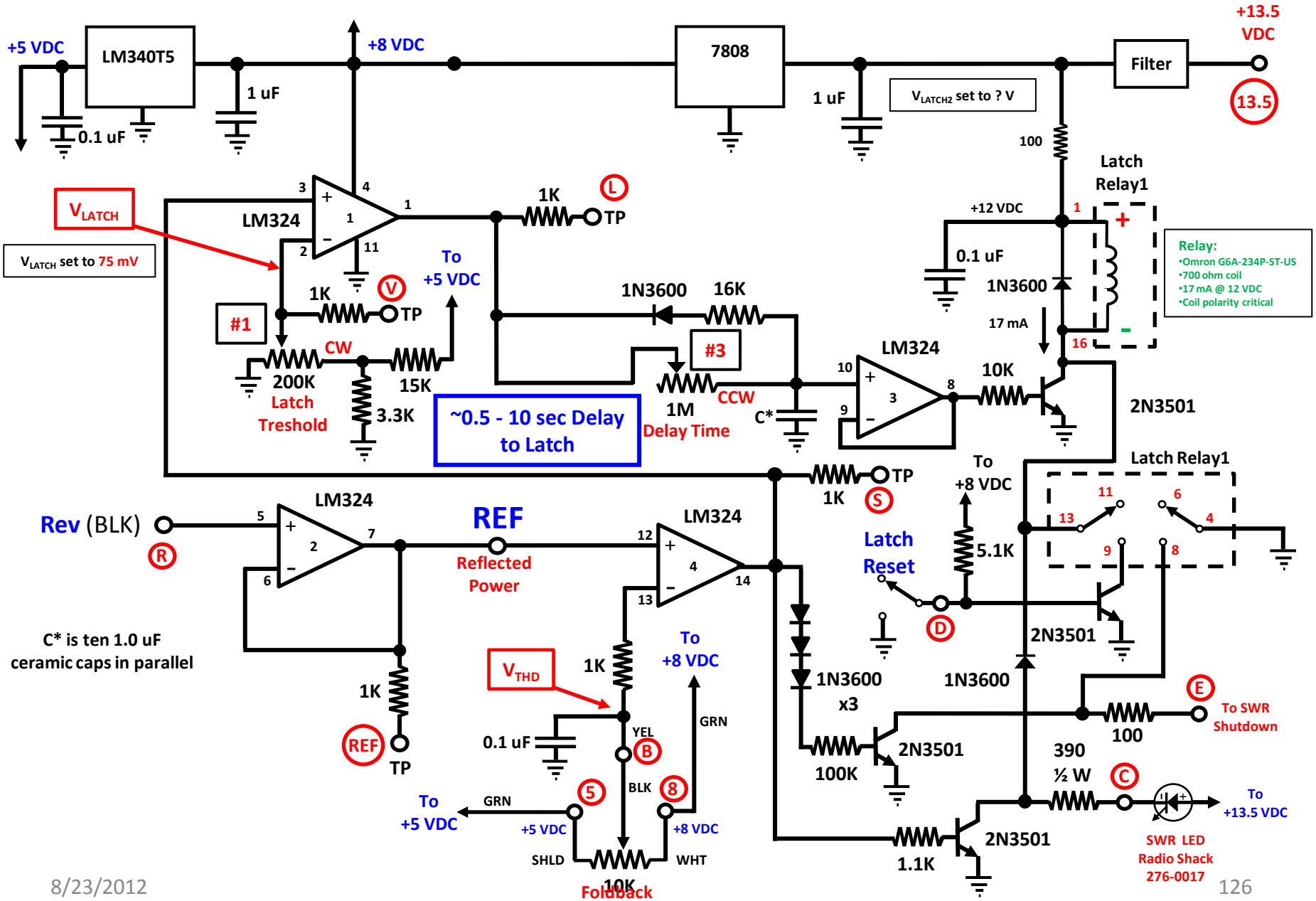


Basic SWR Protection Circuit

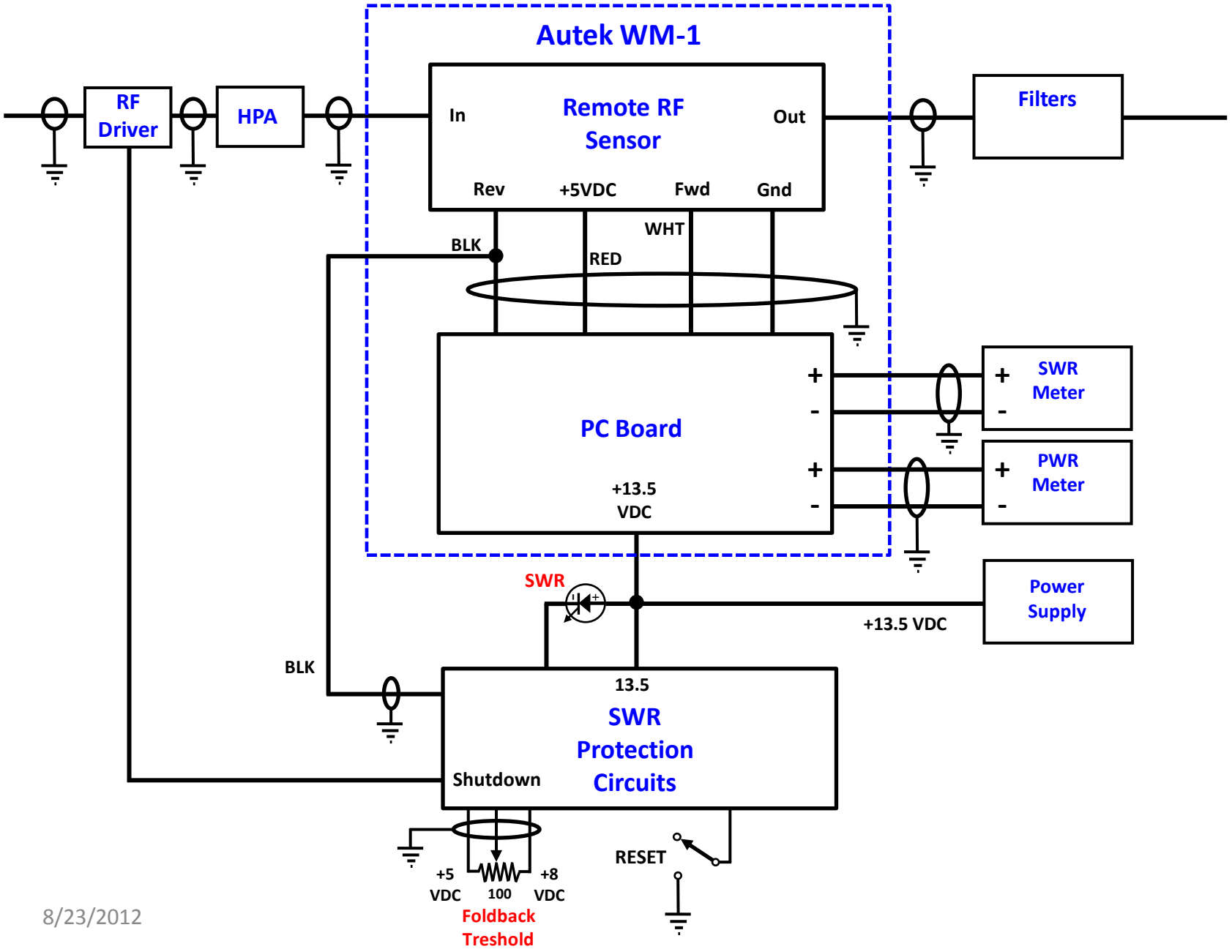
Note: This circuit needs to be well shielded & filtered from RF



SWR Protection Circuits



SWR Protection



RF Power Amp – Switching Power Supply

MegaWatt Model S-400-12

- **9.5 to 15.5 VDC**
- **36 amps** (90% D.C.) 41 amp peak
  - A 90% duty cycle means 30 minutes at 36 amps and 3 minutes at 30 amps to cool down for another run at 36 amps.
- These units are designed for powering HAM radio equipment
  - The output section of the power supply is highly filtered to eliminate RF in the output voltage (**no noise observed**)
- Input 120/240 VAC
- Cost: **$60** thru **eBay** or **http://www.12voltpowersupplies.us/**

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Crowbar protection needed?

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  - The output section of the power supply is highly filtered to

Maximum V_{CE} for MRF421 = 20V

- Cost: **$60** thru **eBay** or **http://www.12voltpowersupplies.us/**

Crowbar Circuit

Crowbar circuit.pdf - Adobe Reader

File Edit View Window Help

3 / 3 140% Tools Sign Comment

From ARRL Handbook 2004 page 11.39

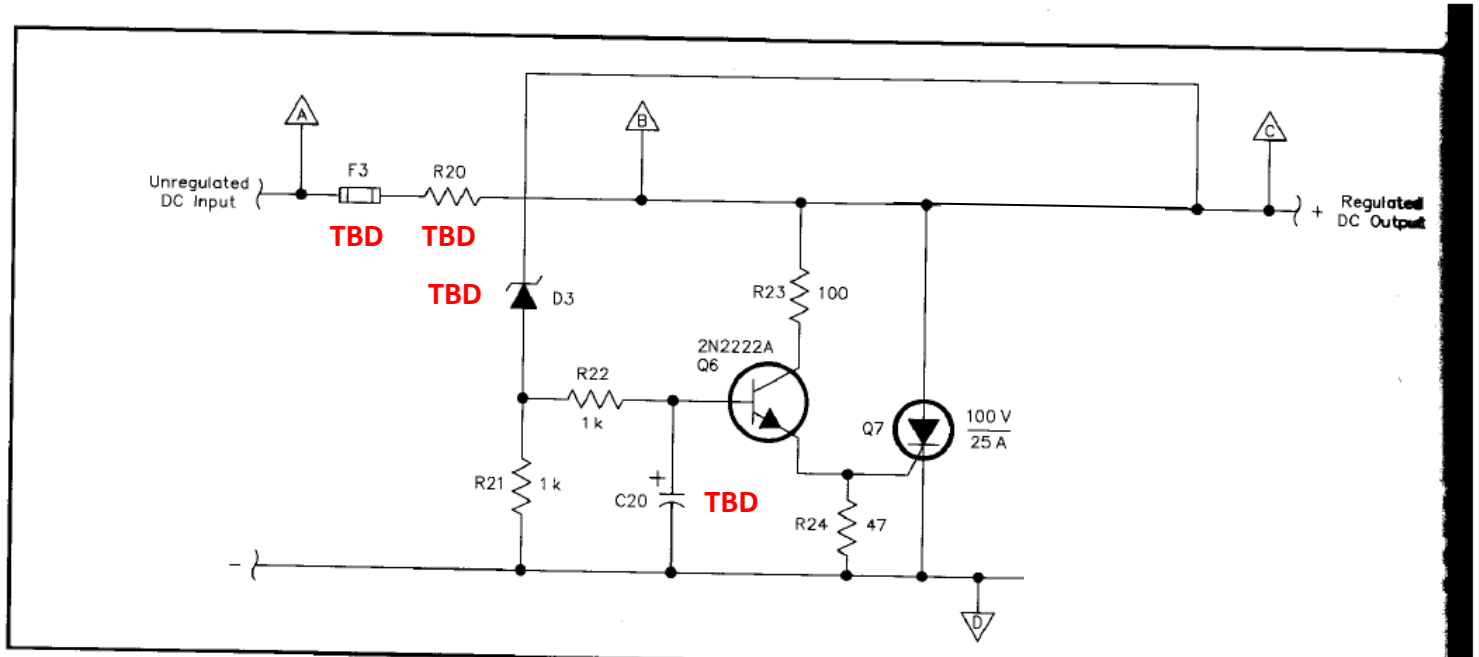

Fig 11-51 - Schematic diagram of the overvoltage protection circuit. Resistors are 1/4-W, 5% carbon types unless noted.
D3 — TBD 1/2 W Zener (NTE 5036A or equiv.).
Q6 — NPN Transistor (2N2222A or equiv.).
Q7 — 100 V, 25A SCR (NTE 5522 or equiv.).

8.50 x 11.00 in

start Microsoft PowerPoint ... TS-930S Crowbar circuit.pdf - ... 9:46 AM

RF Isolation

- **Important to Prevent:**
  - **Degraded out of band rejection of harmonics**
  - **Unwanted parasitic oscillations in power amps**
  - **Computer being unusable**
- **Filter Layout**
  - **Short leads on inputs and outputs**
  - **Wide separation between input and output relays/connectors**
  - **Ground inactive filter inputs and outputs**
- **TX/RX Relays**
  - **Use small (and fast) relays**
    - **3A rating for 100 watt switching**
  - **Insure that isolation is >10 dB more than:**
    - **Filter isolation**
    - **Net gain of switched amplifiers**
- **Aluminum coatings (Alodine, etc) are poor conductors**
- **Ferrite beads on all lines (non-RF) IN & OUT of the chassis**
  - **Ferroxcube (old P/N VK200 09 3B)**
- **<u>*Metal*</u> screens advisable for large openings**

Summary

- **Many options are available for homebrewing for all experience levels**
- **SDR homebrewing options are available for all performance and experience levels at attractive prices**
  - ***Do your homework first!***
- **Don't be intimidated by "Digital" or "DSP"**
  - **You don't need to be an expert in either to build/operate a SDR**
  - **Most of the "Digital" is in the computer/sound card**
  - **All of the "DSP" is in the computer software/firmware**
- **With SDRs, low cost does *not* mean poor performance**