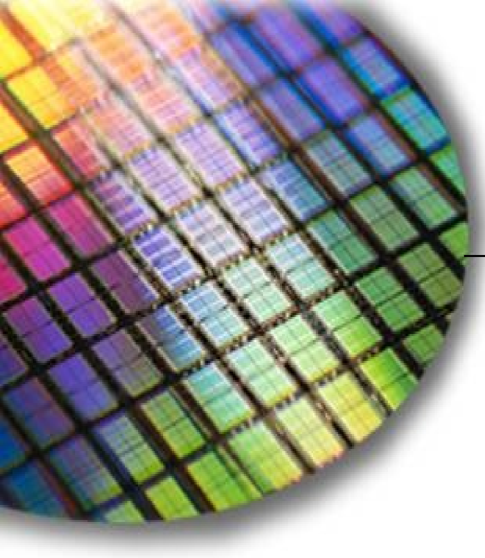

The World Leader in High Performance Signal Processing Solutions

The Path to build a SDR

Ice-Bird Talks
VIENNA HAM-RADIO CLUB
Apr.16.2015

Doc. Rev. 4.7.2
Last Saved: Apr.17.2015
Saved by: Johannes.horvath@analog.com
OE1JHB

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Abstract
Software Defined Radio (SDR)

Wir besprechen die Grundlagen der Quadraturmodulation und lernen den Zusammenhang zur Einseitenbandmodulation. Grundlegende mathematische Modelle werden uns helfen, die nötige Hardware zu verstehen. Als Grundlage dient uns ein diskret, mit integrierten Funktionsblöcken, aufgebauter Homodyn-Empfänger. Anhand dessen besprechen wir die minimalen Voraussetzungen für einen SDR.

Der zweite Teil des Vortrages beinhaltet einen hochintegrierten Transceiver, seine internen Funktionen und die extra benötigte Hardware, um einen voll funktionsfähigen, autonom lauffähigen, SDR zu realisieren.

Welche existierenden Softwaremodelle für FPGAs zur Verfügung stehen, basierend auf Linux/Ubuntu, und wie man sie mit experimenteller Hardware in Betrieb nimmt, wird im letzten Teil des Vortrages besprochen.

Zusätzlich gibt es eine kleine Demonstration mit Live-Hardware, die das Grafische Benutzer Interface (GUI) zeigt. (Ubuntu on a FPGA).

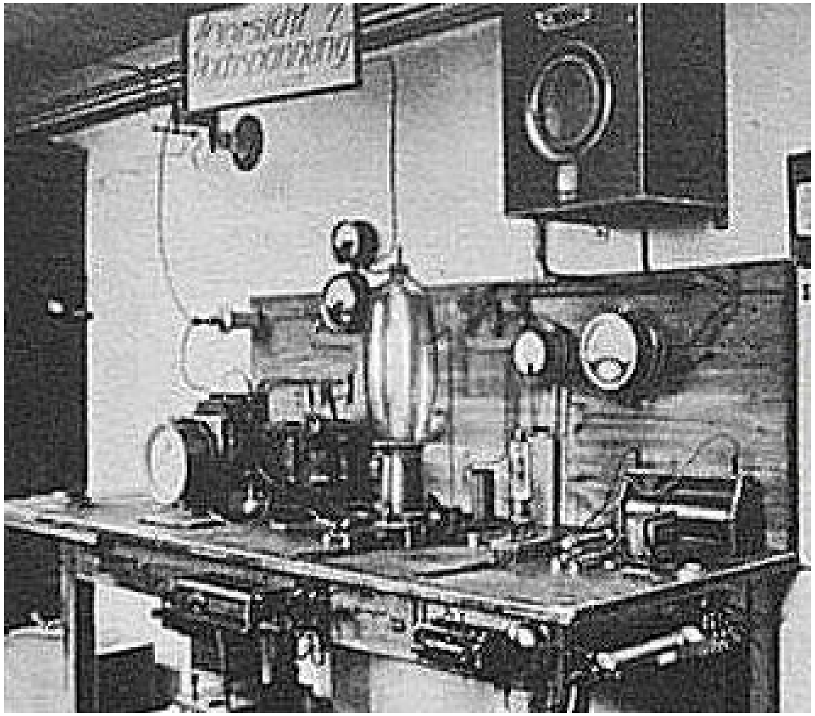
Content

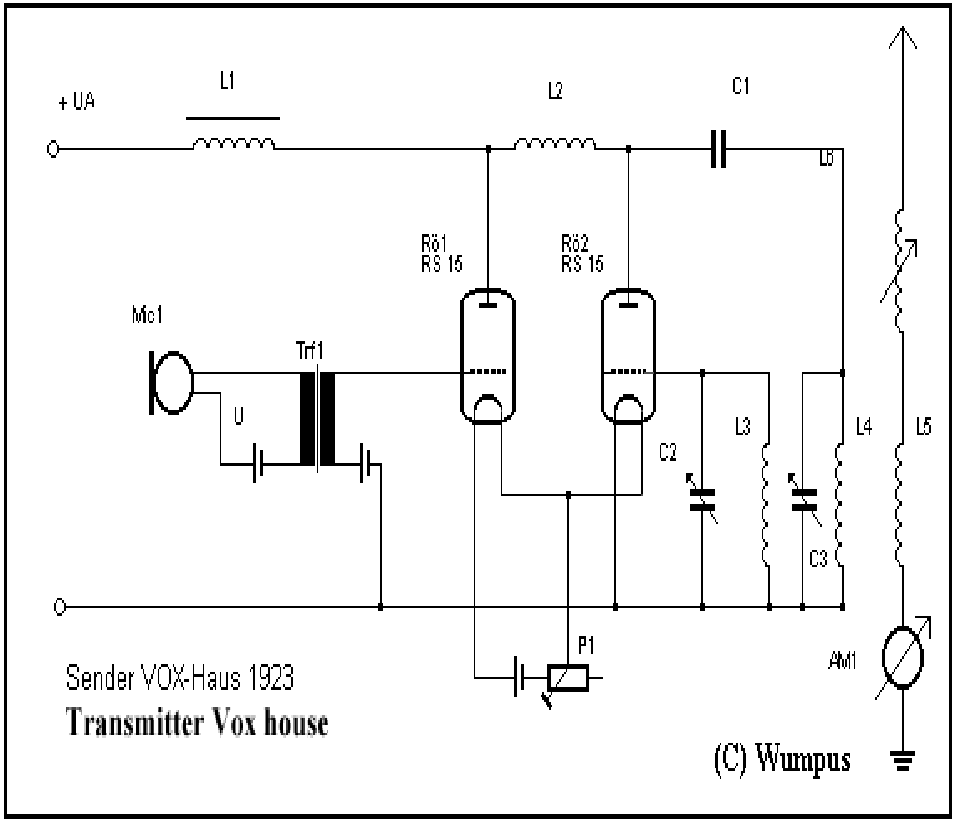
- History & Present Practical design
- Direct-conversion-Radio Technically
- Catalina internal
- Software (xilinx, linux, high level)
- Connection: Xilinx + SDR AFE PCB: setting up hardware
- Demo Setup Explained
- Mini-Quiz

What Is a Software Defined Radio?

- **A software defined radio system (SDR) is a radio communication system where components that have been typically implemented in hardware (e.g., mixers, filters, amplifiers, modulators/demodulators, detectors) are instead implemented by means of software on a personal computer or embedded system.**
- **While the concept of SDR is not new (circa ~1970 DoD labs), many techniques which used to be only theoretically possible are now being implemented due to the rapidly evolving capabilities of analog and digital electronics.**
  - **Why SDR?**
    - Makes RF hardware easier
    - Easy to add new features, since they are all in software
    - Easier to have one set of hardware handle multiple modulation techniques

Historical: 1st Radio Station in Germany





Transmitter 1923
Official start of transmission:
29.10.1923 20:00

L = 400m (750kHz), 250W
Modulation: AM

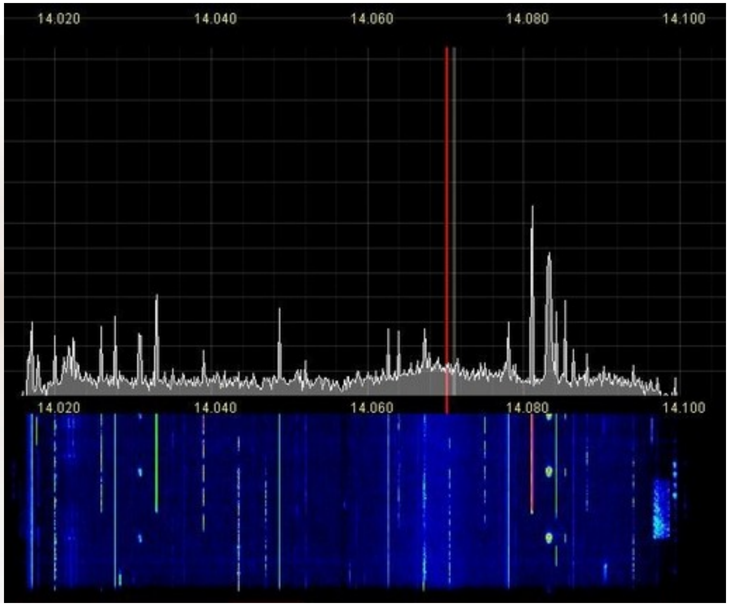
HF „SDR“ Mixed technology Transceiver

- Classic Syperheterodyne & SDR
- 200W HF Output
- SHARC does: filtering, IF Processing, Auto-Notch
- http://www.kenwood.com/i/products/info/amateur/ts_990/pdf/TS-990S_IDM.pdf
- (IDM… In Depth Manual, worth to read, to learn about finest art of HF technology.)

A true SDR inside

ADSP-21479 inside

- Current drain as low as 150 mA



Inside: SDR I-Q ADC/DAC
(Elecraft KX3 HF Radio)
150mA total current in RX

Store, tune, playback the entire spectrum (I/Q)

Live SDR Stream: http://www.websdr.org/

Source: http://www.elecraft.com/manual/KX3%20Manual%20Block%20Diagram.pdf

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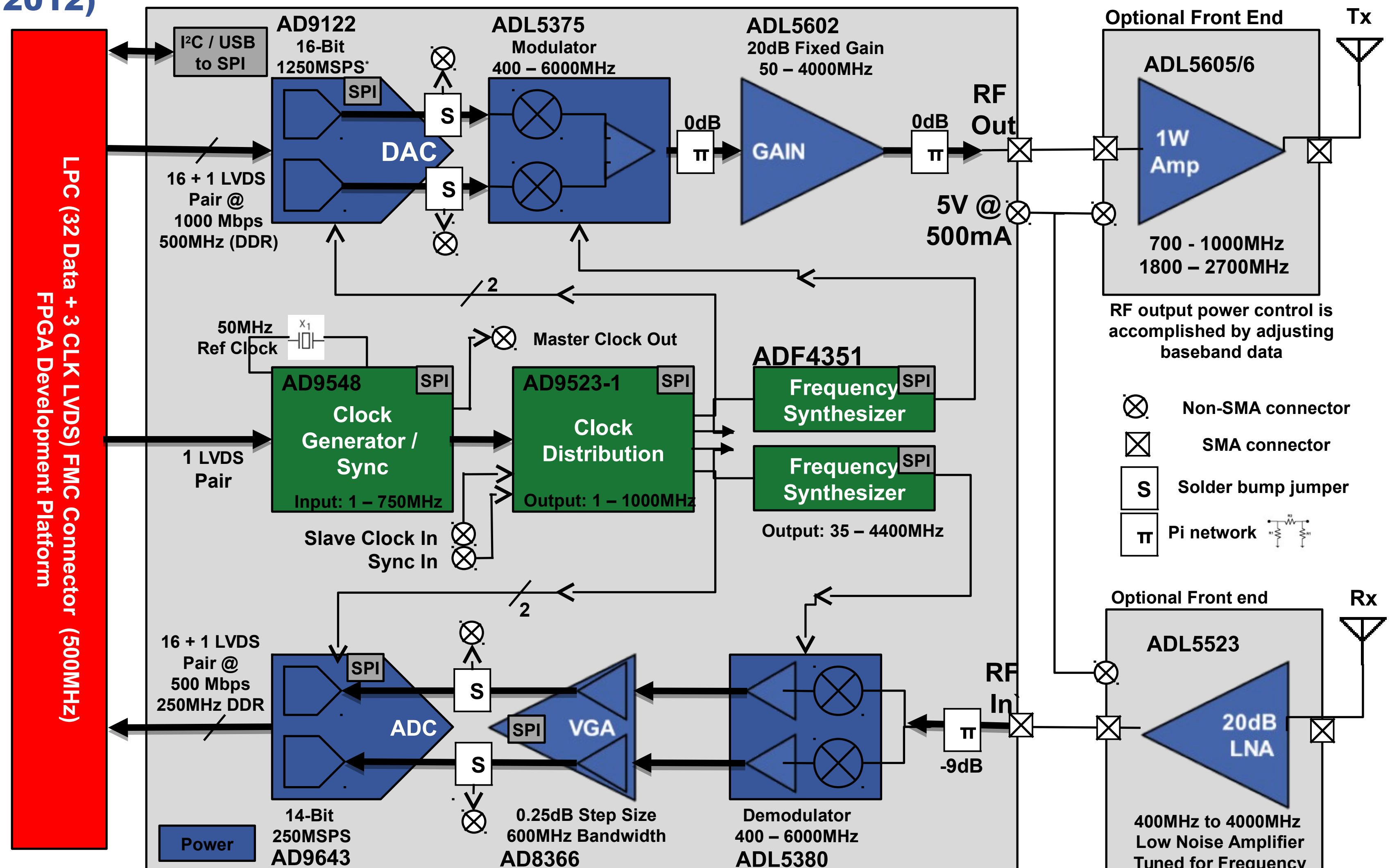
SDR RX Technology Application on PC

(20.Nov.12. RX by OE1JHB frm DB2HS via EASYPAL @ 3733kHz) (1.2Mpixel 1min TX RATE)

Based on DRM, 2 Carriers, 2.5kHz BW, FEC, based on DRM, by VK4QW (Australia)

Direct Conversion Technique (FMCOMMS1)
(Y2012)



Note: FMCOMMS1 Board is not fully supported with latest FPGA Software.

* AD9122 DAC runs at 1000MSPS, due to max speed of AD9523-1

Direct Conversion (Zero-IF) TRx

- **A direct-conversion transceiver, also known as homodyne, synchrodyne, or zero-IF transceiver, is a radio transceiver design that (de)modulates the radio signal using a local oscillator (LO) whose frequency is identical to, or very close to, the carrier frequency of the intended signal.**
  - Carrier frequency = local oscillator (LO) frequency
  - Attractive due to simplicity of the signal path
  - Suitable for high levels of integration
  - Allows wider bandwidth designs

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Homodyne Transmitter Advantages and Challenges

- **Advantages:**
  - **Low component count leads to lower system cost and power consumption**
  - **Direct up-conversion produces less mixing product spurs**
  - **Requires fewer filters**
- **Challenges:**
  - **During the analog modulation process, gain and phase mismatches of IQ signals have a direct impact on sideband suppression performance**
  - **Out of band transmissions**
    - LO / carrier leakage
    - I/Q mismatch causes image in the output spectrum
      - This results in degraded error vector magnitude (EVM) at the receiver, which in turn degrades the bit error rate (BER)

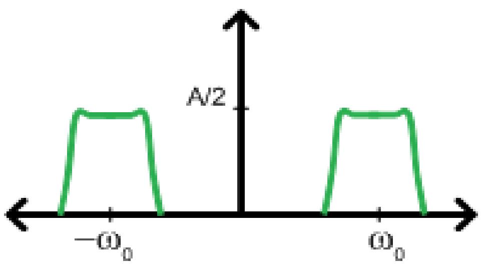
Homodyne Receiver Advantages and Challenges

- **Advantages:**
  - **Low component count leads to lower system cost**
  - **No image reject filter needed**
  - **Filtering requirements more relaxed at baseband**
  - **Gain stages at baseband provide power savings**

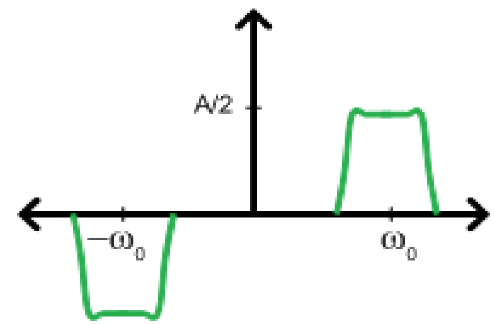
- **Challenges:**
  - **DC offset appearing at baseband**
    - Self mixing
    - Offset voltages
  - **Images appearing symmetrically about zero frequency**
    - I/Q mismatches in phase and amplitude
  - **Even order nonlinearities**
    - Two high frequency interferers close to the channel of interest can result in even order nonlinearities that fall within the band of interest

Back to Basics: Euler's Formulas

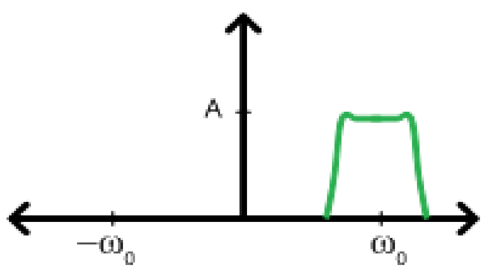
$$\cos\omega_0 t = \frac{A}{2}\left(e^{j\omega_0 t} + e^{-j\omega_0 t}\right)$$



$$\sin\omega_0 t = \frac{A}{2j}\left(e^{j\omega_0 t} - e^{-j\omega_0 t}\right)$$



$$x(t) = e^{j\omega_0 t} = \cos\omega_0 t + j\sin\omega_0 t$$



- **Sin ω0t is 90° out of phase with respect to cos ω0t**
- **With perfect amplitude and phase matching the signal content at - ω0 cancels**

Amplitude and Phase Mismatch

Amplitude Mismatch

$$x(t) = A\cos\omega_0 t + jB\sin\omega_0 t$$

$$x(t) = \frac{A}{2}\left(e^{j\omega_0 t} + e^{-j\omega_0 t}\right) + \frac{B}{2}\left(e^{j\omega_0 t} - e^{-j\omega_0 t}\right)$$

$$x(t) = \frac{A}{2}e^{j\omega_0 t} + \frac{A}{2}e^{-j\omega_0 t} + \frac{B}{2}e^{j\omega_0 t} - \frac{B}{2}e^{-j\omega_0 t}$$

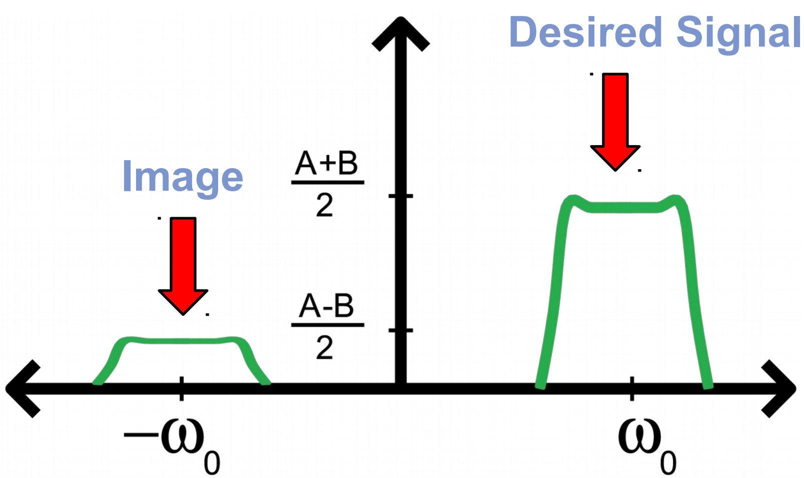
$$x(t) = \frac{A+B}{2}e^{j\omega_0 t} + \frac{A-B}{2}e^{-j\omega_0 t}$$

Phase Mismatch

$$x(t) = \cos(\omega_0 t + \theta) + j\sin\omega_0 t$$

$$x(t) = \frac{1}{2}e^{j\omega_0 t}e^{j\theta} + \frac{1}{2}e^{-j\omega_0 t}e^{-j\theta} + \frac{1}{2}e^{j\omega_0 t} - \frac{1}{2}e^{-j\omega_0 t}$$

$$x(t) = \frac{(e^{j\theta}+1)}{2}e^{j\omega_0 t} + \frac{(e^{-j\theta}-1)}{2}e^{-j\omega_0 t}$$



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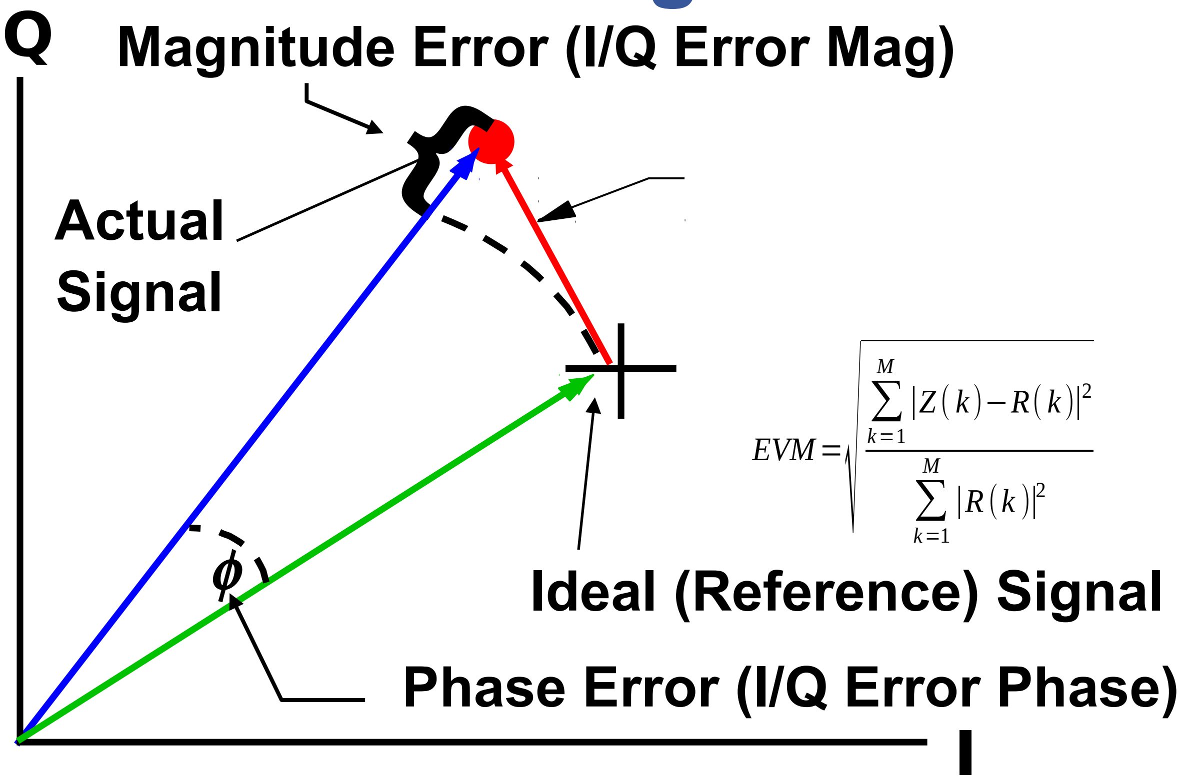
Error Vector Magnitude—EVM

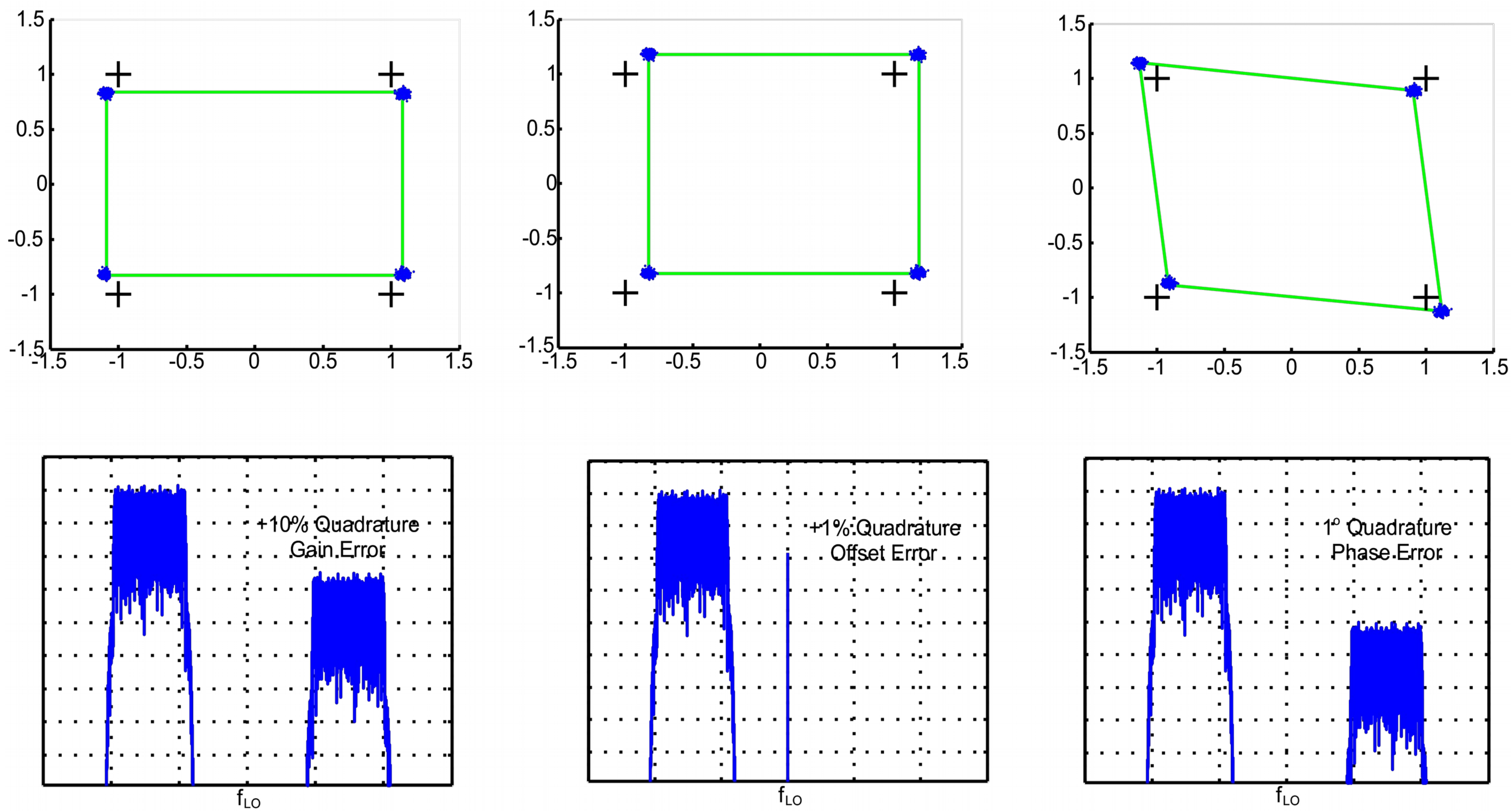


$$EVM = \sqrt{\frac{\sum_{k=1}^{M} |Z(k) - R(k)|^2}{\sum_{k=1}^{M} |R(k)|^2}}$$

Unit = %, dB

- Noise and Imperfections in transmit and receive signal chains result in demodulated voltages which are displaced from their ideal location.
- Error Vector Magnitude expresses this dislocation
- Large EVM will result in Symbol Errors and degraded Bit Error Rate
- Higher Order Modulation Schemes → Symbols Closer Together → EVM More Critical

Effects of Gain, Offset, and Phase Errors



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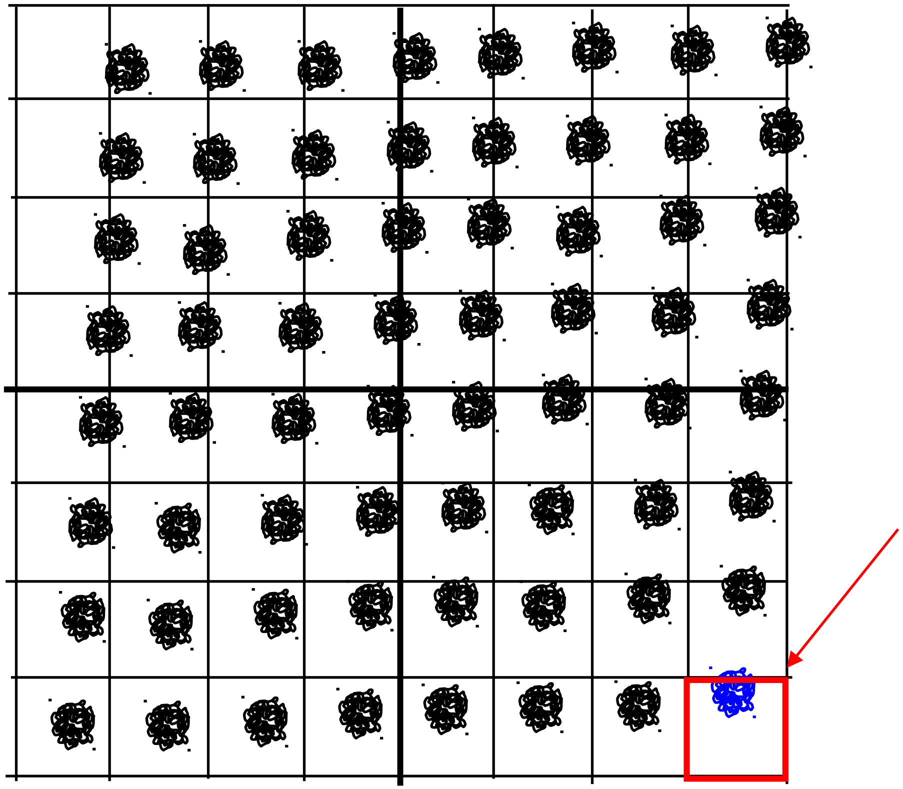
What Is Causing the Poor Quality of This Demodulated Constellation?



Symbol Decision Threshold

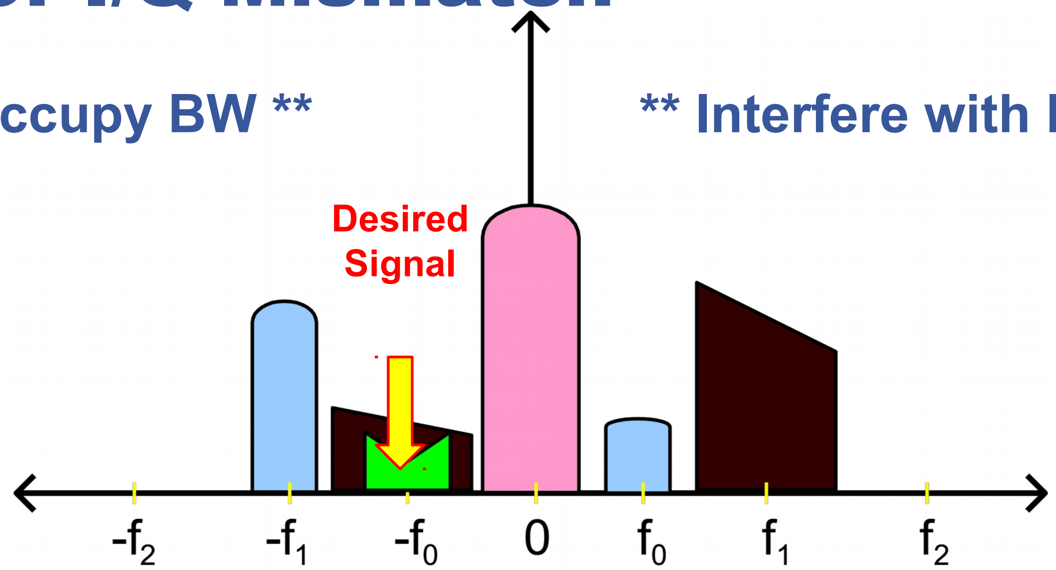
If the symbol lands on the edge or outside of the box, bit errors will occur

- **Very poor LO Quadrature Phase Split (in DMOD)**
- **DC Offset of the complete constellation (probably LO to RF leakage in Tx)**
- **Noise has enlarged the footprint of the constellation points (poor Receiver Noise Figure)**

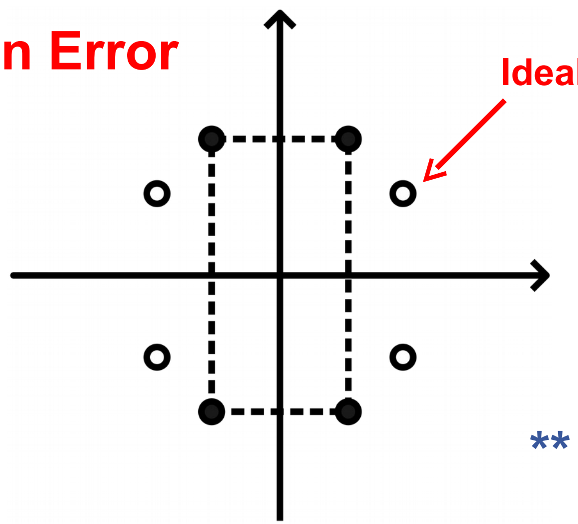
Effects of I/Q Mismatch

** Images Occupy BW **

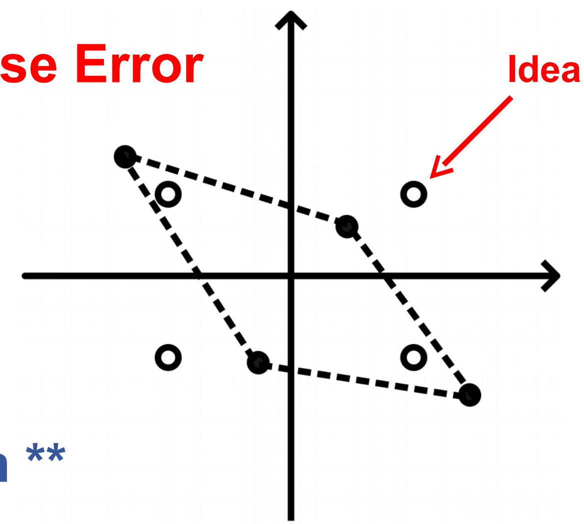
** Interfere with Desired Signal **



Gain Error



Phase Error



** EVM Degradation **

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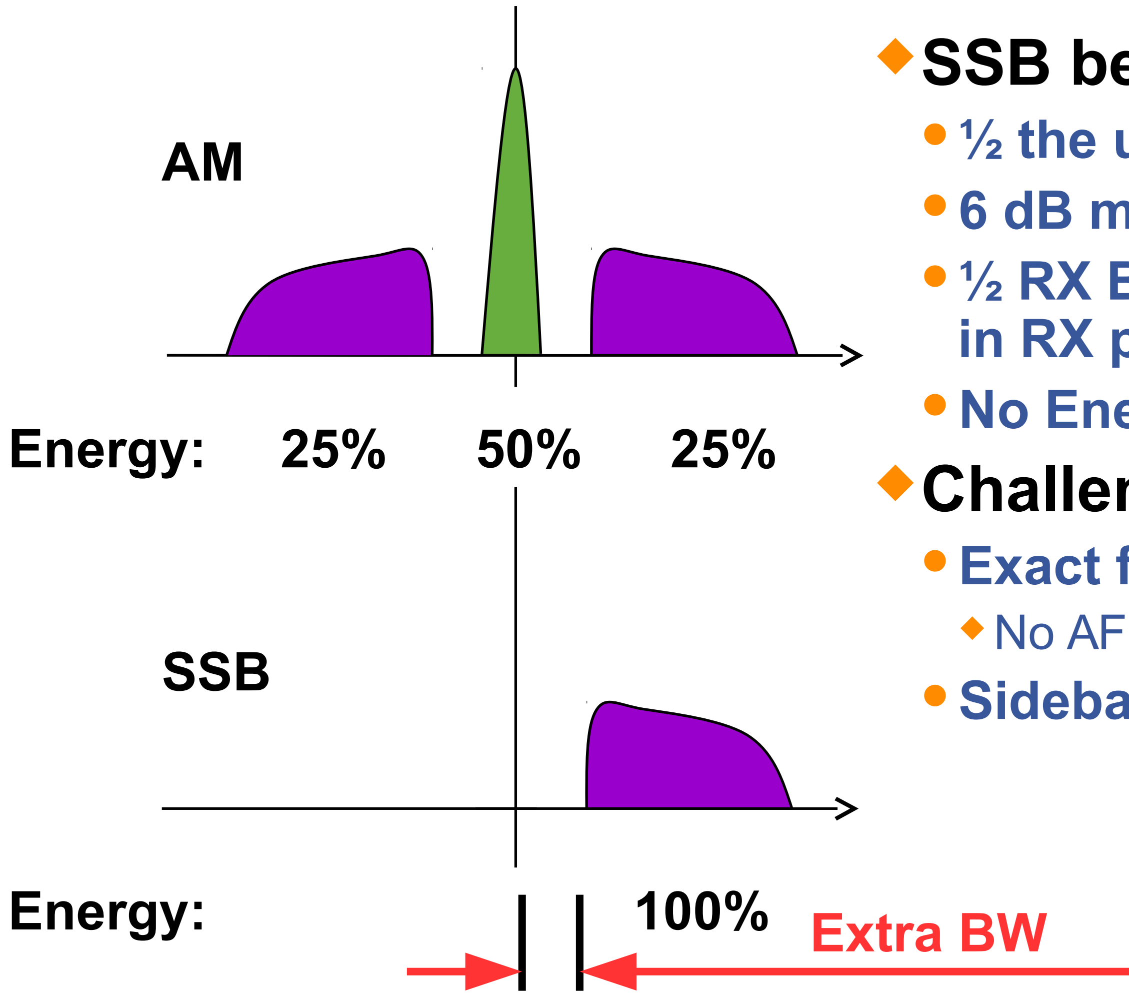
Historical Questions

- When „QAM“ was developed?
  - Dec. 1. 1915, by John Renshaw Carson
- What was it really called?
  - SSB
- Was initially used for which purpose?
  - Military, low noise, long range, cypher voice (vs. AM)
- When and what was the 1st commercial use?
  - Jan.7.1927. Long-Wave Radio Telephone: New York – London
- Radio Amateurs used it since…?
  - 1957

Main Advantage of QAM/SSB vs. AM



- **SSB benefits from**
  - **½ the utilized BW (or less)**
  - **6 dB more signal**
  - **½ RX BW → 1.5dB lower noise in RX path**
  - **No Energy for Carrier**
- **Challenges**
  - **Exact frequency OSC.**
    - No AFC due to lack of Carrier
  - **Sideband attenuation**

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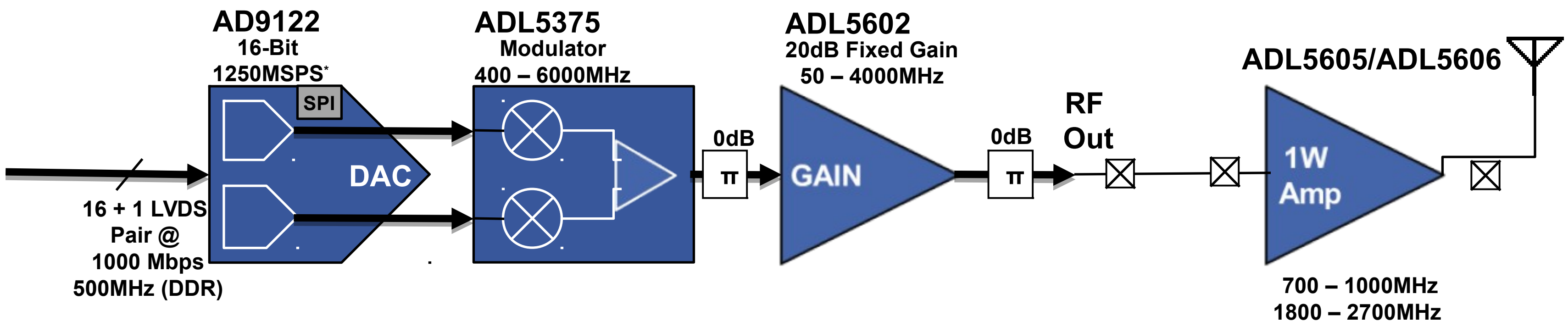
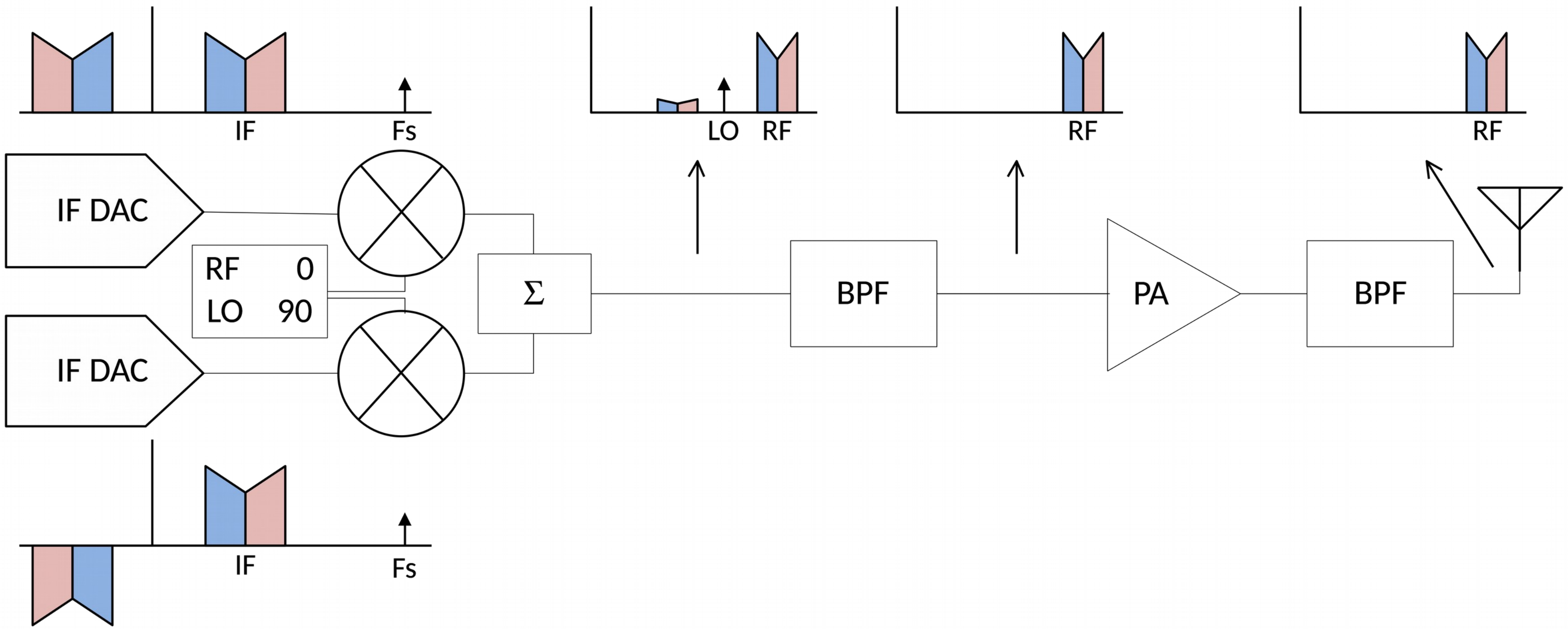
Direct Conversion Transmitter Architecture 99 Years After Its Invention



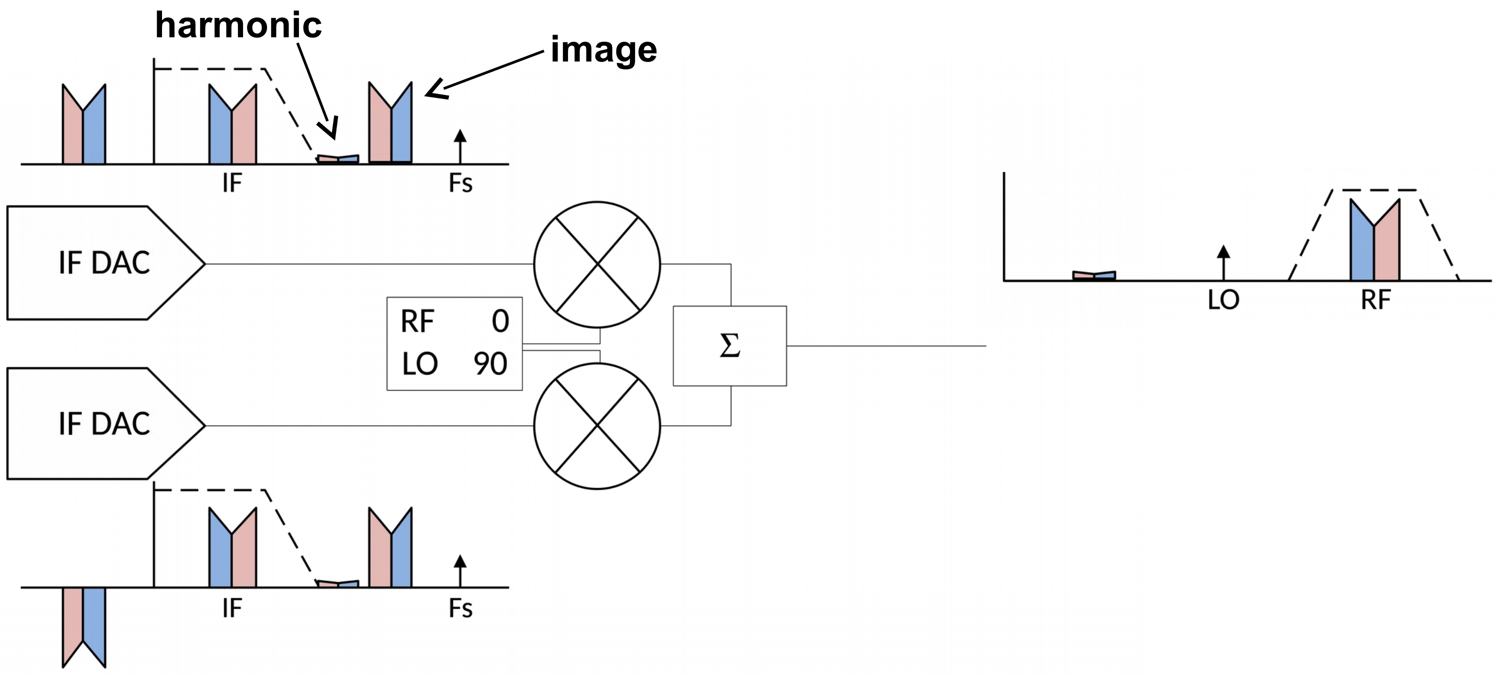
Note: AD9122 is use for high-end transmitters with low harmonics

Complex IF Using IF DACs



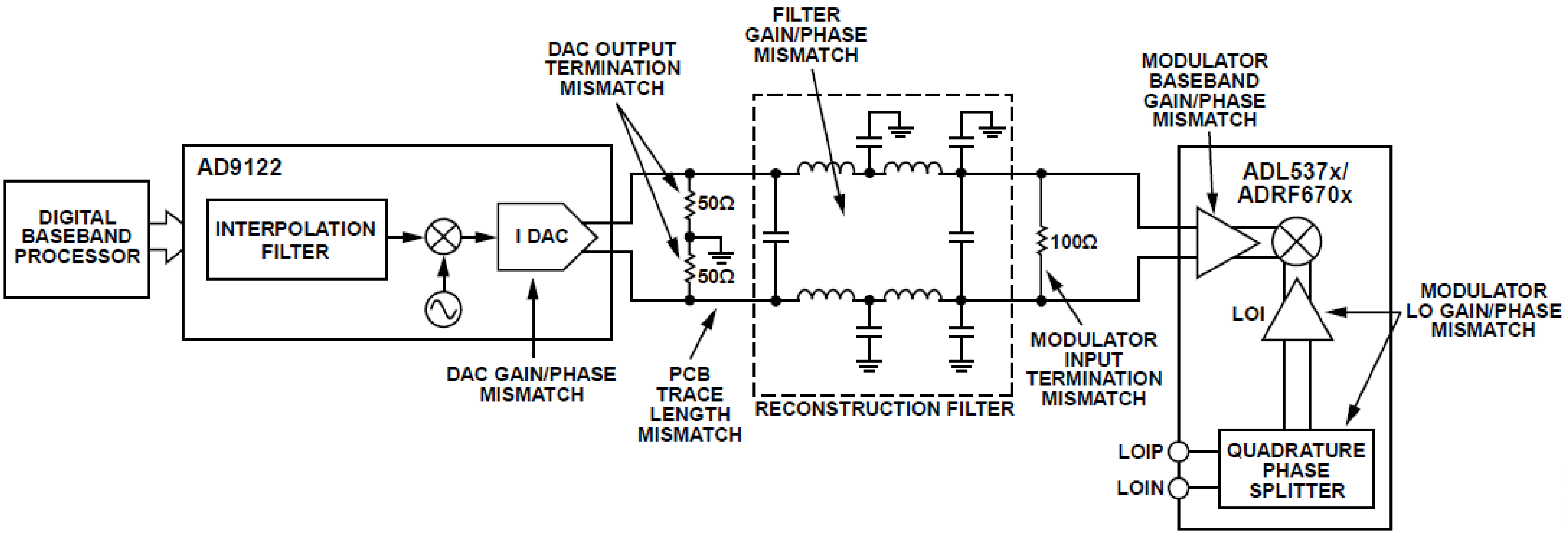
- A complex IF architecture uses IF DACs to synthesize an IF signal and its complex conjugate as the inputs to a quadrature modulator
- This makes a single sideband (SSB) upconverter that rejects the normal mixing product, easing the BPF filtering requirements

Complex IF Imperfections



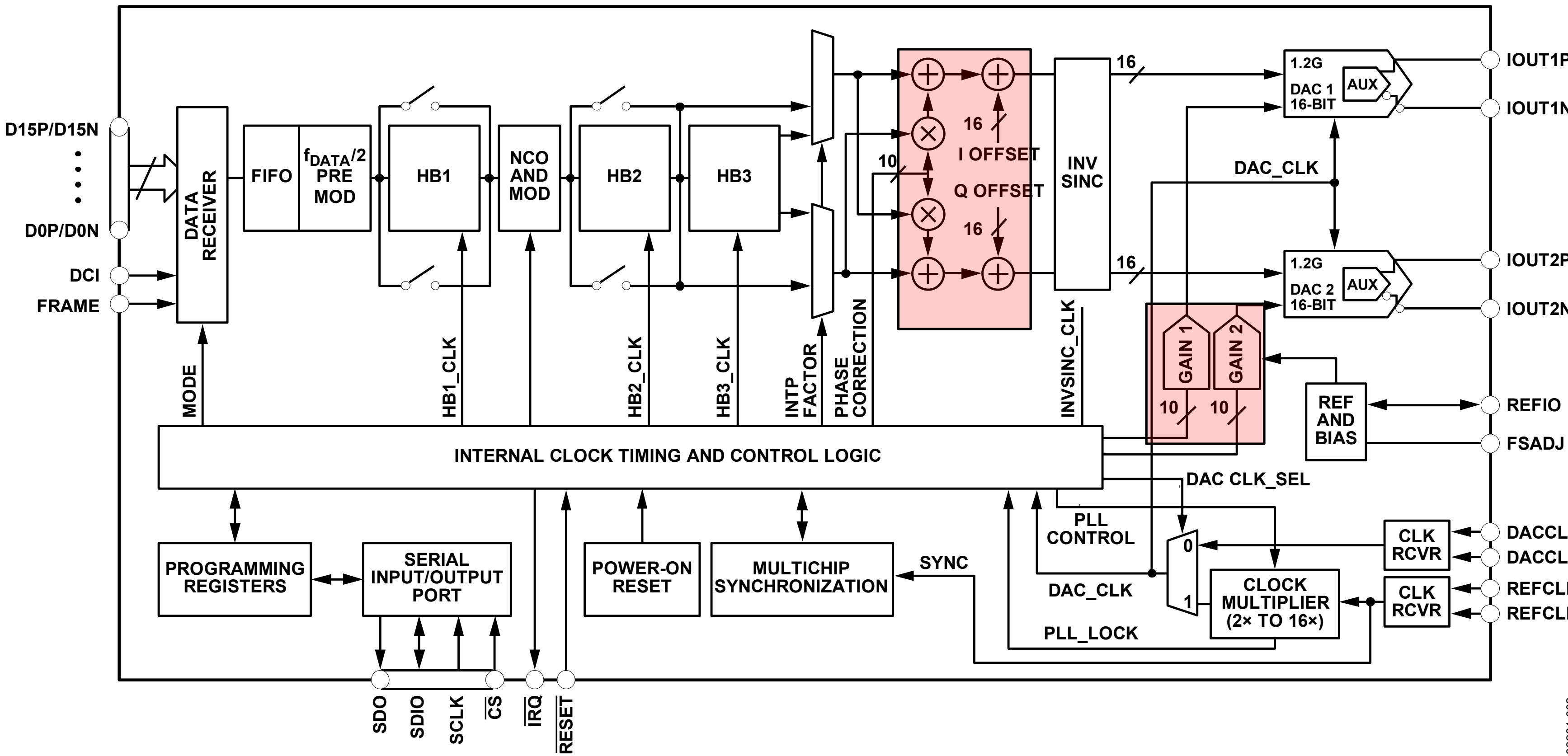
- Complex IF systems create several images:
  - $F_{DAC} - F_{OUT}$: the main desired signal's image
  - Harmonics (2nd, 3rd, etc.), real or folded
- These must be low pass filtered prior to the quadrature modulator
- Careful frequency planning must be done to avoid folded products falling too close to the desired signal that are then upconverted
- Post-modulator, a band pass filter is used to filter the undesired products

Causes of Non-Ideal Sideband Suppressions

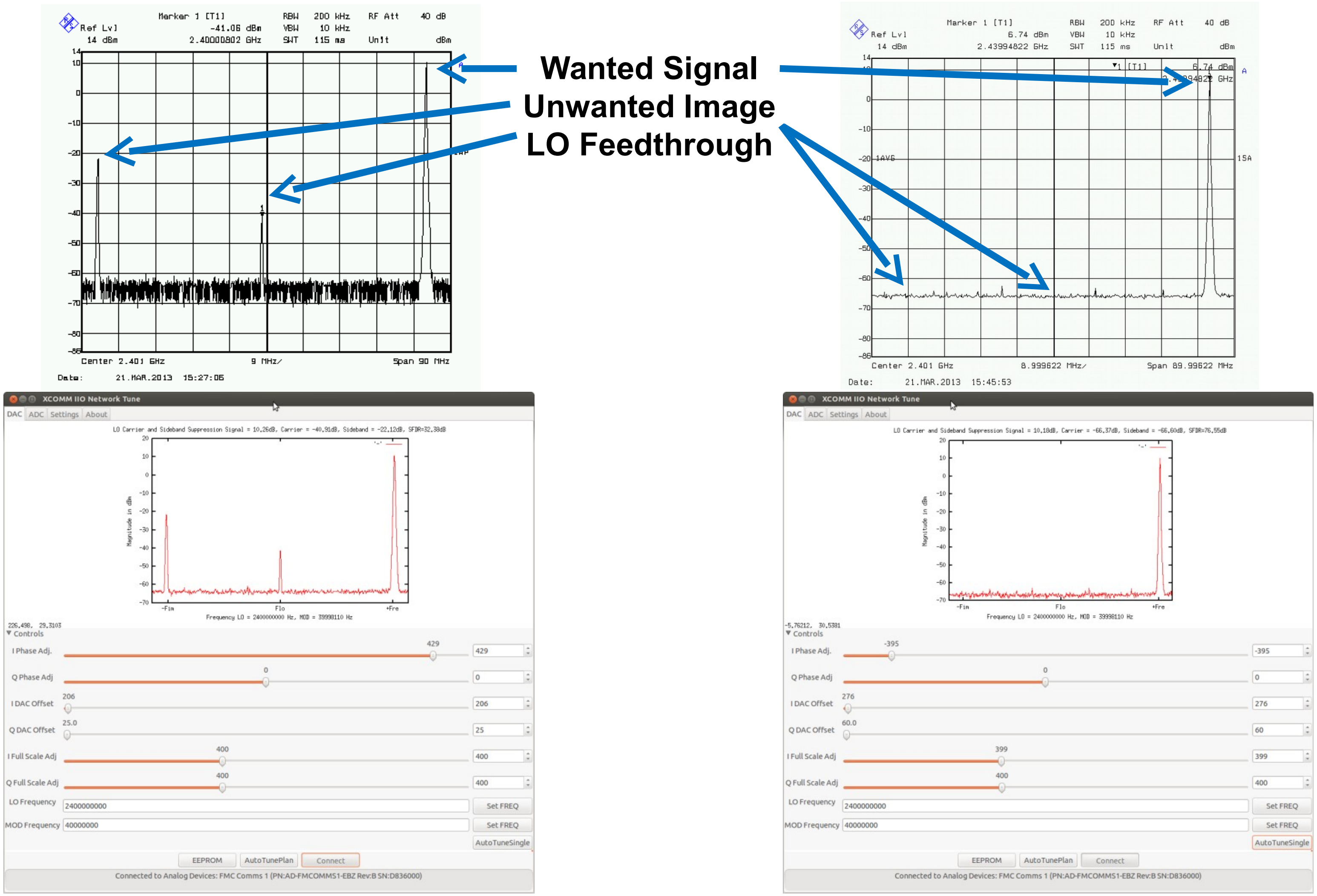


Fixes for Non-Ideal Issues

- AD9122 Block Diagram (Evolutionary step in history)

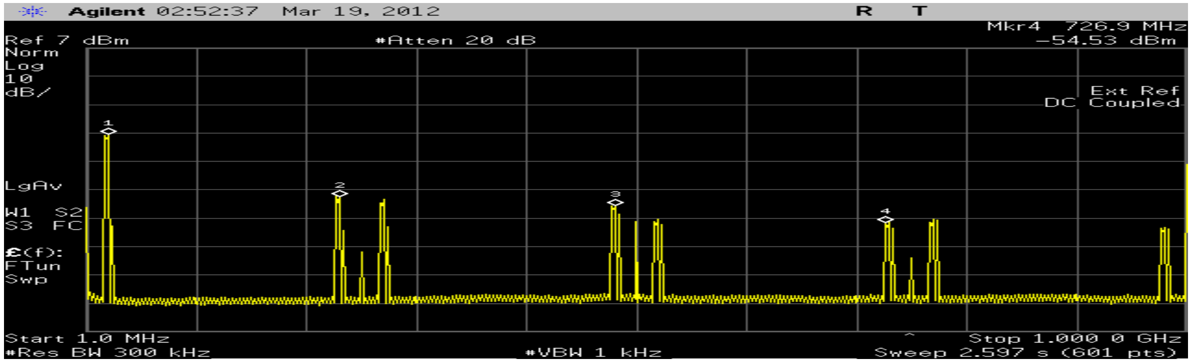


Fixes for Non-Ideal Issues

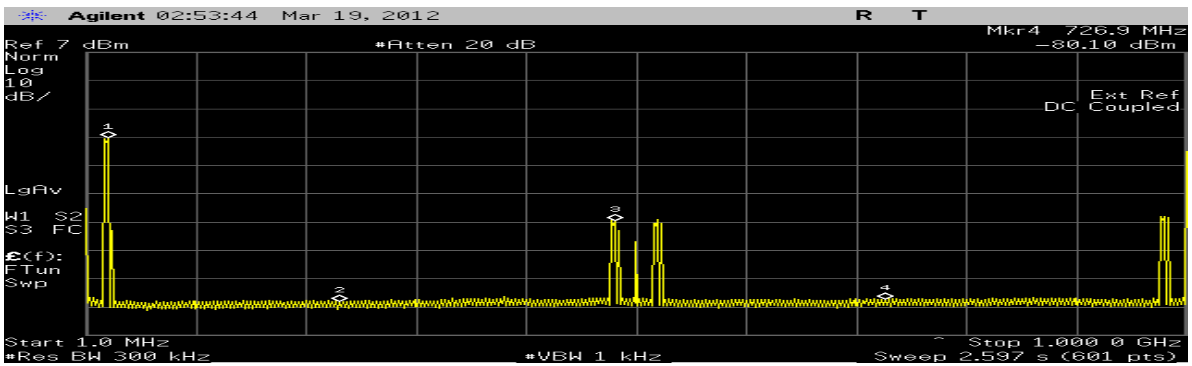


AD9122 Interpolation at a DAC Output

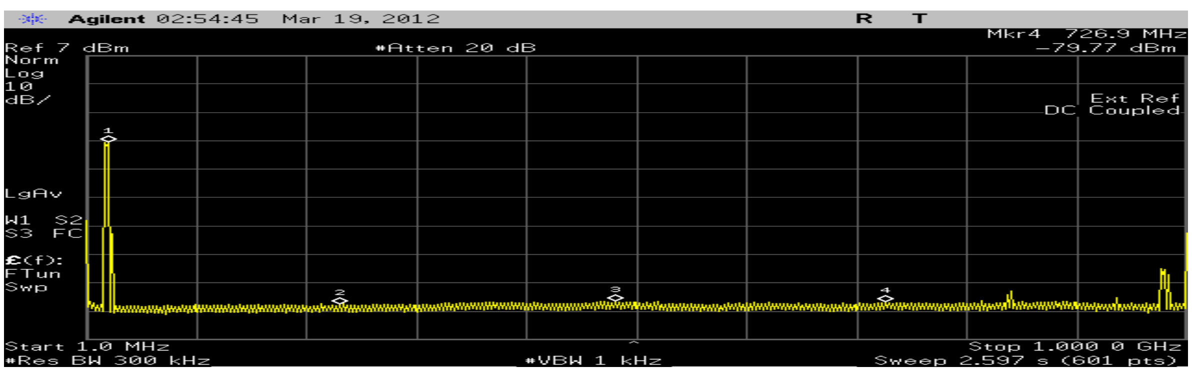
1X



2X



4X



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TX/RX PLL Difference: When is This Useful?

- No “cans” on top of Tx or Rx chains to isolate them
- Any interaction between Tx and Rx PLLs will “bleed into the other” when the frequencies are within 100 kHz (due to PCB size constraints)

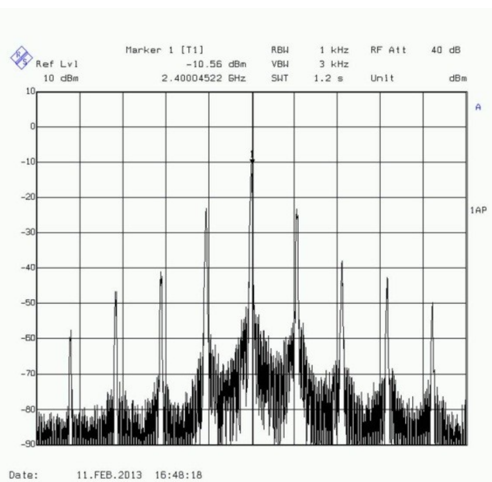


Figure A
Rx and Tx PLL 50 kHz different

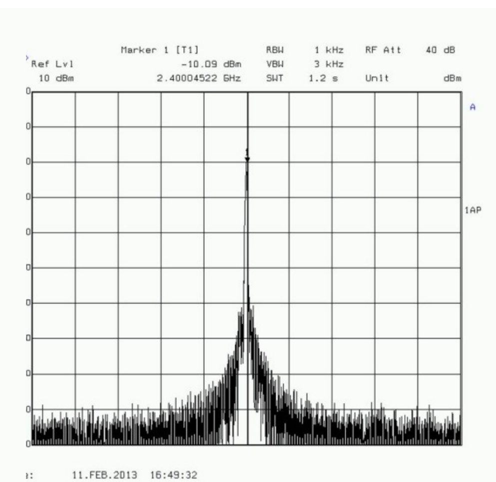
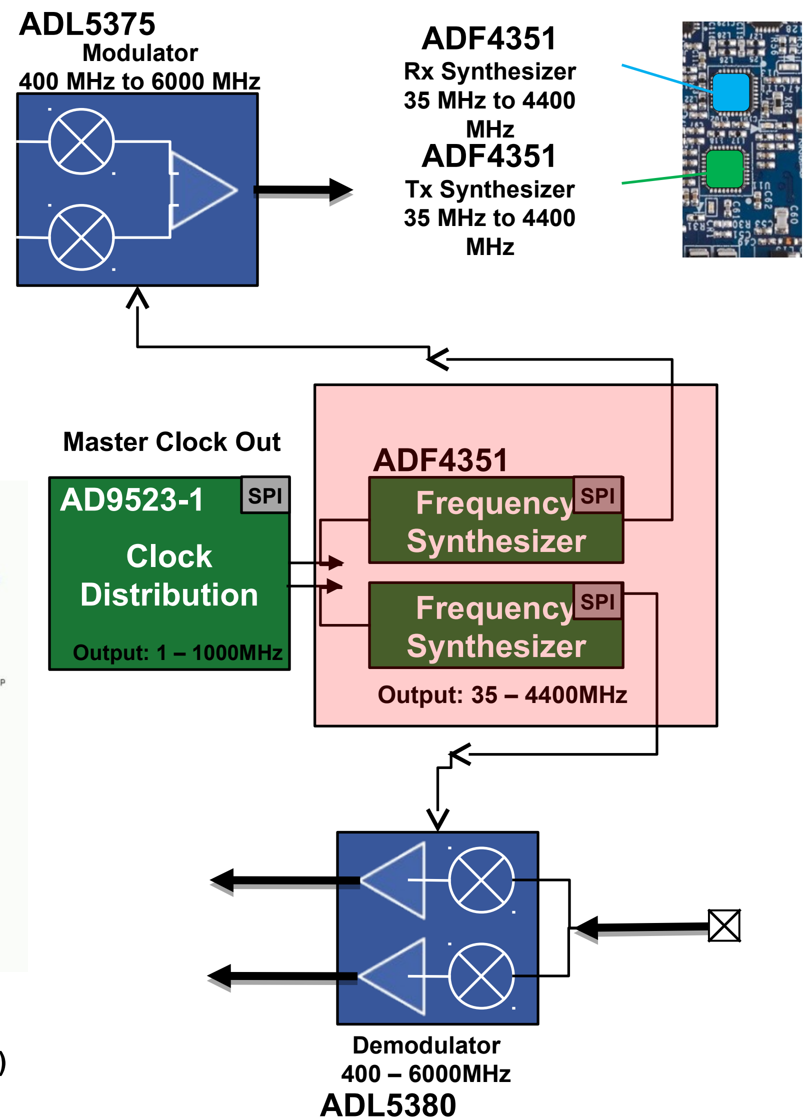
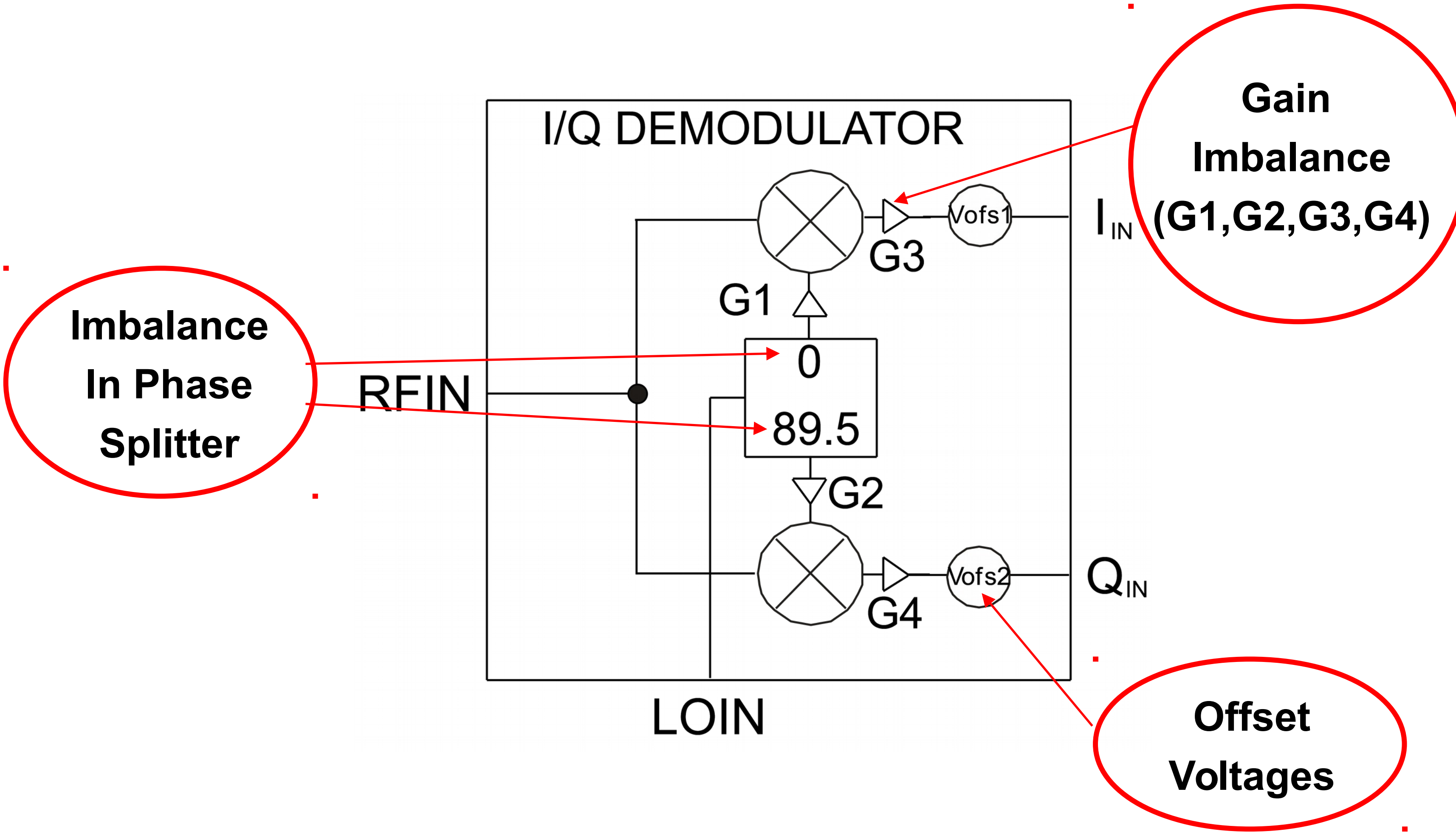


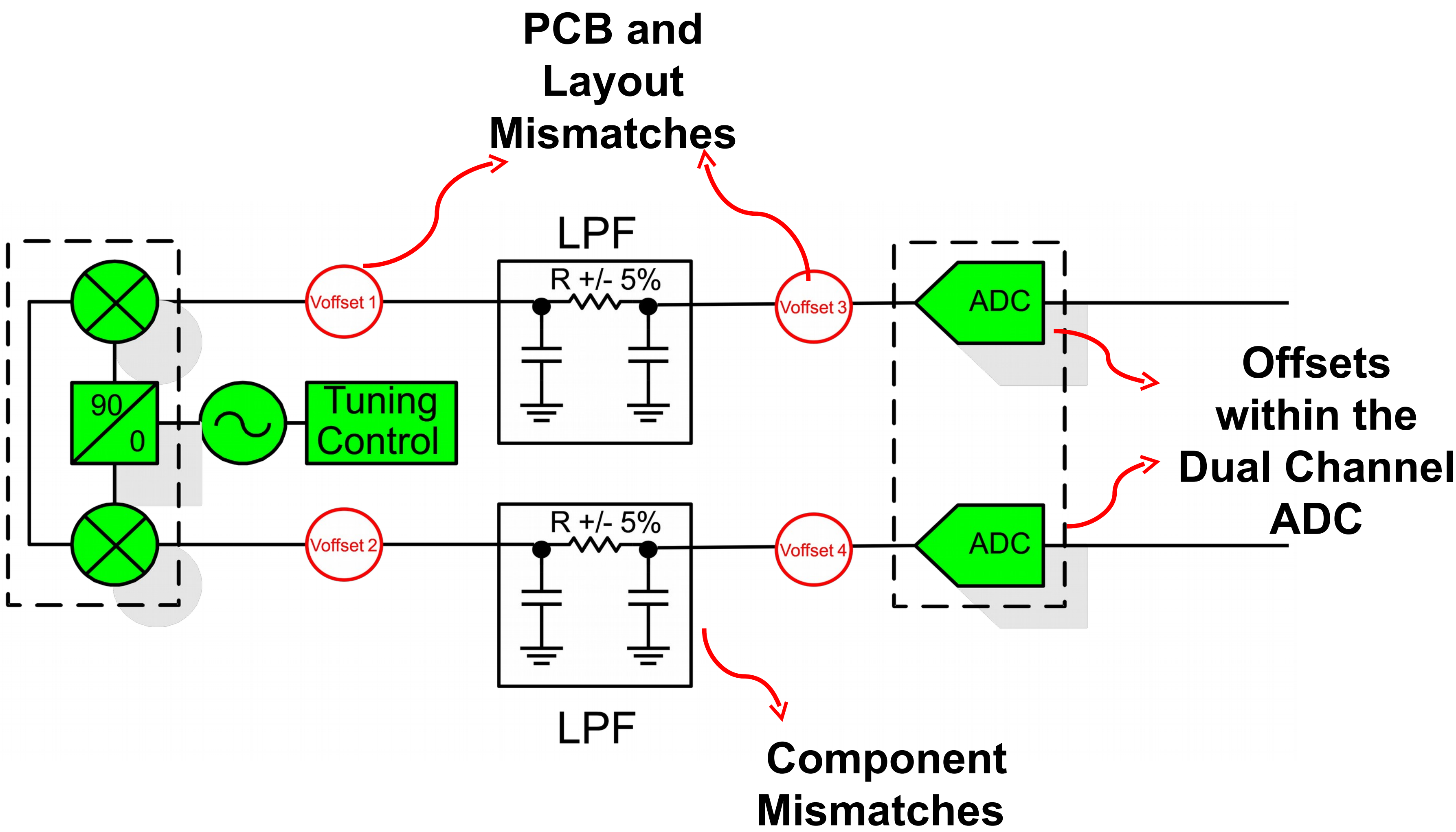
Figure B
Rx and Tx PLL 100 MHz different
(RF is the same due to the DAC shift)



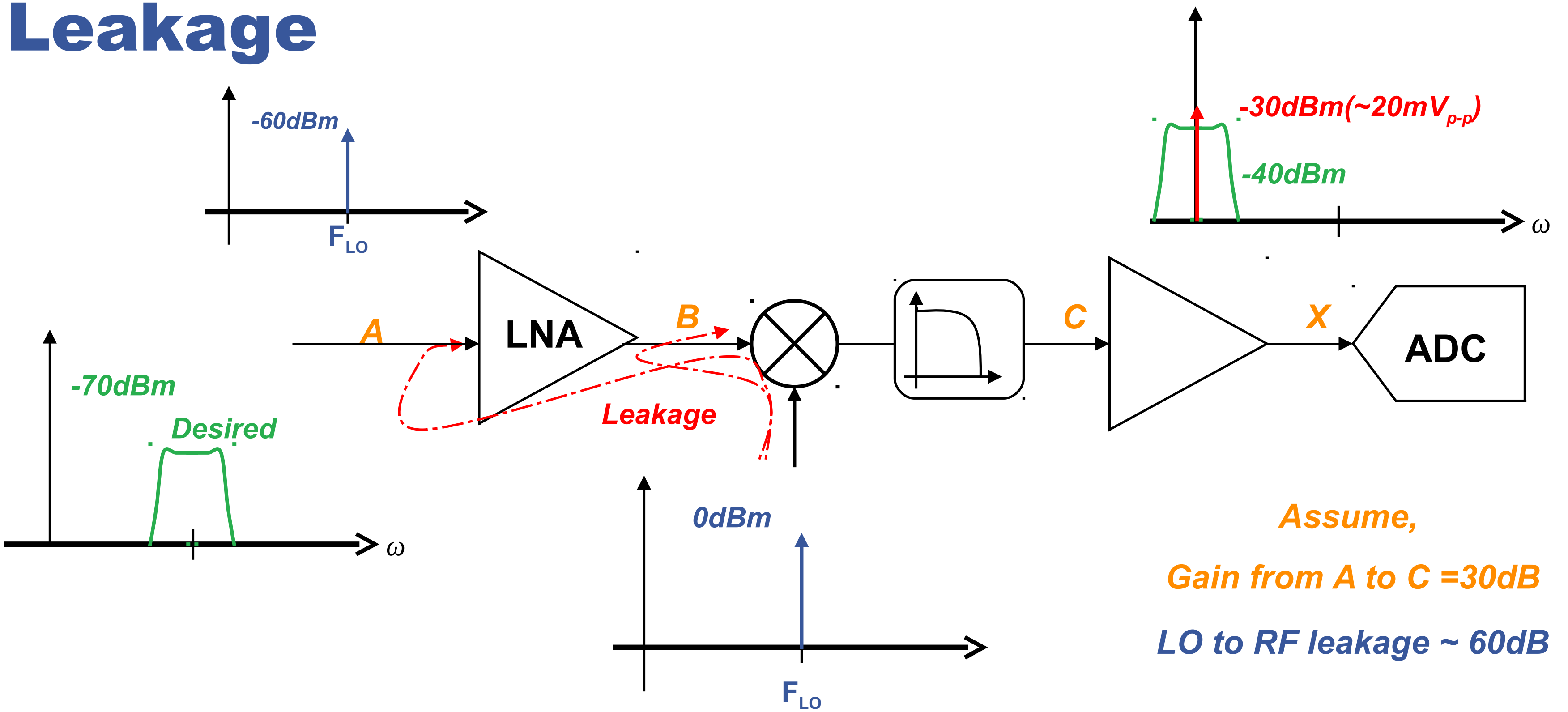
The Imperfect I/Q Demodulator



Imperfections in the I/Q Signal Path



Critical IQ Demodulator Specs—LO to RF Leakage



Assume,

Gain from A to C =30dB

LO to RF leakage ~ 60dB

- If some of the LO leaks to the RF input, it mixes (multiplies) with itself in the mixer, generating unwanted dc offsets on top of the recovered baseband data stream

DC Offset and Quadrature Error Correction

- **DC offset and quadrature error correction implemented digitally at the end of the receive chain**
  - **Most efficient approach in order to compensate for all potential mismatches or errors in the signal path**
- **DC Correction**
  - **If DC free coding is used, a notch filter can be applied**
- **Quadrature Error Correction**
  - **Gain Correction**
    - Calculate I^2 – Q^2 to determine the power difference between I and Q.
    - The power difference should be driven to zero.
  - **Phase Correction**
    - Perform a cross-multiply between I and Q.
    - Can be viewed as a mixer. The DC term is proportional to the phase difference between I and Q.
    - By definition this should be zero if they are perfectly orthogonal.

Summary

- Direct conversion or homodyne receivers have there own merits and challenges
- Gain, phase, and offset errors are a few of the challenges that can be addressed with quadrature error correction algorithms
  - Gain, phase, and offset errors cause degradations in receiver EVM and sensitivity
  - Quadrature error correction will improve EVM and sensitivity
- Direct conversion offers advantages in power, cost, and performance over IF sampling architectures
- Quadrature error correction enables realizable direct conversion solutions for macro level base stations/SDR platforms
- Analog Devices' first generation of QEC is available integrated into the following products
  - AD9262 – dual 16b continuous time sigma delta ADC
  - AD9269 – dual 16b pipeline ADC

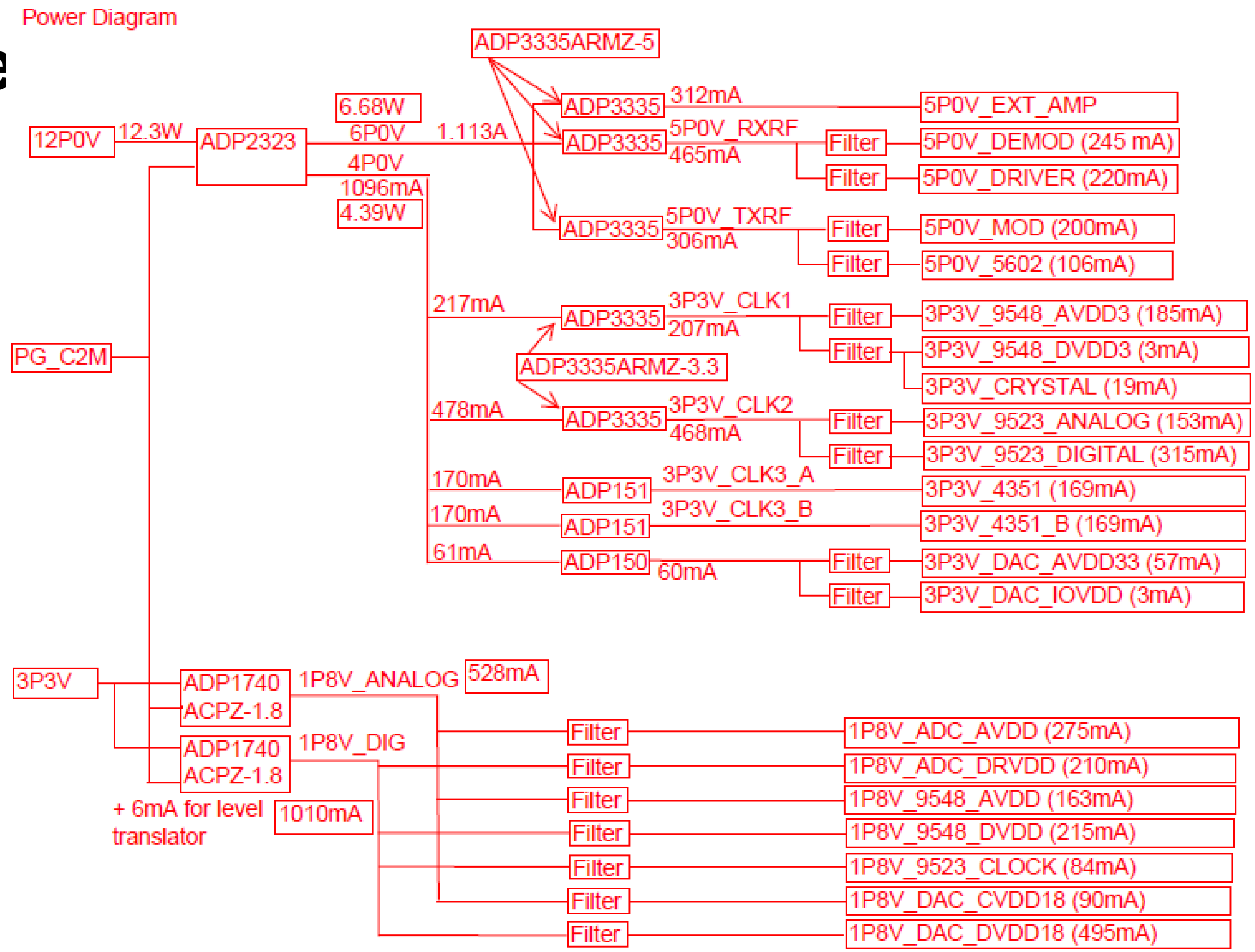
Dave Robertson
VP Technology, Analog Devices

„Silicon is always cheaper than Bandwidth"

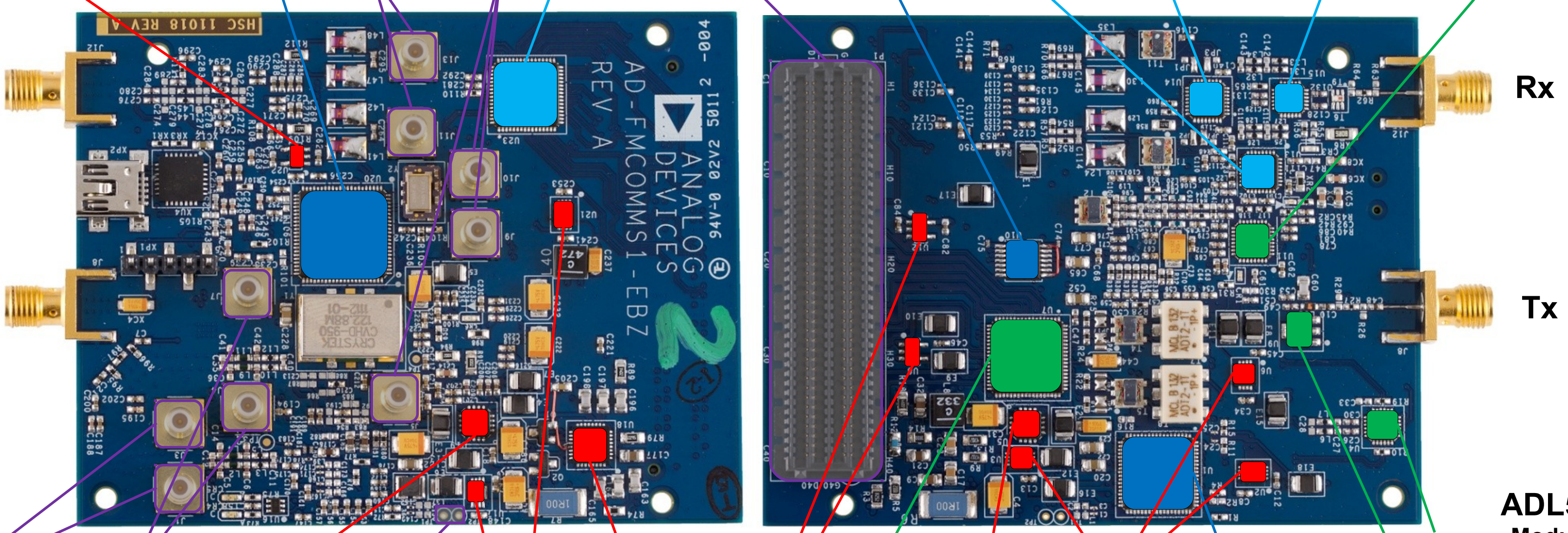
~Y2000

Power

- FMC provide and 3.3 V
- Switchers
  - ADP2323
- LDOs
  - ADP3335
  - ADP3333
  - ADP151
  - ADP150
  - ADP1740



FMC-Comms Board – Tx, Rx, Clocks, Power



• AD9122 DAC runs at 1000MSPS, due to max speed of AD9523-1

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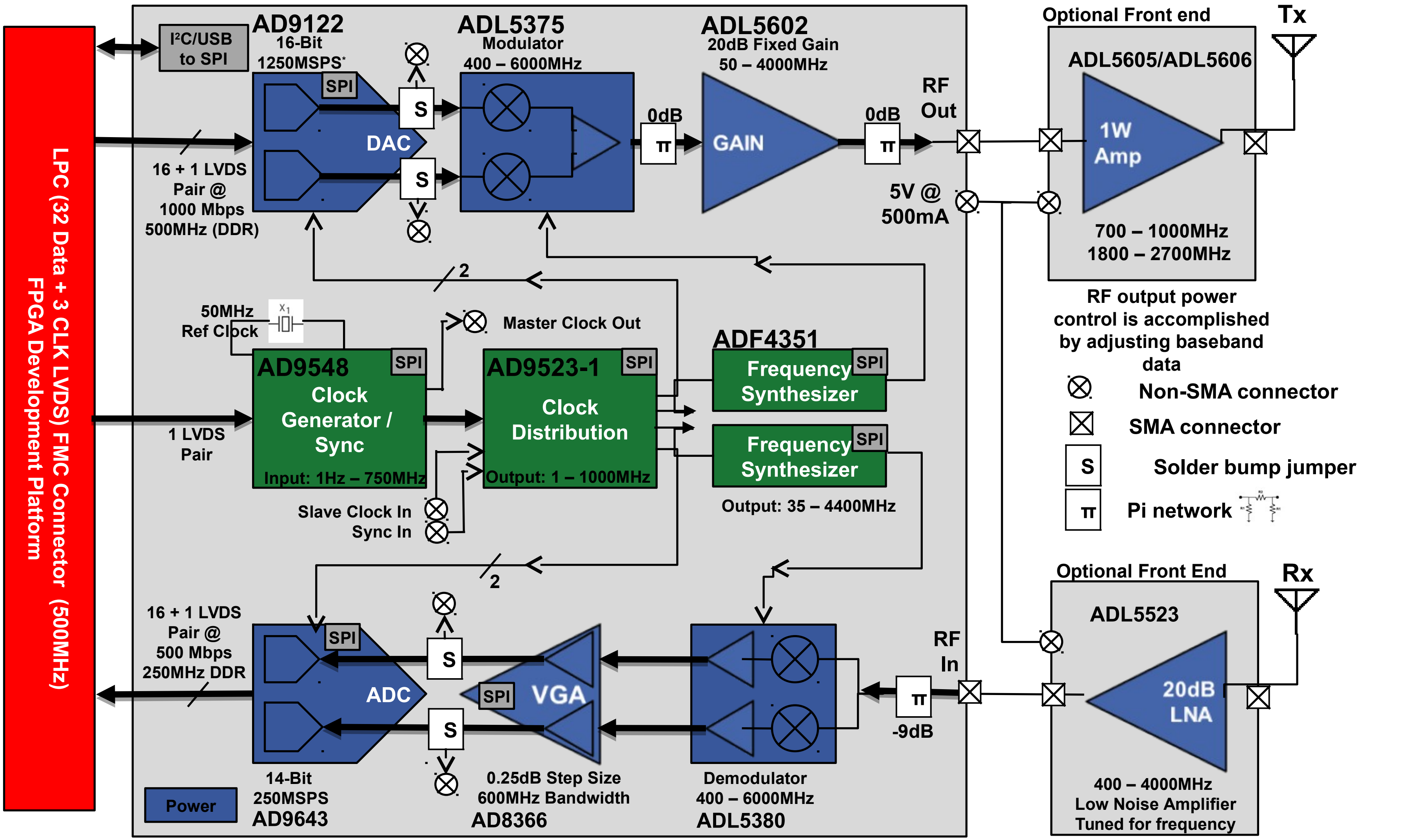
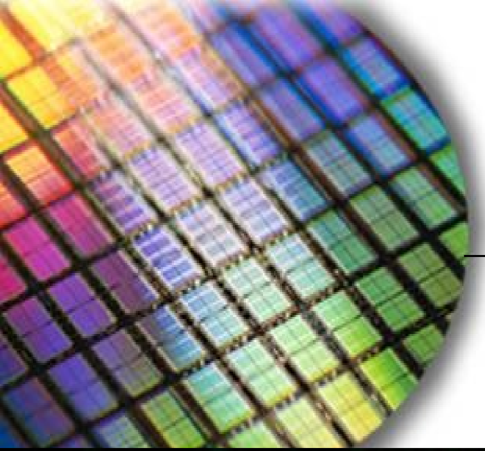
FMCOMMS1-EBZ Block Diagram

Y2012



• AD9122 DAC runs at 1000MSPS, due to max speed of AD9523-1



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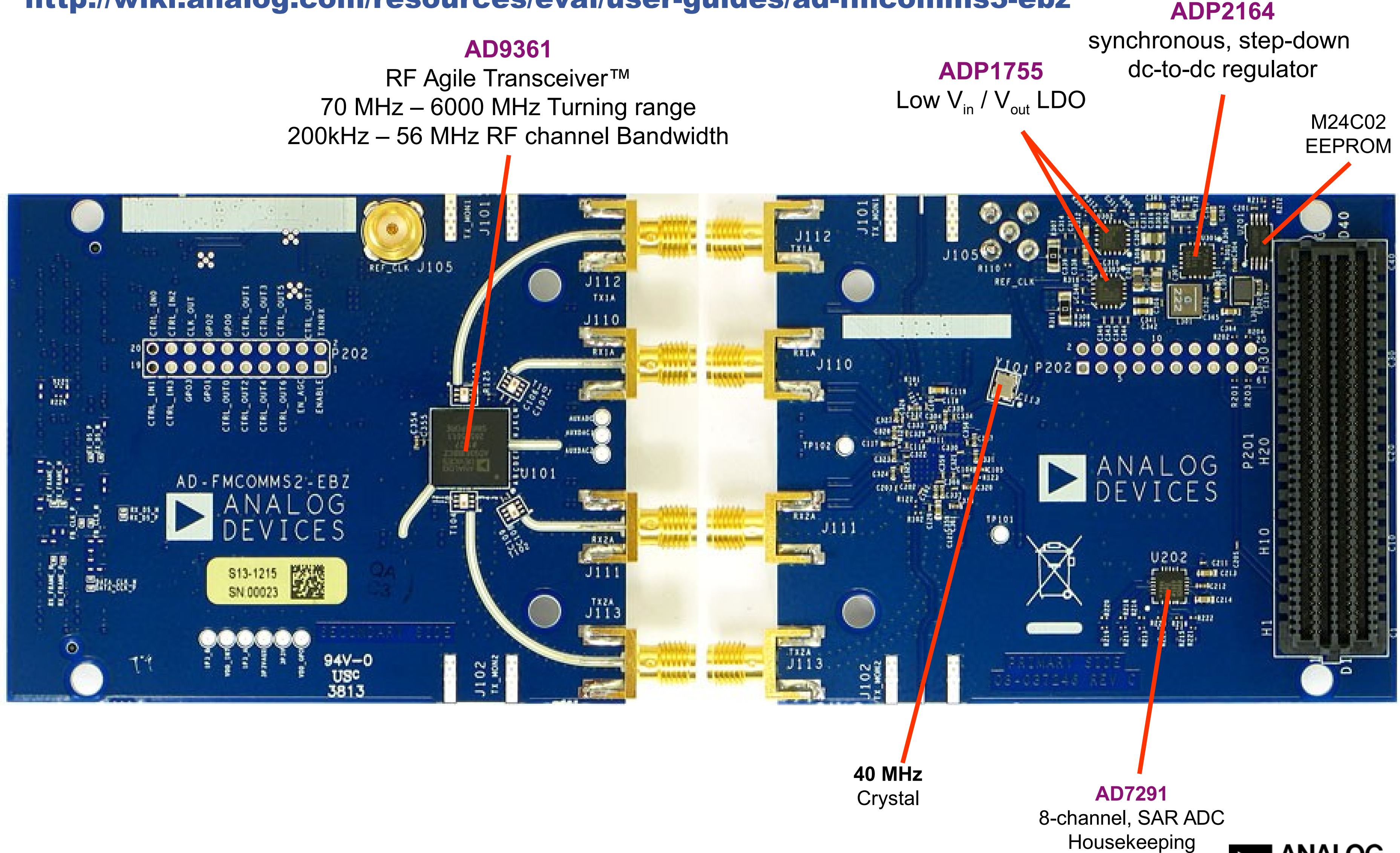
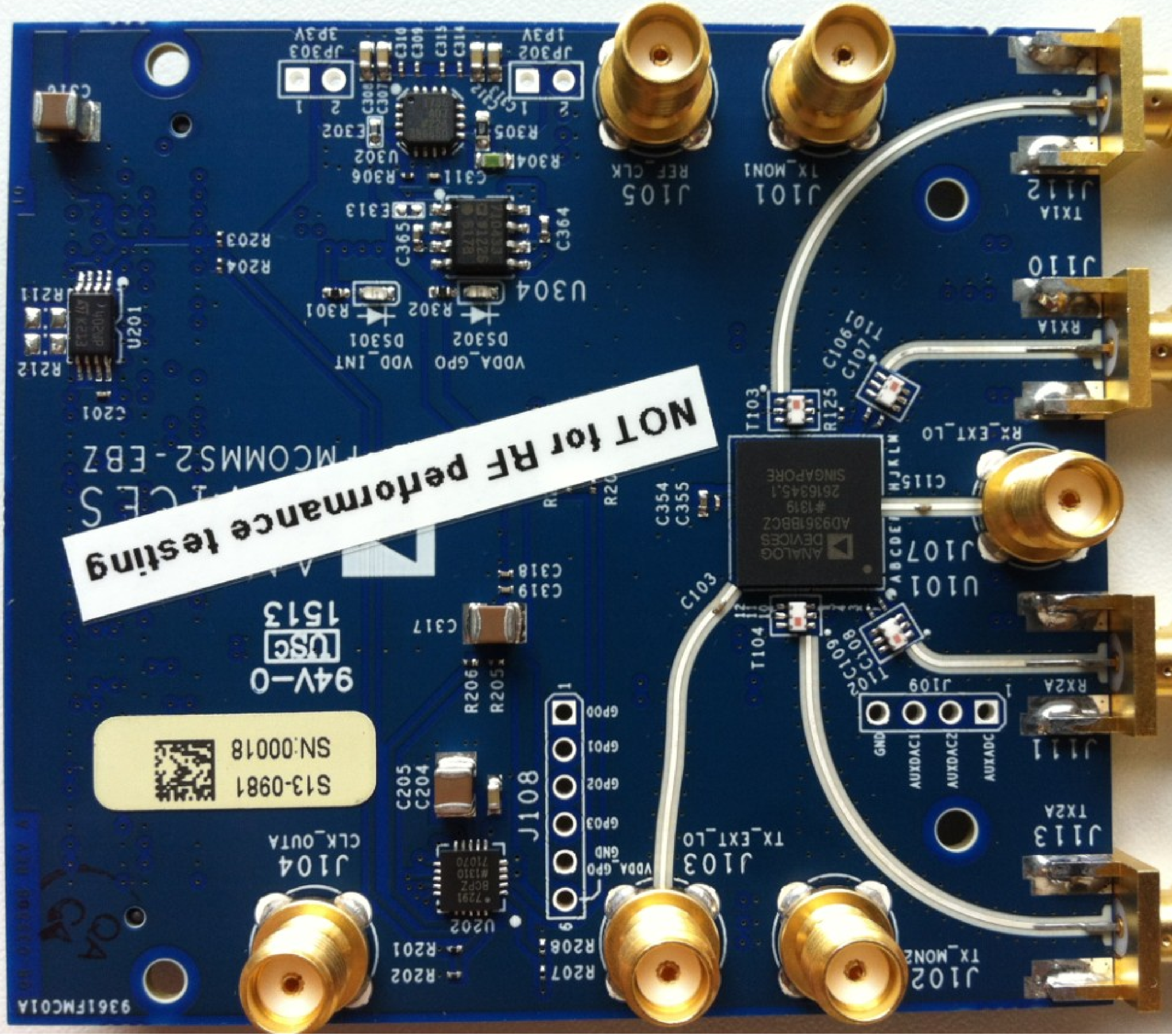
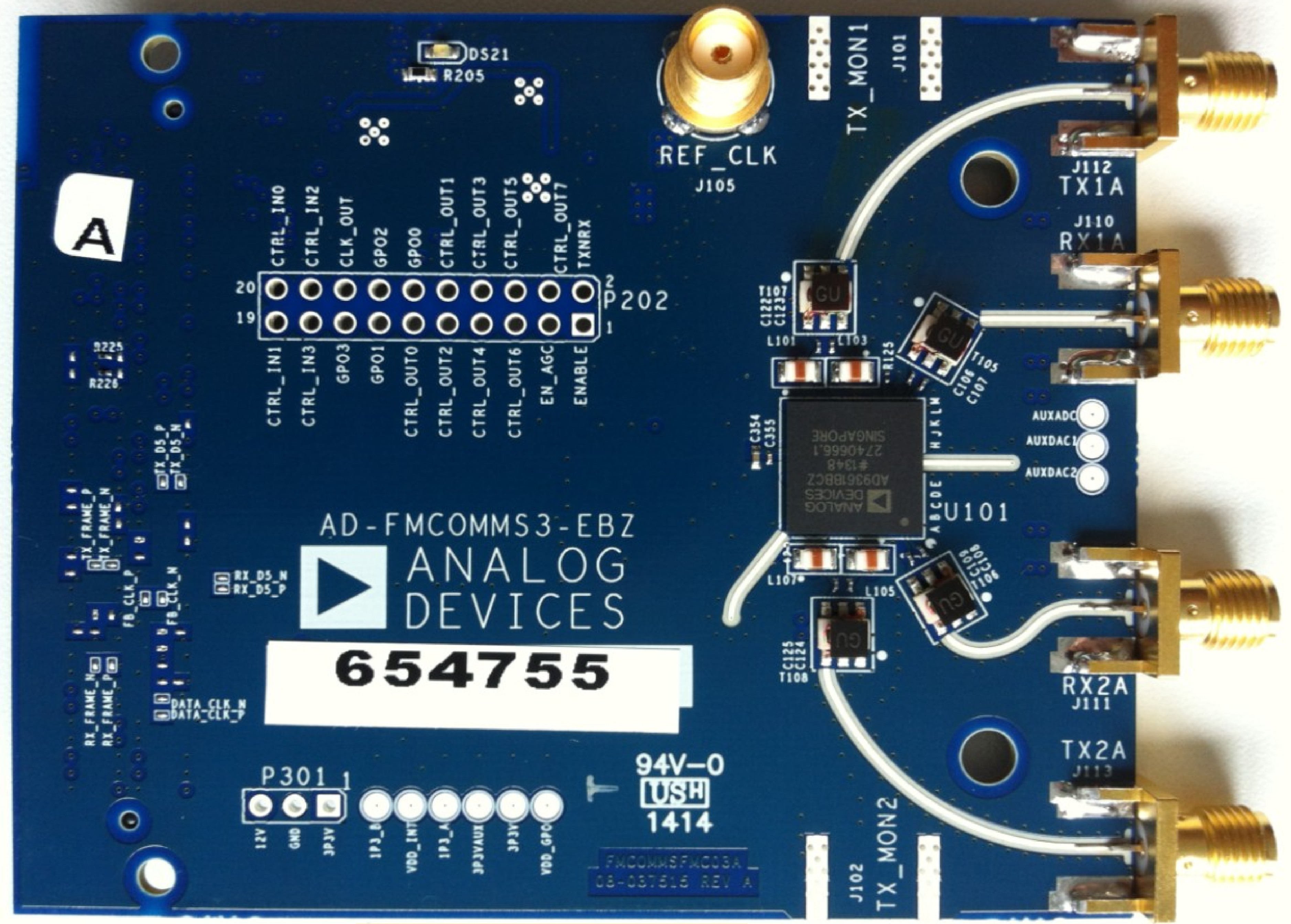
FMCOMMS2 – Moore's Law in action

http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms3-ebz



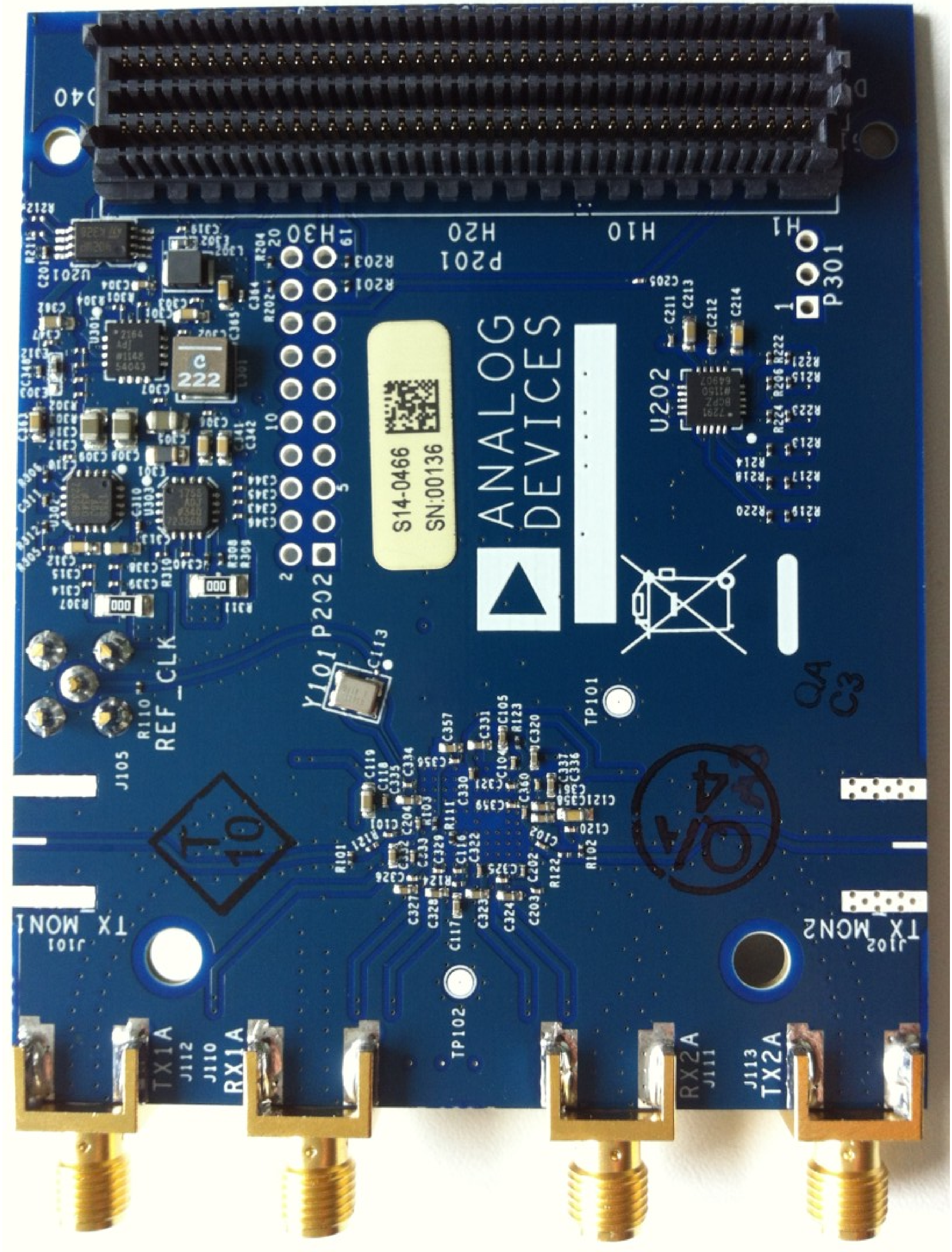


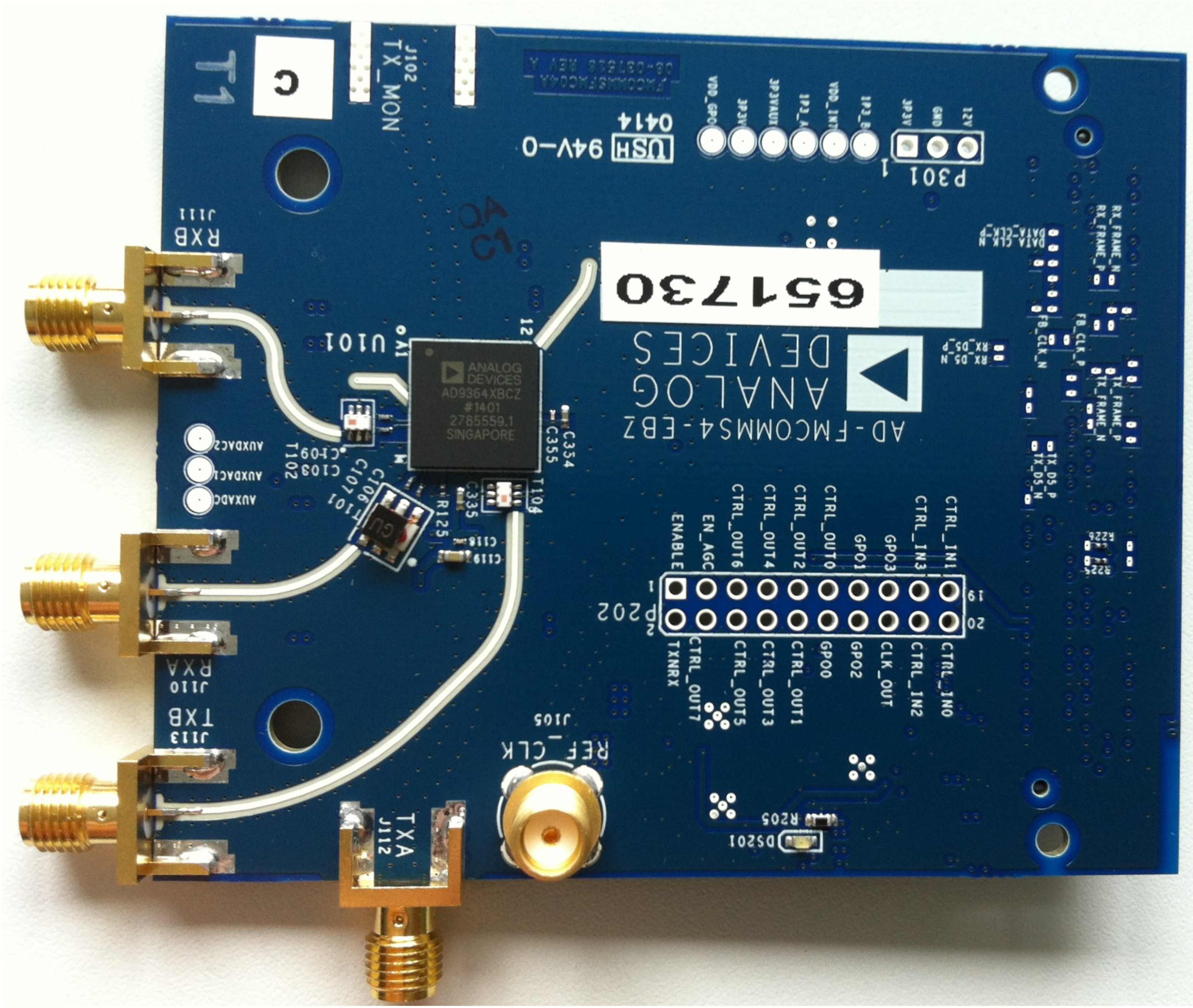
AD-FMCOMMS2-EBZ



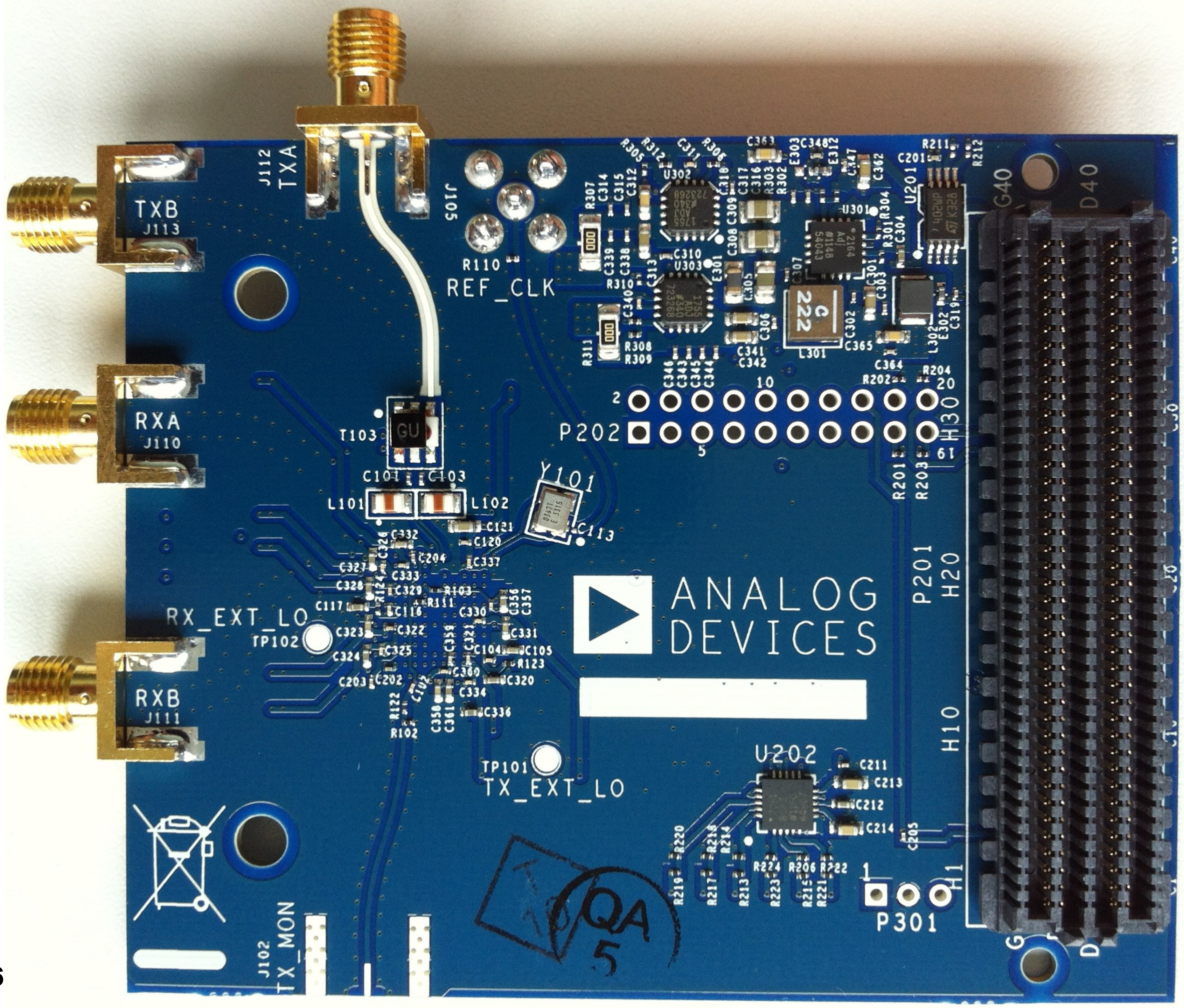
AD-FMCOMMS3-EBZ

AD-FMCOMMS3-EBZ



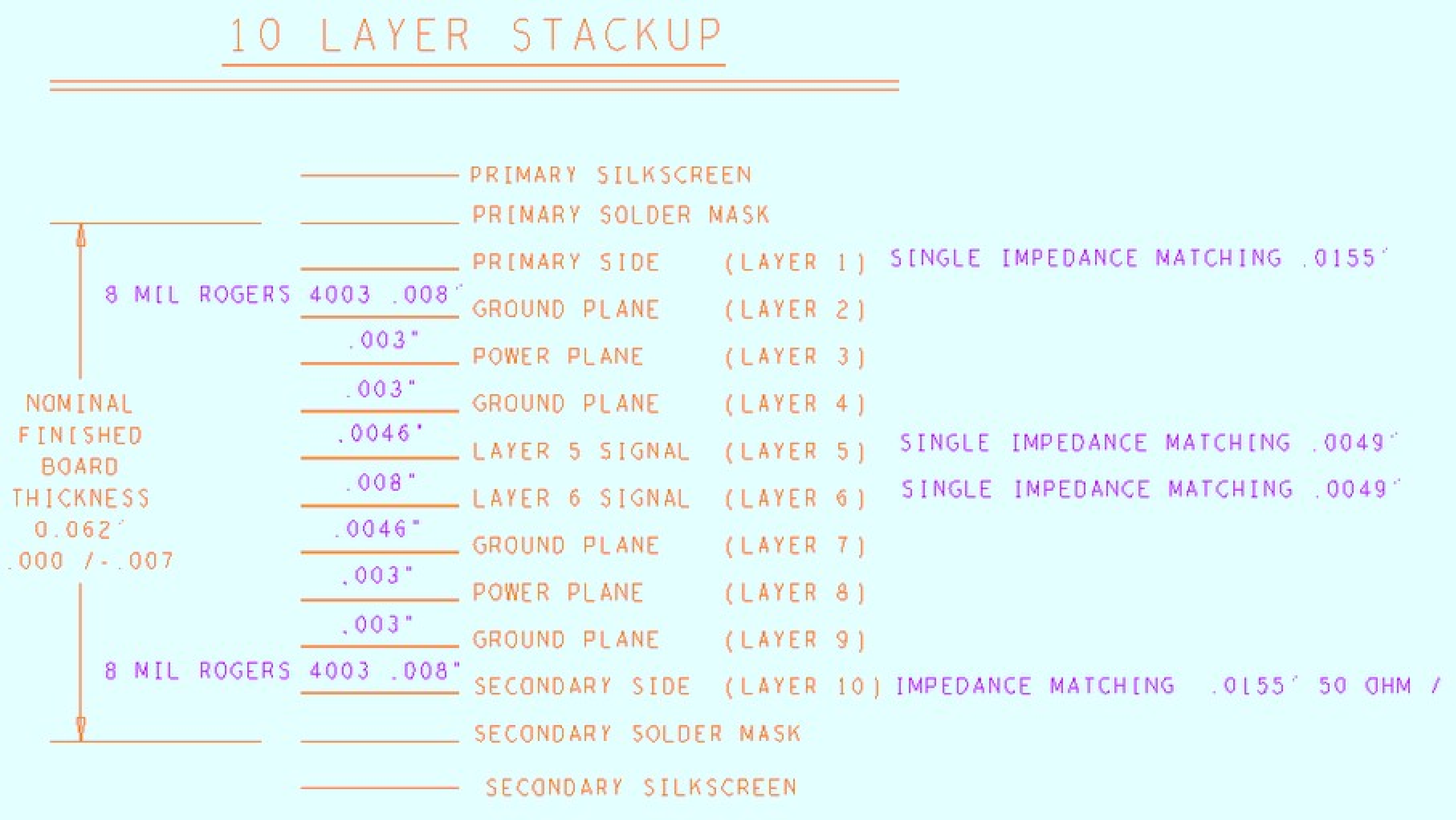


AD-FMCOMMS4-EBZ



AD-FMCOMMS4-EBZ

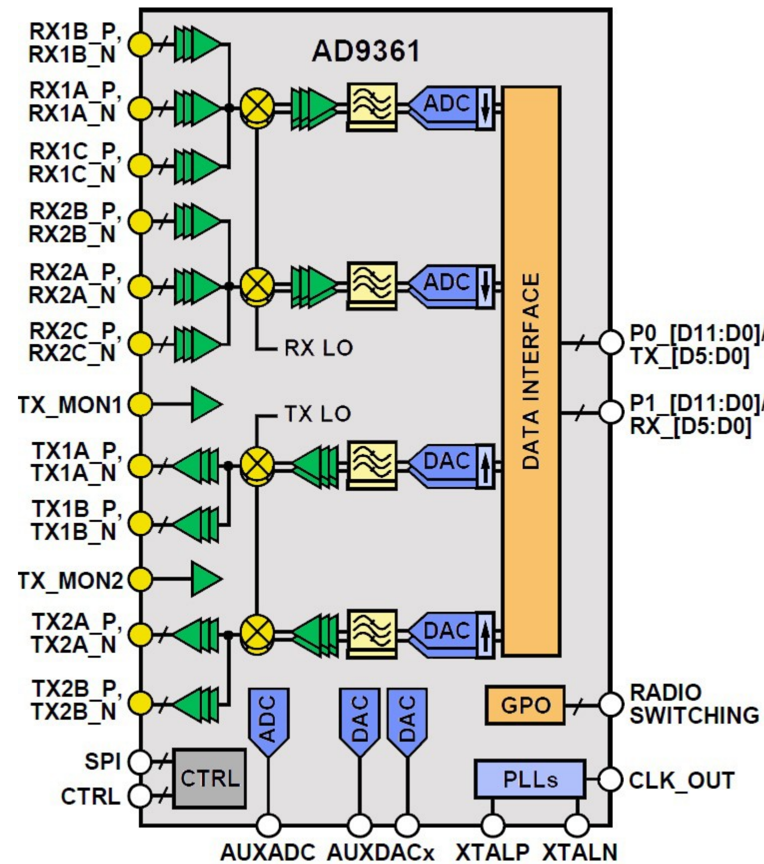
Stackup



http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms2-ebz/hardware

AD9361 Key Facts & Features

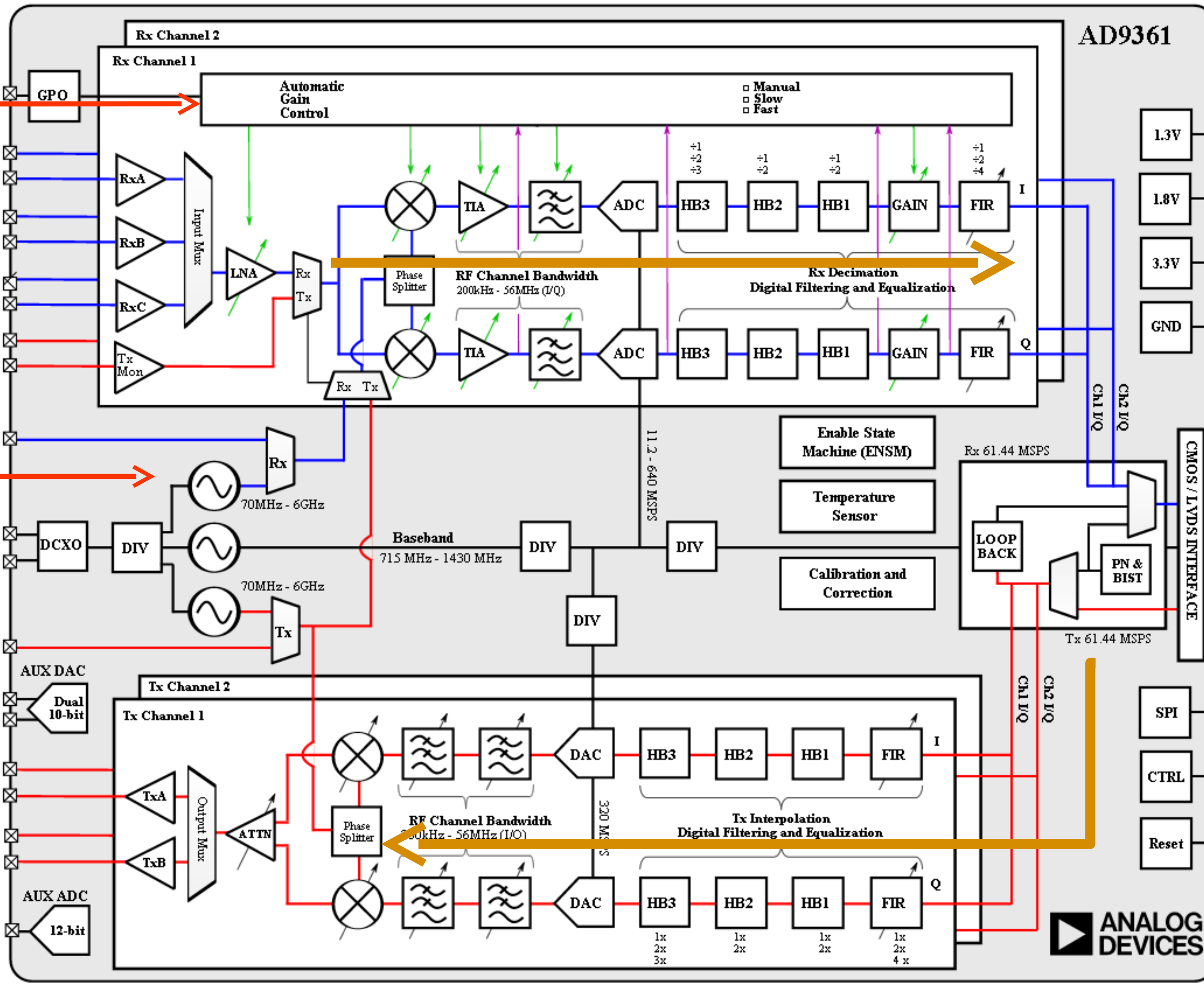
- Complete, highly configurable RF transceiver
- Integrated 12-bit ADCs and DACs, LNAs, mixers, analog filters, clocking solution, frequency synthesizers
- 2 x Tx, 2 x Rx Channels
- Tunable RF bandwidth 70 MHz to 6.0 GHz
- Programmable channel bandwidth; 200 kHz to 56 MHz
- Superior receiver sensitivity with noise figure <2.5 dB
- Highly-linear broadband transmitter with EVM: ≤ -40 dB
- Integrated low phase noise fractional-N synthesizers
- 128 complex-tap programmable FIR filters
- Meets 3G/4G wireless standards

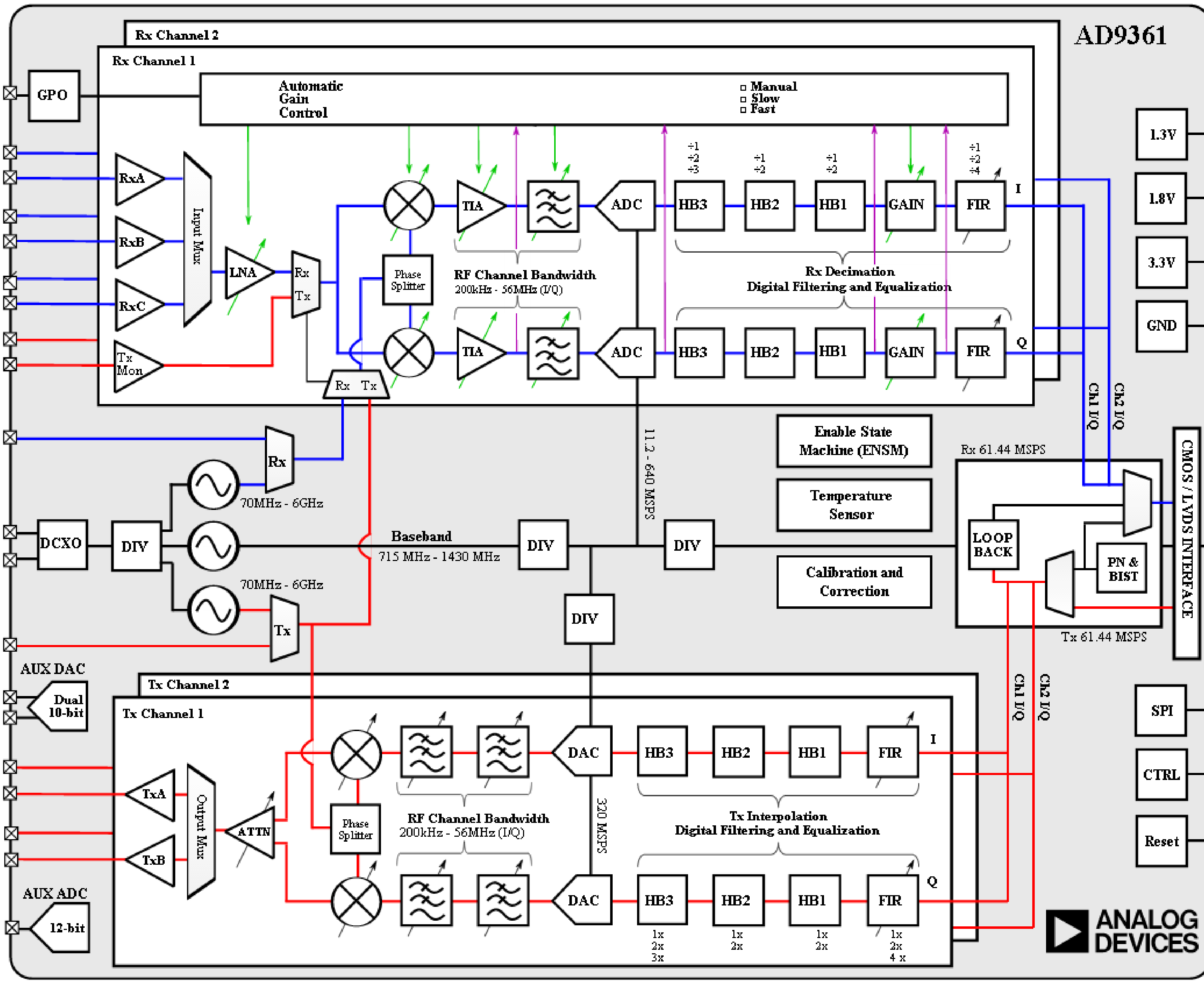


RF Bandwidth	Channel Bandwidth	Rx Noise Figure	Tx EVM	Tx Noise	Package	Temp
70MHz to 6GHz	200kHz to 56MHz	2.5dB	<-40dB	<-155dBm/Hz	10mm x 10mm CSPBGA	-40°C to +85°C

AD9361/AD9364 Under the Hood

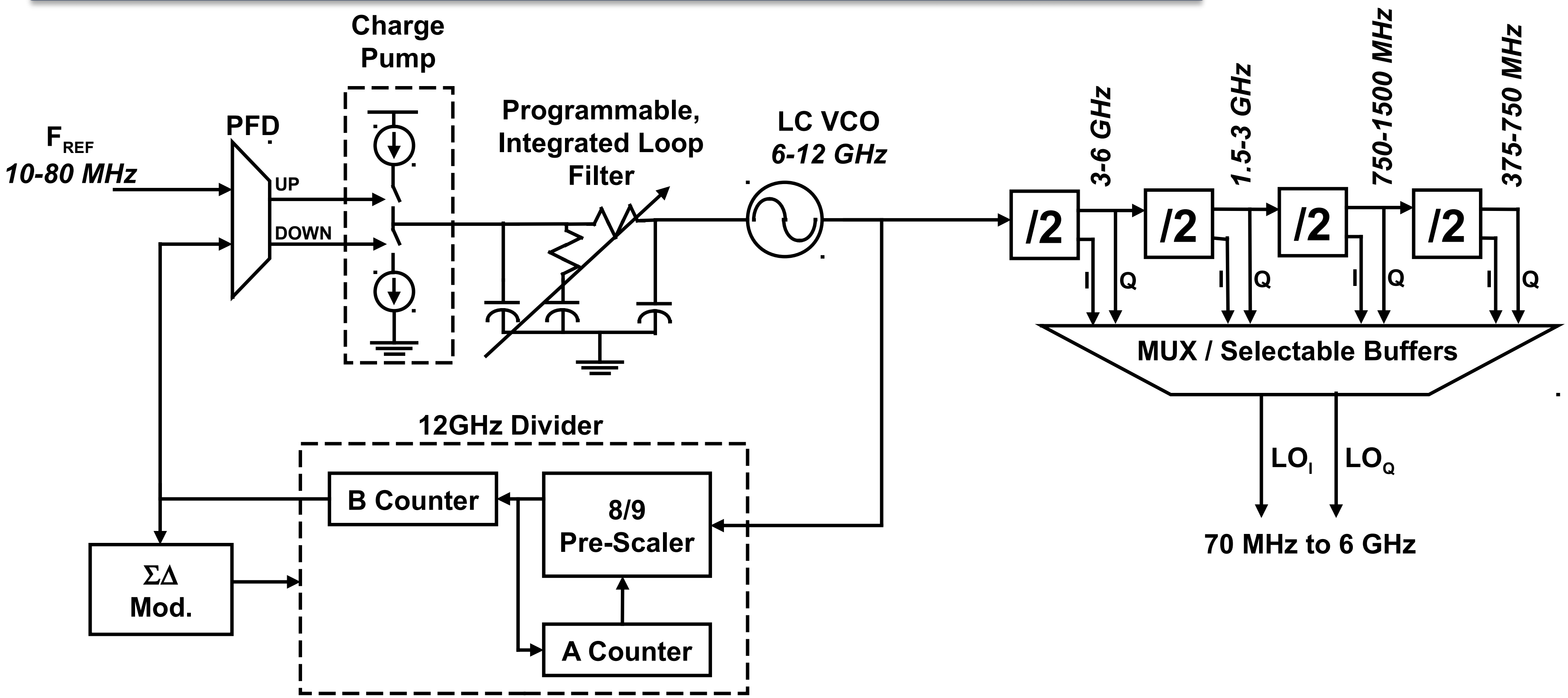
- **Major Blocks**
  - RX Gain (AGC)
  - Amp-TIA
  - Low Pass filter
  - Half Bands
  - Programmable FIR
  - Clock generation
  - ADC/DAC
  - Digital filters
  - RF PLL/LO
  - Digital interface
  - Enable state machine
  - TX Attenuation
  - Aux DAC/ADC and GPOs
  - Analog and Digital Correction/Calibration
- **AD9361: 2 Rx + 2 Tx**
- **AD9364: 1 Rx + 1 Tx**




AD9361
Rx Channel 2
Rx Channel 1
GPO
Automatic Gain Control
Manual
Slow
Fast
RxA
RxB
RxC
Tx Mon
Input Mux
LNA
Rx
Tx
Phase Splitter
TIA
RF Channel Bandwidth
200kHz - 56MHz (I/Q)
ADC
HB3
HB2
HB1
GAIN
FIR
÷1 ÷2 ÷3
÷1 ÷2
÷1 ÷2
÷1 ÷2 ÷4
I
Q
Rx Decimation
Digital Filtering and Equalization
Ch1 I/Q
Ch2 I/Q
1.3V
1.8V
3.3V
GND
70MHz - 6GHz
DCXO
DIV
Baseband
715 MHz - 1430 MHz
11.2 - 640 MSPS
Enable State Machine (ENSM)
Temperature Sensor
Calibration and Correction
Rx 61.44 MSPS
LOOP BACK
PN & BIST
Tx 61.44 MSPS
CMOS / LVDS INTERFACE
AUX DAC
Dual 10-bit
AUX ADC
12-bit
Tx Channel 2
Tx Channel 1
TxA
TxB
Output Mux
ATTN
DAC
320 MSPS
Tx Interpolation
Digital Filtering and Equalization
1x 2x 3x
1x 2x
1x 2x
1x 2x 4x
SPI
CTRL
Reset
ANALOG DEVICES

RF PLL and LO Generation

70MHz to 6GHz operation covers FM radio, ISM Bands, TV whitespace, 2G/3G/3G cellular, WiFi bands…. and everything in between!

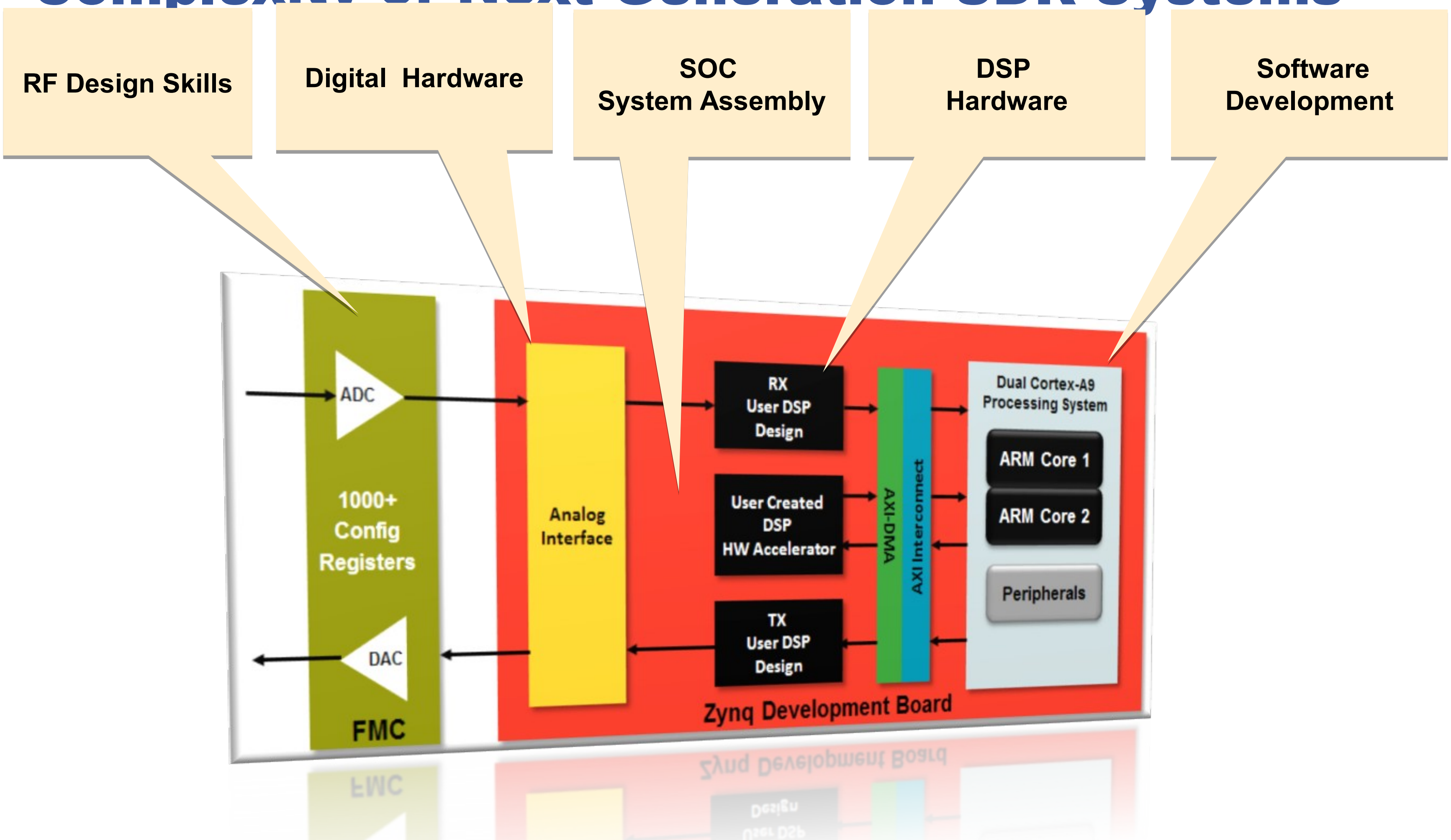


Applications for the AD9361 2x2 SW-Defined RF Transceiver IC

- Defense electronics
  - Radar, handheld and manpack battlefield radios
- RF test equipment and instrumentation
- Communications and telemetry equipment
- Communications infrastructure
  - Femtocell / picocell / microcell basestations, data card dongles
- General software-defined radio platforms

ANALOG DEVICES

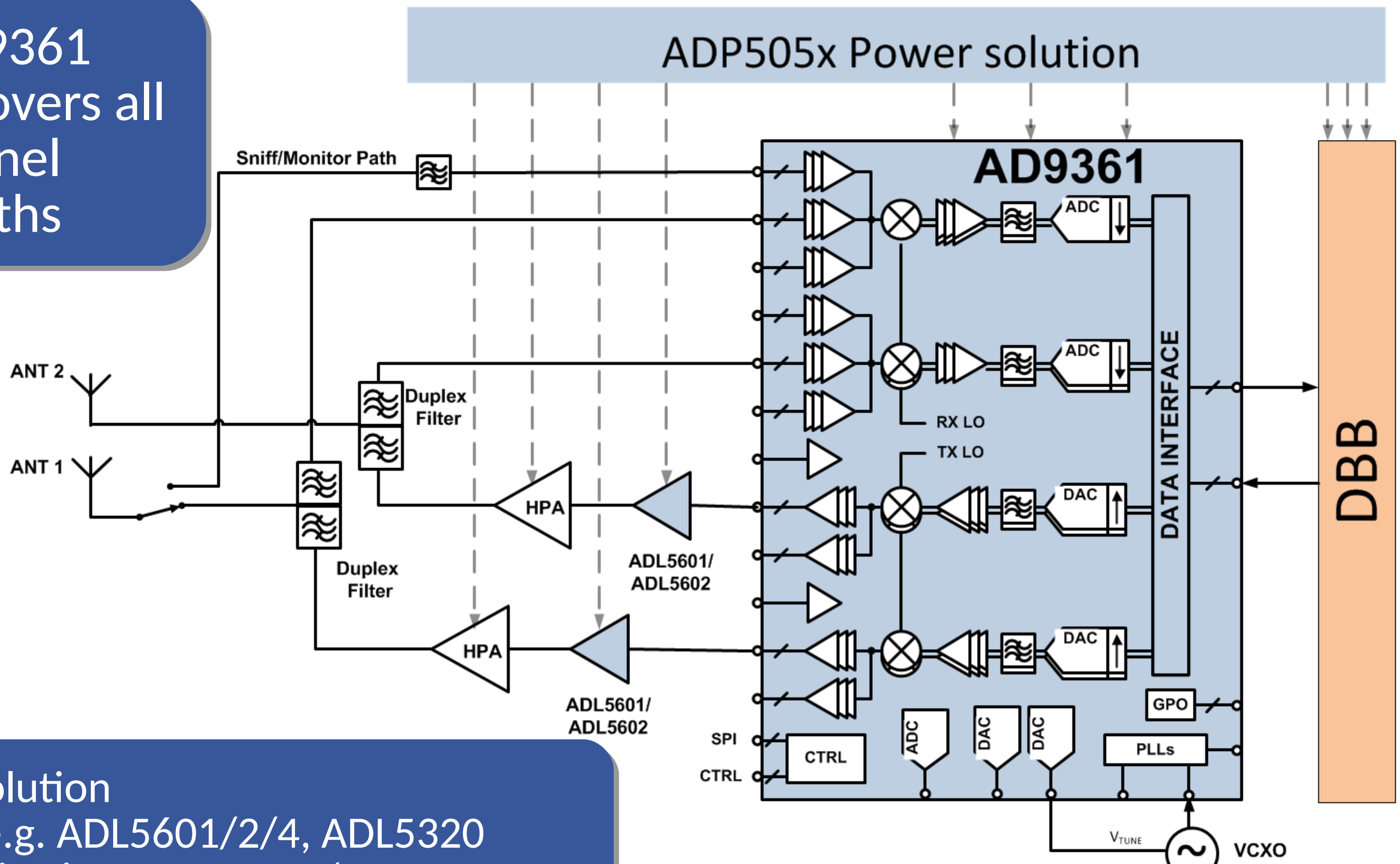
Complexity of Next Generation SDR Systems



Requires 5 different design skills to be successful
ADI references shows working example!

CIFR Application Example
2 x 2 MIMO LTE picoCell

Single AD9361 Transceiver covers all LTE channel bandwidths



ADP505x power solution
Linear Amplifiers e.g. ADL5601/2/4, ADL5320
LNAs in some applications: ADL5521/ADL5523

ANALOG DEVICES

AD9361 / AD9364 Support Model

- Buy AD-FMCOMMS2-EBZ for RF evaluation
  - AD9361 with narrow RF tuning range (optimized for 2.4GHz)
- Buy AD-FMCOMMS3-EBZ for rapid proto-typing
  - AD9361 with wide RF tuning range (70 MHz - 6GHz)
- Buy AD-FMCOMMS4-EBZ for either
  - AD9364 with narrow (2.4GHz) and wide ranges (70MHz - 6GHz)
- AD9361 Design Files

→ analog.com

- Application and Drivers for Linux and No-OS
  - Linux IIO: Linux Abstraction for Data Converters
- HDL
- PCB Schematics, Gerbers, BOM

→ wiki.analog.com

- Online support via EngineerZone
  - Wideband RF Transceiver Community
  - FPGA Reference Design Community
  - Linux and Microcontroller Devices Drivers Comm.

→ ez.analog.com

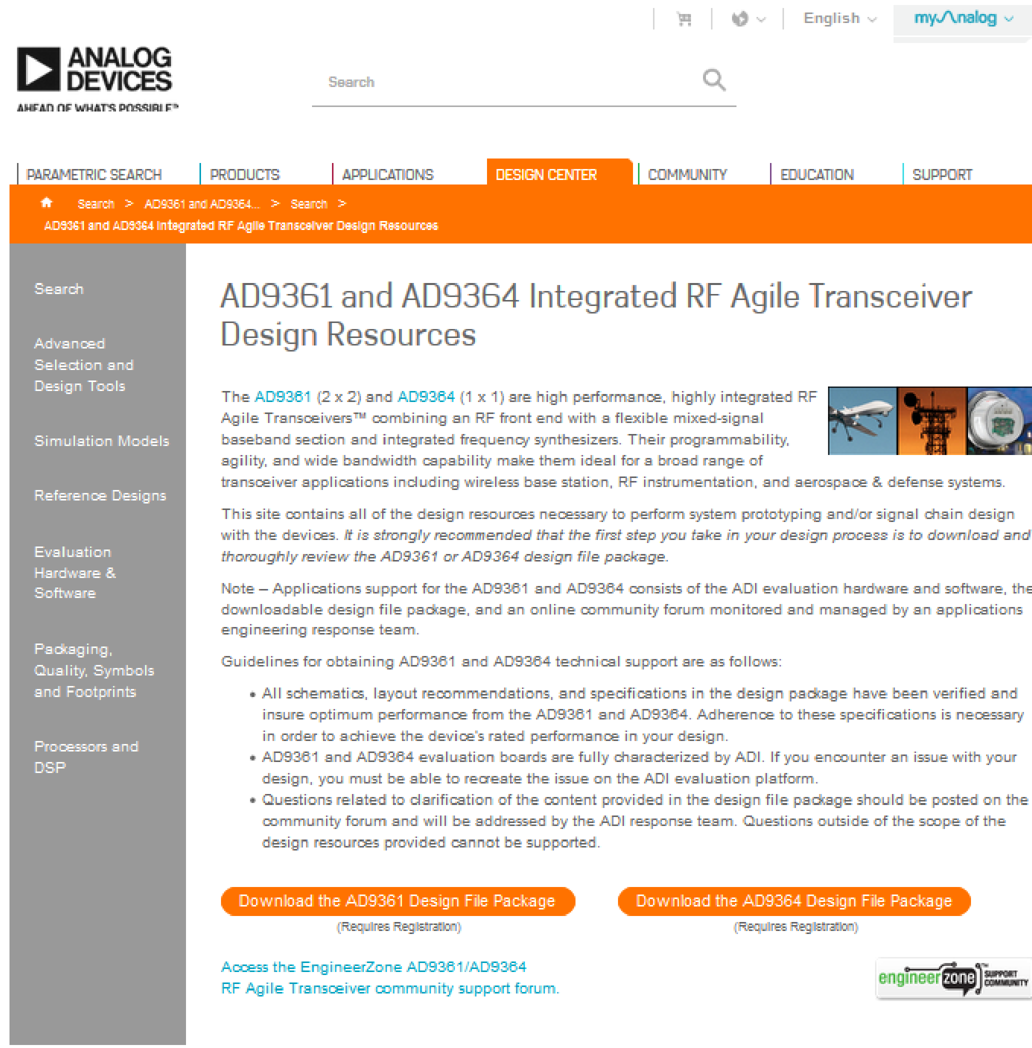
Design Files on

http://www.analog.com/en/design-center/landing-pages/001/ad9361-ad9364-integ-rf-agile-transceiver-design-res.html

Include details about the internal blocks and how to program them.

AD9361_Reference_Manual_UG-570.pdf
AD9361_Register_Map_Reference_Manual_UG-671.pdf

AD9364_Reference_Manual_UG-673.pdf
AD9364_Register_Map_Reference_Manual_UG-672.pdf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AHEAD OF WHAT'S POSSIBLE™
Search

PARAMETRIC SEARCH | PRODUCTS | APPLICATIONS | DESIGN CENTER | COMMUNITY | EDUCATION | SUPPORT

Search > AD9361 and AD9364... > Search >
AD9361 and AD9364 Integrated RF Agile Transceiver Design Resources

Search
Advanced Selection and Design Tools
Simulation Models
Reference Designs
Evaluation Hardware & Software
Packaging, Quality, Symbols and Footprints
Processors and DSP

AD9361 and AD9364 Integrated RF Agile Transceiver Design Resources

The AD9361 (2 x 2) and AD9364 (1 x 1) are high performance, highly integrated RF Agile Transceivers™ combining an RF front end with a flexible mixed-signal baseband section and integrated frequency synthesizers. Their programmability, agility, and wide bandwidth capability make them ideal for a broad range of transceiver applications including wireless base station, RF instrumentation, and aerospace & defense systems.

This site contains all of the design resources necessary to perform system prototyping and/or signal chain design with the devices. *It is strongly recommended that the first step you take in your design process is to download and thoroughly review the AD9361 or AD9364 design file package.*

Note – Applications support for the AD9361 and AD9364 consists of the ADI evaluation hardware and software, the downloadable design file package, and an online community forum monitored and managed by an applications engineering response team.

Guidelines for obtaining AD9361 and AD9364 technical support are as follows:

- All schematics, layout recommendations, and specifications in the design package have been verified and insure optimum performance from the AD9361 and AD9364. Adherence to these specifications is necessary in order to achieve the device's rated performance in your design.
- AD9361 and AD9364 evaluation boards are fully characterized by ADI. If you encounter an issue with your design, you must be able to recreate the issue on the ADI evaluation platform.
- Questions related to clarification of the content provided in the design file package should be posted on the community forum and will be addressed by the ADI response team. Questions outside of the scope of the design resources provided cannot be supported.

Download the AD9361 Design File Package
(Requires Registration)

Download the AD9364 Design File Package
(Requires Registration)

Access the EngineerZone AD9361/AD9364 RF Agile Transceiver community support forum.

engineer zone SUPPORT COMMUNITY

Rapid Proto-typing/Demo with AD-FMCOMMS[234]-EBZ

- **Hardware FMC cards**
  - **AD-FMCOMMS2-EBZ (AD9361)**
    - Narrow RF Tuning Range
  - **AD-FMCOMMS3-EBZ (AD9361)**
    - Wide RF Tuning Range
  - **AD-FMCOMMS4-EBZ (AD9364)**
- **FPGA Boards**
  - **Xilinx Zynq based**
    - ZC706 (shown), ZC702,
    - Zedboard
  - **Xilinx Kintex**
    - (KC705)
    - Virtex (VC707)
- **Software**
  - **Device drivers**
    - Linux and/or No-OS
  - **FPGA HDL**
  - **IIO scope**
    - Data visualization application
    - Graphical configuration application

- **SD-Card (Demo)**
  - **8GB with SDR Immage on it**
  - **Linux + IIO Scope**

Linux Support for Xilinx FPGA Hard and Soft Cores

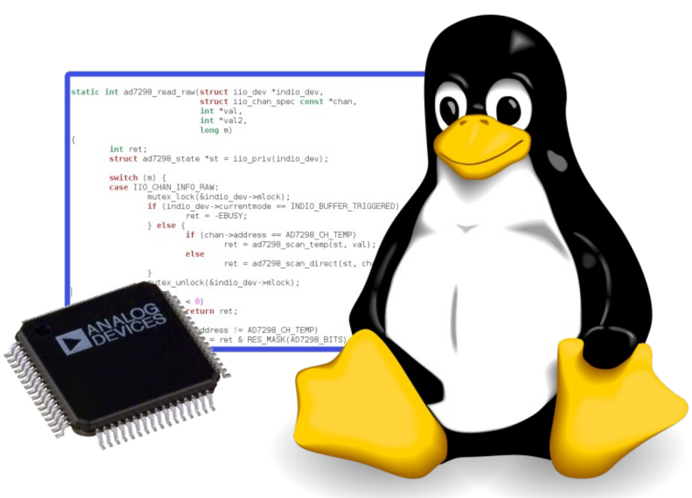
- **FPGA Hard Core:**
  - **Zynq**
    - Dual core **ARM Cortex**™-A9
  - **PowerPC (PPC)**
- **Pros**
  - **Avoids extra co-processor**
  - **Fast data exchange between FPGA and CPU**
  - **Less power, board space, and system cost**
- **Cons:**
  - **May require external memory**

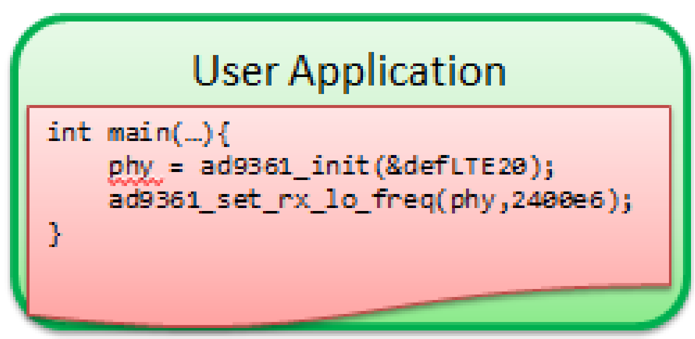
- **FPGA Soft Core:**
  - **Microblaze**
- **Pros**
  - **Avoids extra co-processor**
  - **Fast data exchange between FPGA and CPU**
  - **A soft core can be customized to meet system demands**
- **Cons:**
  - **Requires some extra gates and external memory**
  - **May not be as fast as a hard core**
  - **Power consumption**

Linux is an ideal OS and a significant part of the ecosystem for FPGA hard and soft cores

Device Drivers on Wiki

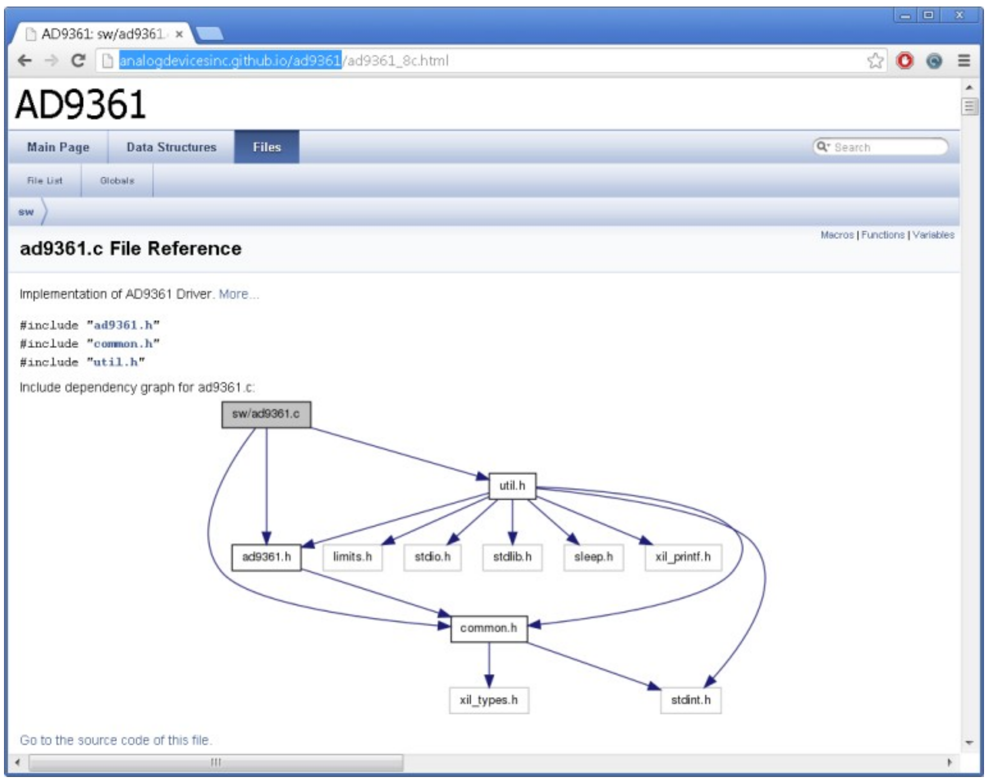
- **Linux**
  - Released under GPL license
  - High Level API
  - Easy interface to various high level programming languages: C++, Python, Shell, etc.
- **No-OS**
  - Released under BSD type license
  - No-OS device drivers are purely written in C and feature an Hardware abstraction layer (HAL)
  - Similar feature set as Linux device driver

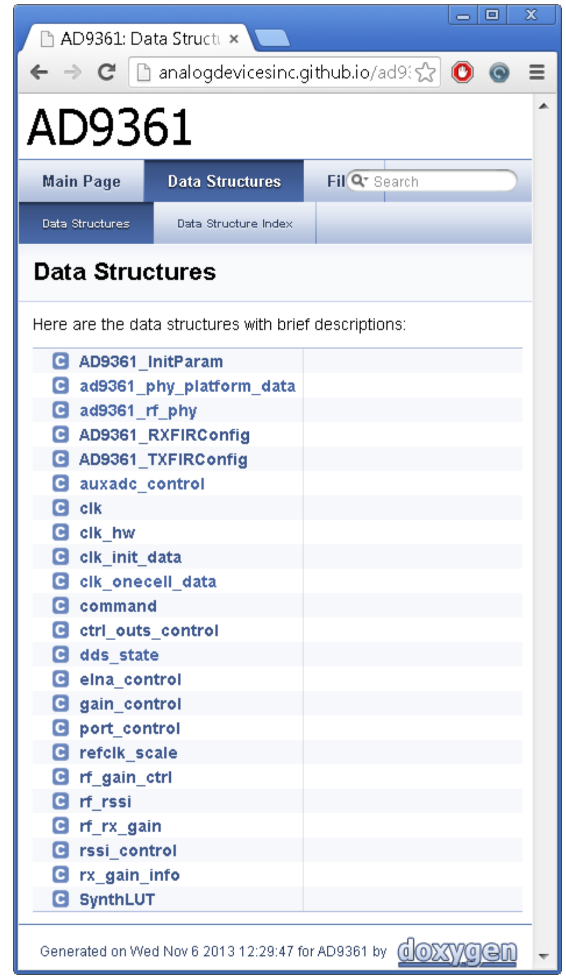




Device Driver Documentation/Description

- Doxygen files for no-os code
  - http://analogdevicesinc.github.io/ad9361

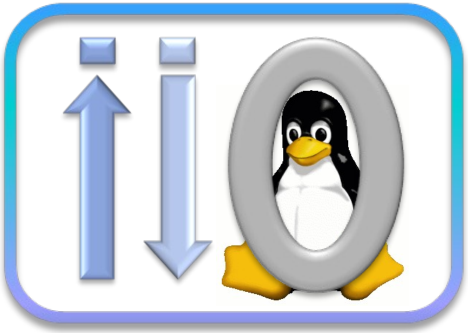




ANALOG DEVICES

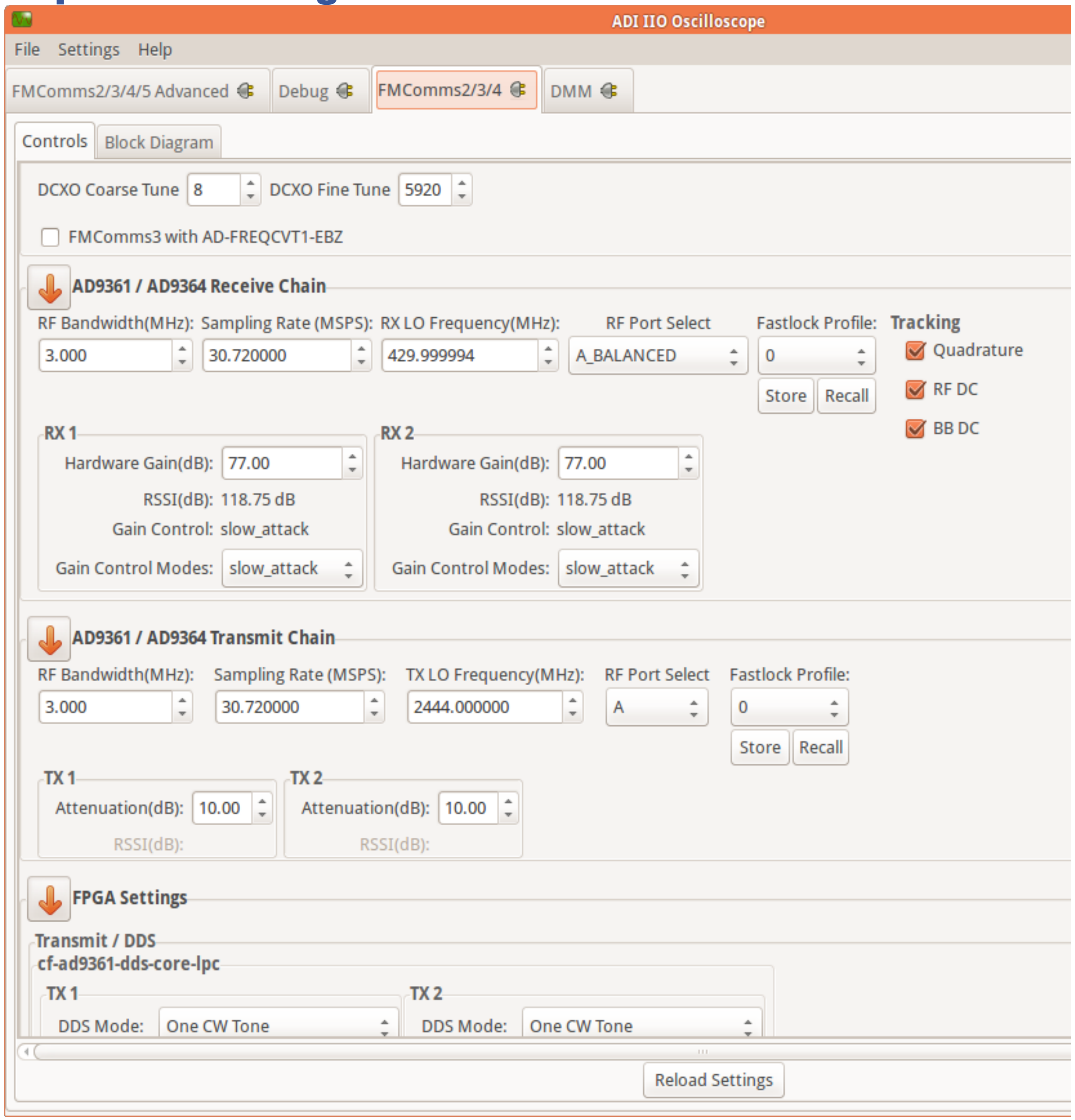
IIO: A New(er) Kernel Subsystem for Converters

- The Linux Industrial I/O (IIO) subsystem is intended to provide support for devices that, in some sense, are analog-to-digital or digital-to-analog converters
  - Devices that fall into this category are:
    - ADCs
    - DACs
    - Accelerometers, gyros, IMUs
    - Capacitance-to-Digital converters (CDCs)
    - Pressure, temperature, and light sensors, etc.
    - RF Transceivers (like the AD9361/AD9364)
  - Can be used on ADCs ranging from a 1MSPS SoC ADC to >250 MSPS industrial ADCs
  - Developed during 2009, committed Jan 2010, moved out of staging Nov 2011, now in all mainline Linux kernels.



IIO Scope : Understands AD9361 / AD9364

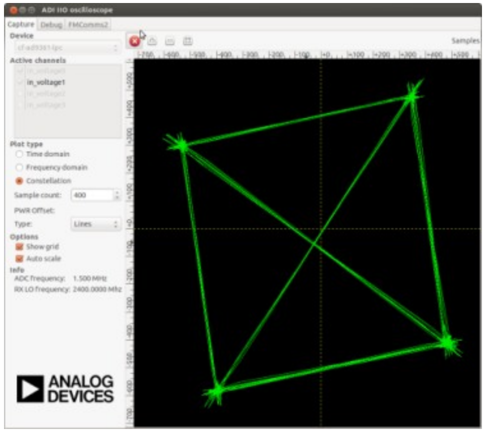
http://wiki.analog.com/resources/tools-software/linux-software/fmcomms2_plugin

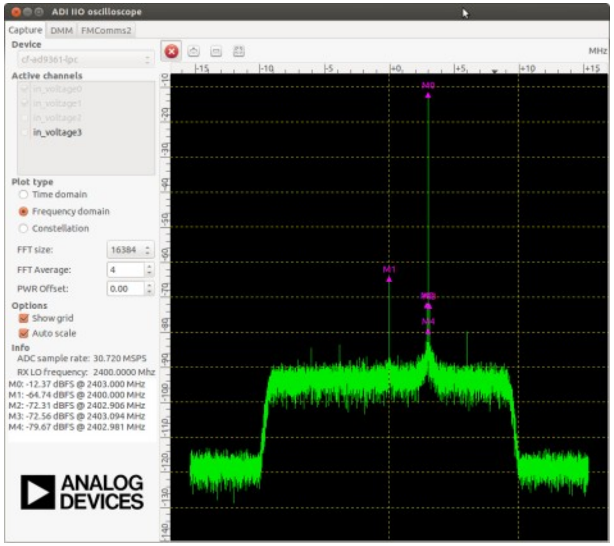


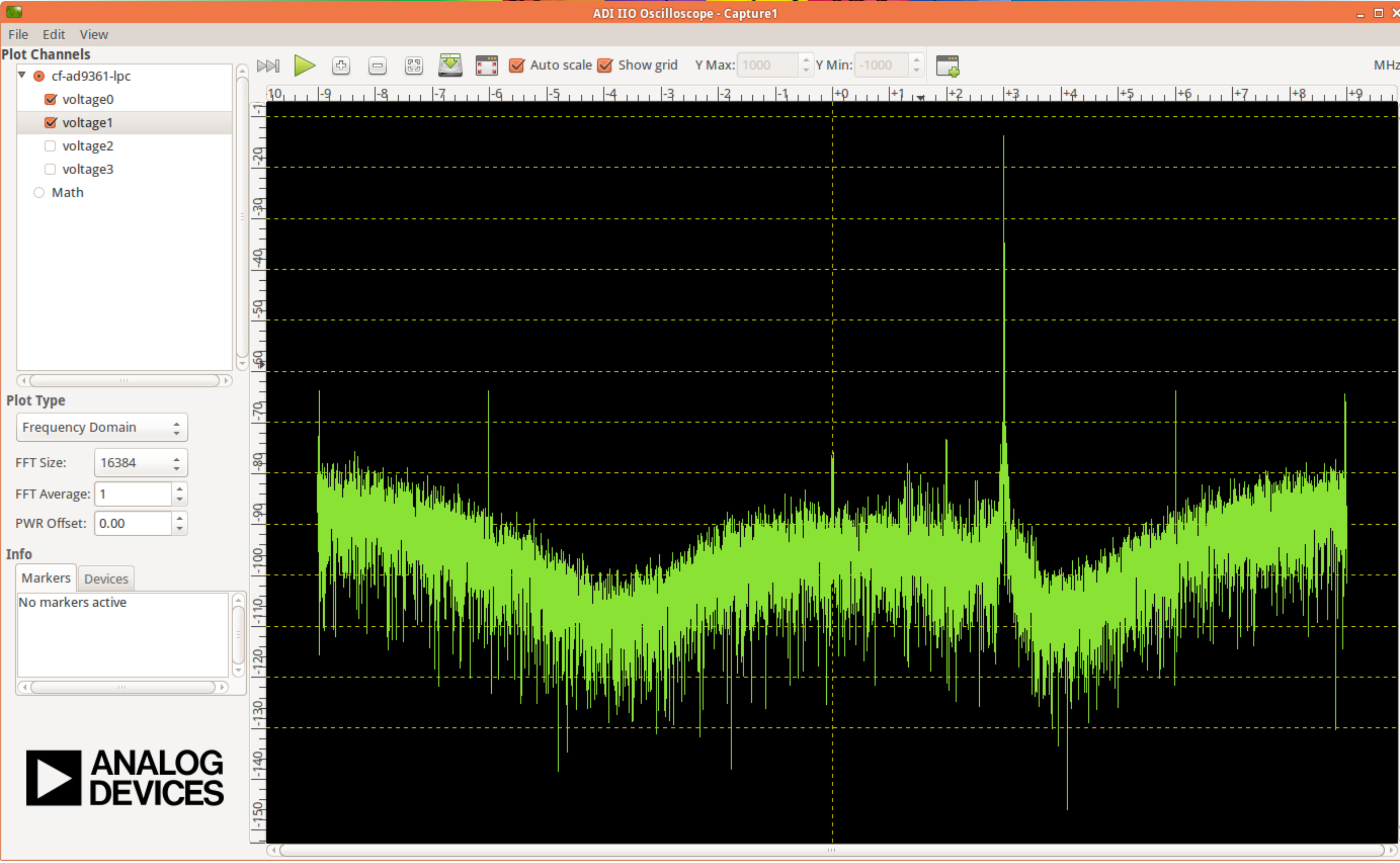
- **Configure and Control**
  - Rx/Tx LO frequency
  - TRX control
  - Rx/Tx Sampling Rates
  - RF Bandwidths analog and digital filters
  - Gain and AGC modes
  - Quadrature and DC tracking control
- **Monitor**
  - Gain
  - RSSI
  - Etc.

IIO Scope for Real Time Data Visualization

- **Runs directly on Xilinx Zynq**
  - **HDMI monitor, USB Keyboard/Mouse**
- **Visualize data:**
  - **Frequency**
    - simple and complex FFT
  - **Time Domain**
  - **Constellation (I vs Q)**
- **Capture data:**
  - **Save sequences to file**
  - **Supports different formats**
- **Drive data:**
  - **Dual tone polyphase DDS**
  - **Arbitrary Waveforms and Sample files**

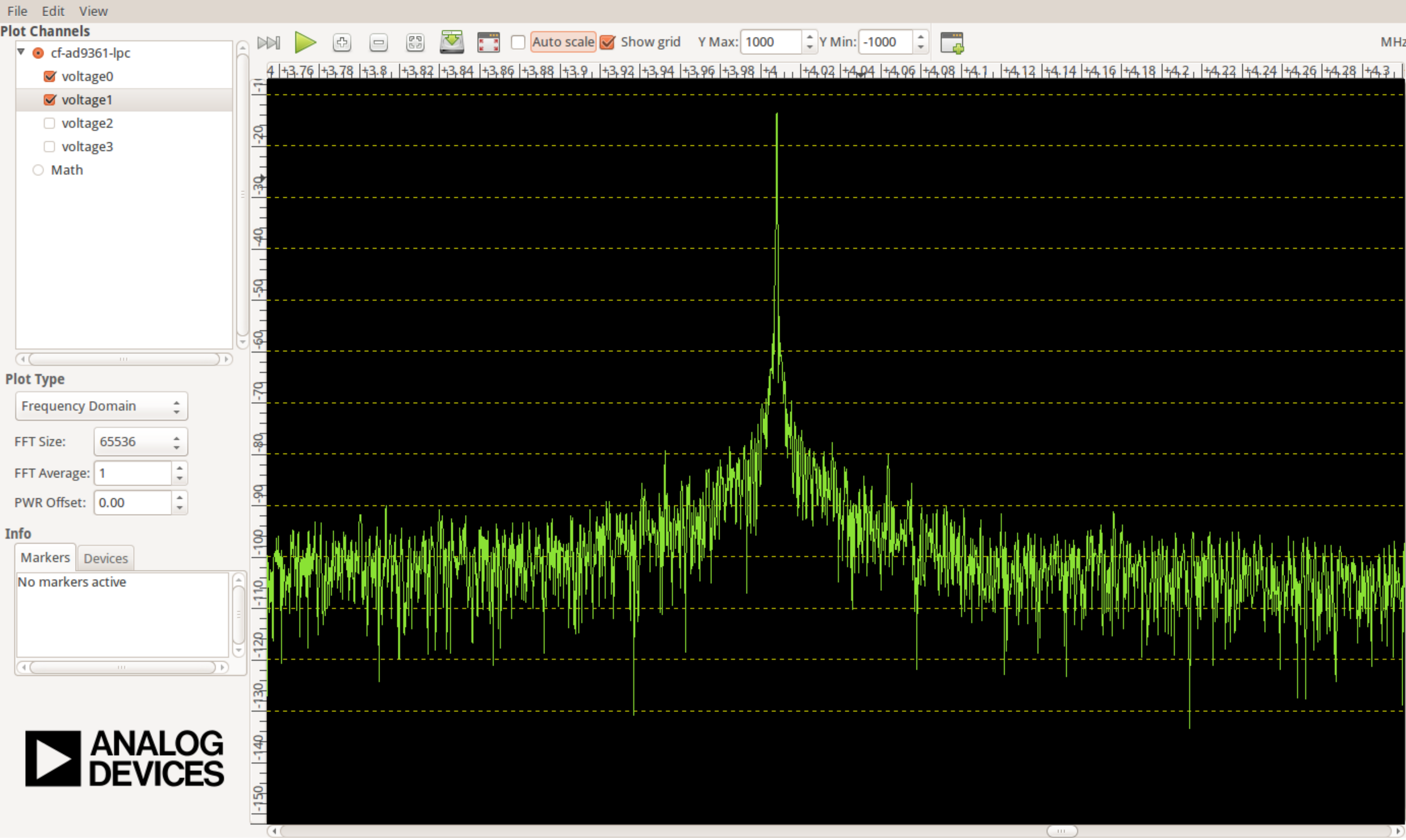






Spectrum of a 434.000MHz Carrier

ANALOG DEVICES



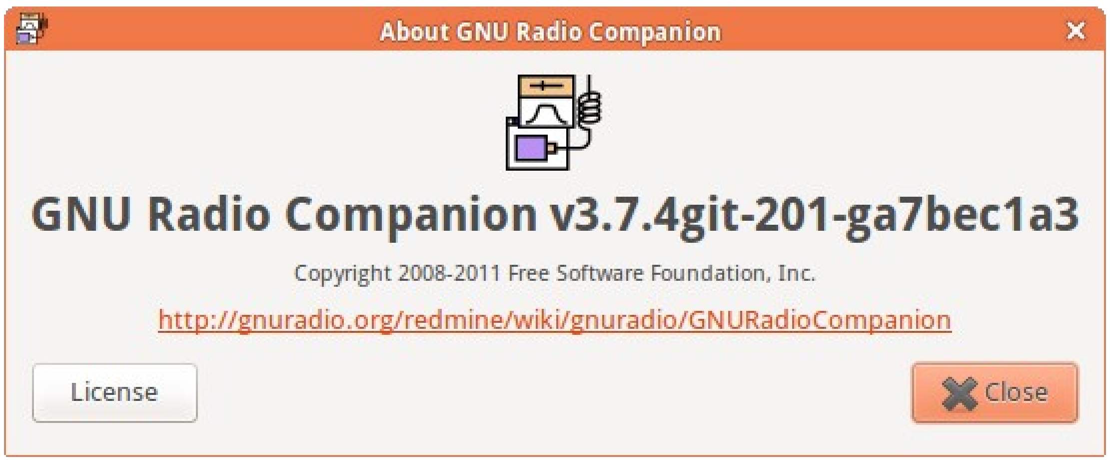
Zoomed in Spectrum

GNU Radio

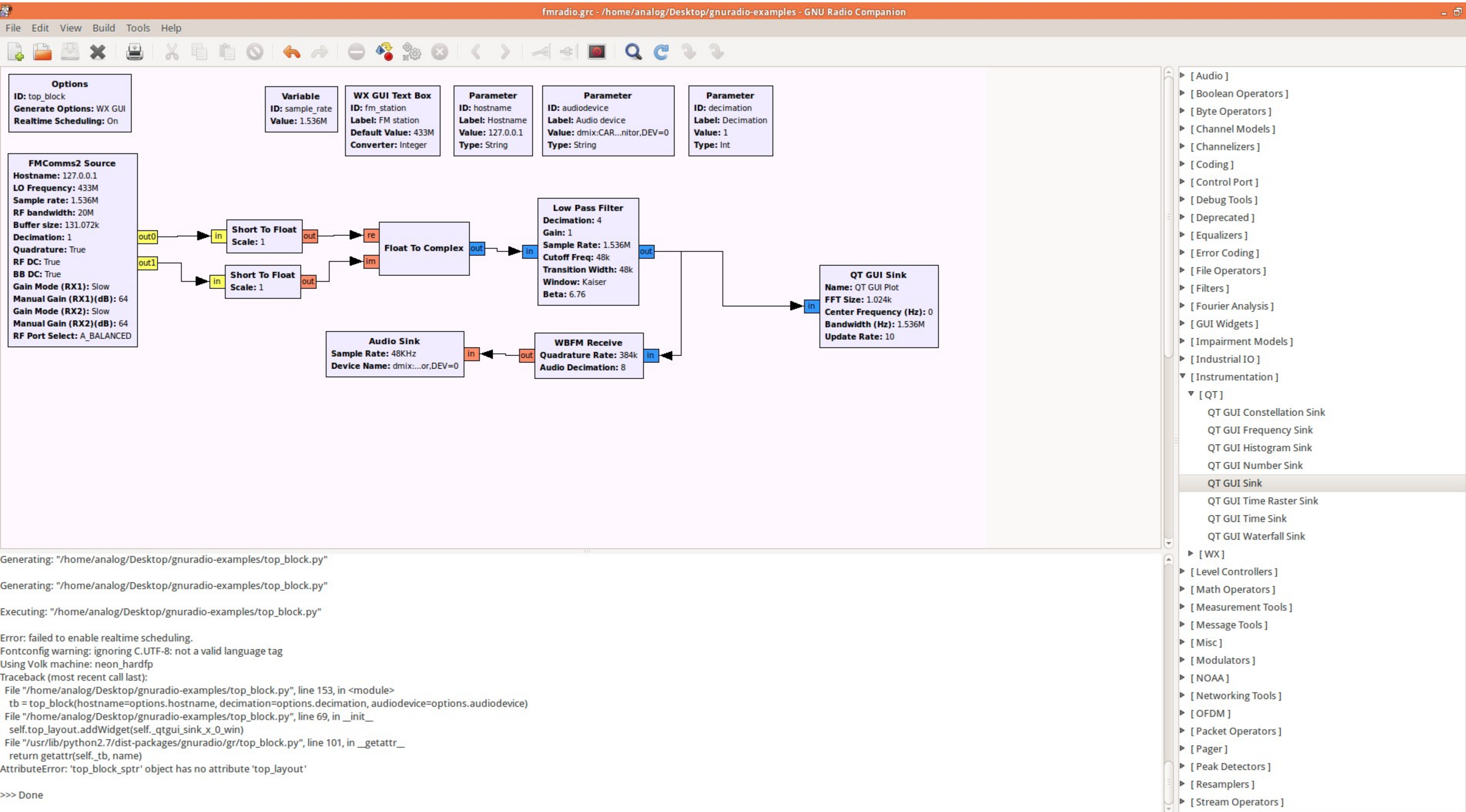
http://wiki.analog.com/resources/tools-software/linux-software/gnuradio

GnuRadio

GnuRadio comes pre-installed on the SD card image that ships with the AD-FMCOMMS2-EBZ, AD-FMCOMMS3-EBZ, AD-FMCOMMS4-EBZ, ARRADIOand AD-FMCOMMS5-EBZ, as well as the FMCOMMS-2 IIO blocks. GnuRadio can also be compiled for a host PC.

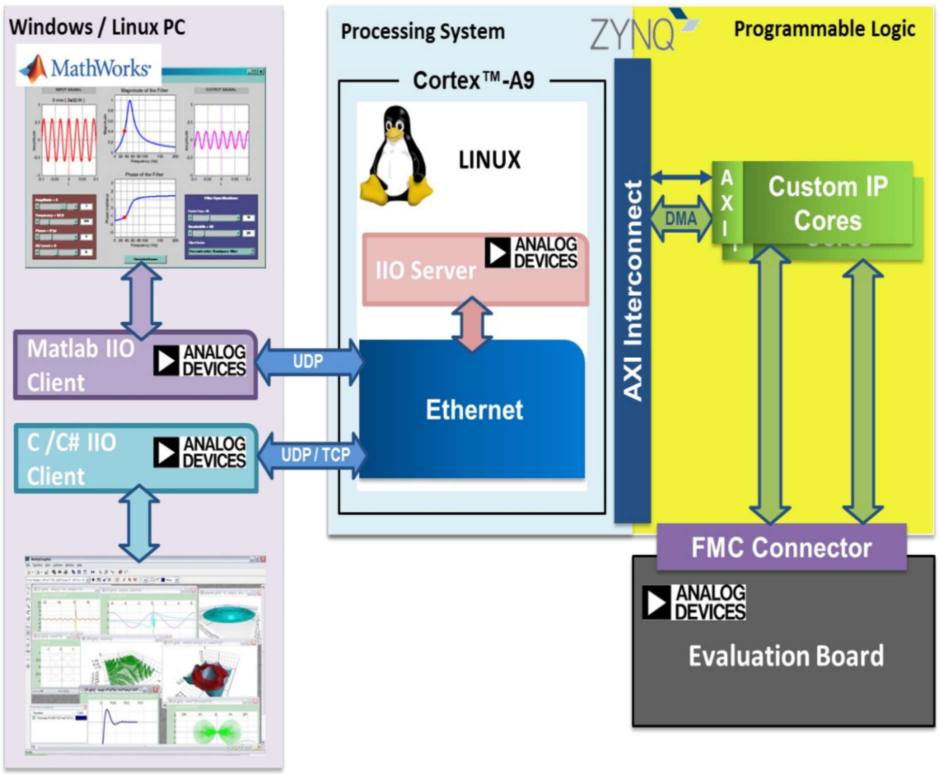


GNU Radio GUI



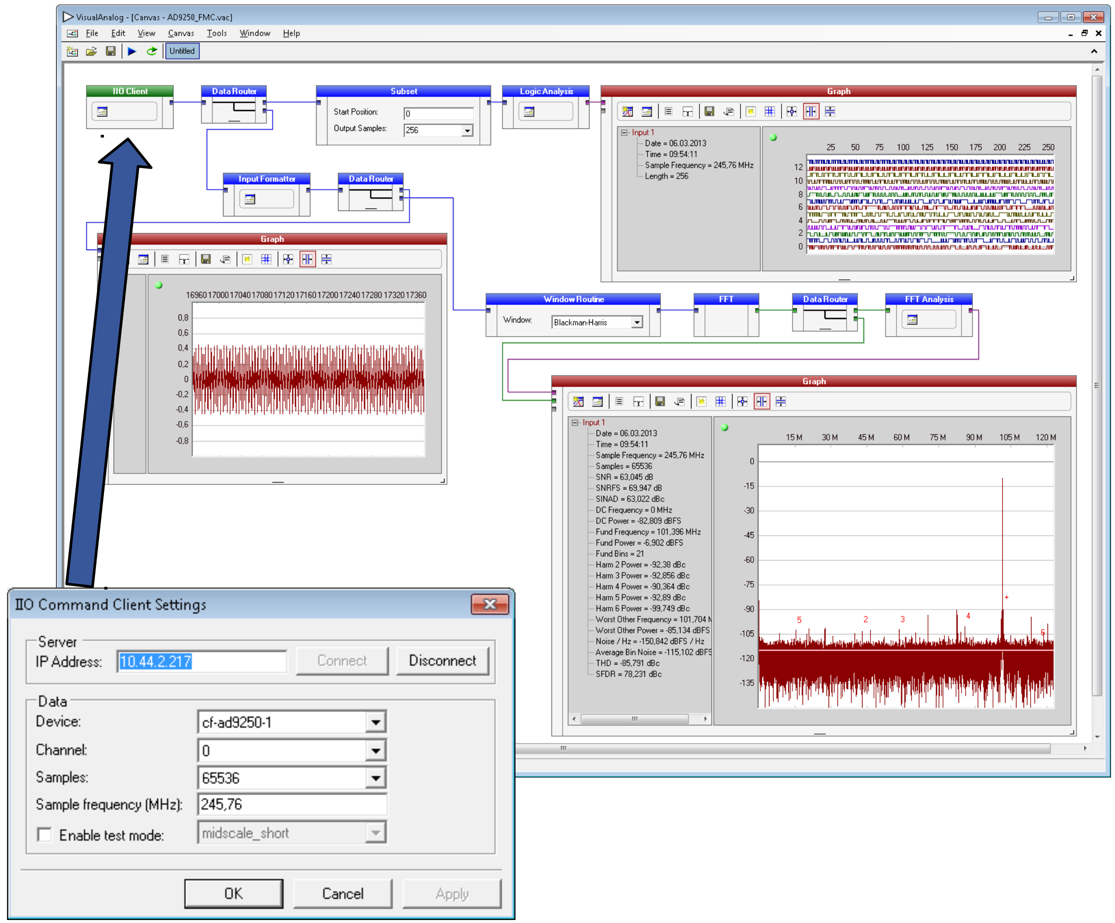
IIO Server/Client

- **ADI IIO Command Server**
  - Runs on and embedded target under Linux
  - Manages real-time data exchange over TCP or UDP between the target and a remote client
  - Data Exchange is based on a simple communication protocol
- **Matlab IIO Client**
  - Implements the communication protocol with the IIO Server
  - Based on the UDPReceiver / UDPSender classes from the Mathworks DSP toolbox
  - Controls the embedded target using specific commands
  - Acquires real-time data from the embedded target
- **C Client**
  - Generic C source
- **C# Client**
  - C# source
- **Visual Analog Client**
  - Visual Analog



Data to VisualAnalog

- **VisualAnalog™ is a software package that combines a powerful set of simulation, product evaluation, and data analysis tools with a user-friendly graphical interface**
- **Measure and visualize**
  - **SNR, SFDR, THD, power, etc.**
- **IIO command client**
  - Control Linux IIO device drivers and capture data via a TCP network connection



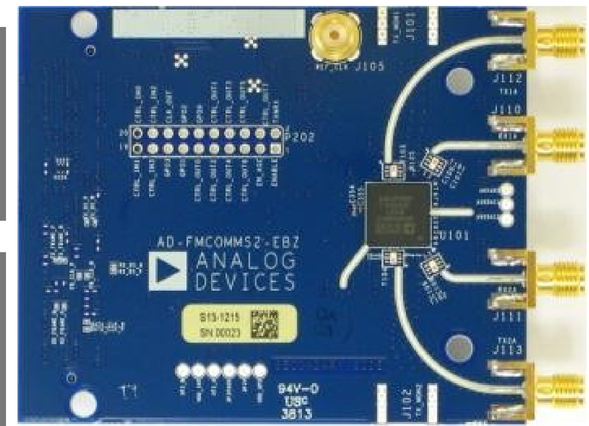
Next Steps to get it working

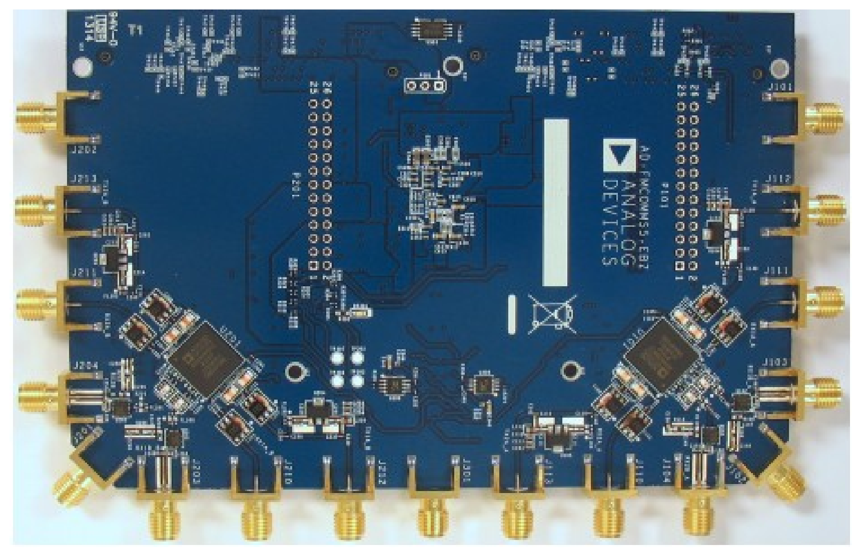
- **Get the AD-FMCOMMS[234]-EBZ Board (self assemble your own kit)**
  - SD-CARD to boot Linux is part of the FMCOMMSx Eval.board
- **Or buy the Avnet Kit**
- **Avnet ZedBoard 7020 baseboard**
  - Xilinx ISE® WebPACK software with a device locked ChipScope license (device locked to XC7Z020)
  - Analog Devices AD-FMCOMMS[1234]-EBZ FMC module
  - Linux drivers, applications software, HDL source, reference designs, full schematics, and Gerbers
  - Two pulse LTE blade antennas (2500 MHz to 2700 MHz)
  - 8 GB SD card (comes with AD-FMCOMMSx Cards)
  - Fan assembly, antenna, screws, and standoffs
- **Ask questions on the EngineerZone**
  - http://ez.analog.com/community/fpga
- **Check out the Wiki**
  - http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms1-ebz or
  - http://www.analog.com/en/evaluation/eval-ad-fmcomms2/eb.html

Summary

- **Orderable!**

AD9361	1ku: US$175
AD9364	1ku: US$130
AD-FMCOMMS2-EZB	$750
AD-FMCOMMS3-EBZ	$750
AD-FMCOMMS4-EBZ	$399
AD-FMCOMMS5-EBZ	$1125 (prelim.)





- **Comprehensive Online Customer Support for all AD9361 and AD9364 reference boards and software on EZ.**

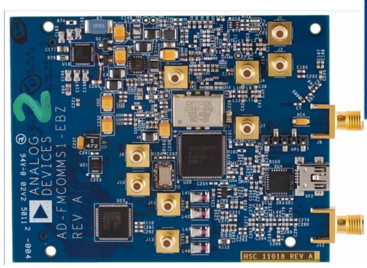
ADI General Purpose SDR Boards

Discrete Version

Narrow band

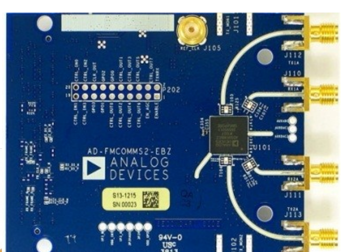
Wide tuning Range

AD-FMCOMMS1
- Discrete
- 1Rx, 1Tx
- 400 MHz – 4GHz tuning range
- 200+ MHz channel bandwidth
- Available Now



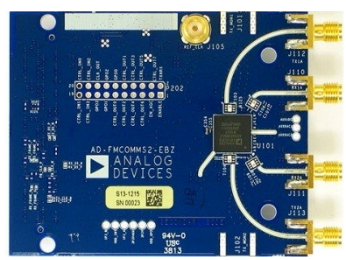
Power, Clocks, ADC, DAC, PLL, DVGA,

AD-FMCOMMS2
- AD9361 Integrated
- 2 x Rx, 2 x Tx
- 2.2 GHz – 2.6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Available Now



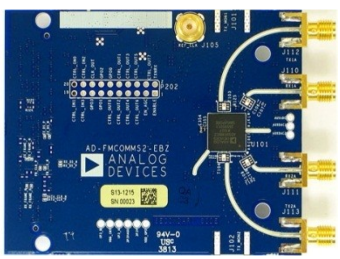
Power, Transceiver

AD-FMCOMMS3
- AD9361 Integrated
- 2 x Rx, 2 x Tx
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Available Now



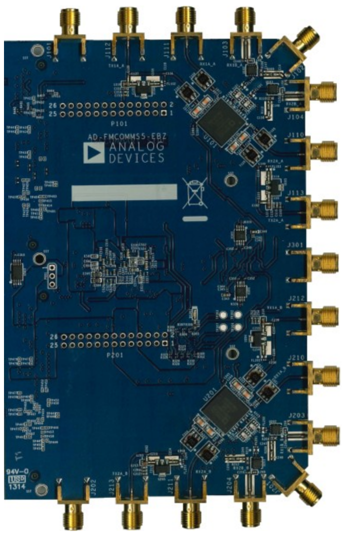
Power, Transceiver

AD-FMCOMMS4
- AD9364 Integrated
- 1 x Rx, 1 x Tx
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Available Now

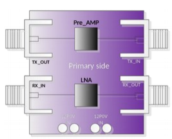


Power, Transceiver

AD-FMCOMMS5
- 2 x AD9361 Integrated
- 4 x Rx, 4 x Tx
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Releasing Aug 2014



Power, Transceiver, PLL, LNA



FMC COMMS BOOSTER
- Rx LNA (ADL5521)
- Tx Pre-Amp (ADL5610)
- Power (ADP2370, ADP7104)
- Releasing July 2014

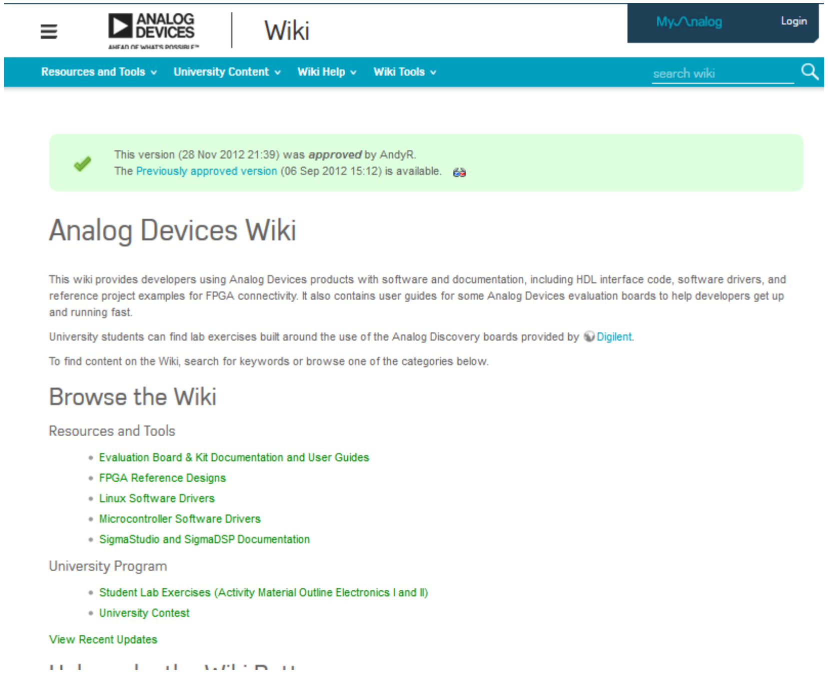
ANALOG DEVICES

ONLINE TECHNICAL SUPPORT AND DOCUMENTATION

Analog Devices Wiki

- **This Wiki provides developers using Analog Devices products with:**
  - Software and documentation
  - HDL interface code
  - Software device drivers
  - Reference project examples for FPGA connectivity
- **It also contains user guides for some Analog Devices evaluation boards to help developers get up and running fast**

- **http://wiki.analog.com/**



This version (03 Mar 2015 20:32) was *approved* by rgetz.
The Previously approved version (03 Mar 2015 20:26) is available.

AD-FMCOMMS2-EBZ User Guide

Table of Contents

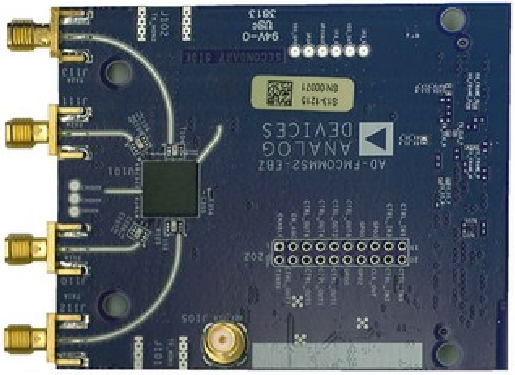
The AD-FMComms2-EBZ is an FMC board for the AD9361, a highly integrated RF Agile Transceiver™. While the complete chip level design package can be found on the the ADI web site. Information on the card, and how to use it, the design package that surrounds it, and the software which can make it work, can be found here.

The purpose of the AD-FMComms2-EBZ is to provide an RF platform to which shows maximum performance of the AD9361. It's expected that the RF performance of this platform can meet the datasheet specifications without issues at 2.4 GHz, and not much anywhere else. This is due to the external Johanson Technology's 2450BL15B050E 2.45 GHz Balun that is on the board. This balun is rated for a operating frequency of 2400~2500 MHz.

This platform is primarily for hardware / RF investigation and bring up of various waveforms from a RF team before their custom hardware is complete, where they want to see waveforms at their frequency of interest, and are not afraid of changing out the balun if necessary. (Have a look in the Configuration sections).

The AD-FMComms2-EBZ board is very similar to the AD-FMComms3-EBZ board with only one exception, the RX/TX RF differential to single ended balun/transformer. The AD-FMComms3-EBZ is more targetted for wider tuning range applications, that is why we use the TCM1-63AX+ from mini Circuits as the RF transformer of choice. We affectionately call the FMCOMMS3-EBZ the "Software Engineers" platform, and the FMCOMMS2-EBZ, the "RF Engineers" platform to denote the difference.

Table of Contents



People who follow the flow that is outlined, have a much better experience with things. However, like many things, documentation is never as complete as it should be. If you have any questions, feel free to ask.

1. Introduction
2. Hardware: This provides a brief description of the board by itself, and is a good reference for those who want to understand a little more about the board. If you just want to use the board, you can skip this section, and come back to it when you want to incorporate the AD9361 into your product.
   1. Hardware (including schematics)
      1. Functional Overview & Specifications
      2. Characteristics & Performance

http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms3-ebz

Community Support http://ez.analog.com

- Three Very Active Communities
  - **FPGA Reference Designs**
    - 804+ discussions *
  - **Wide Band RF Transceivers**
    - 283+ discussions *
  - **Linux Drivers**
    - 326+ discussions *
- Support a variety of questions
  - **FPGA on FPGA Reference Designs Community**
  - **AD9361 on Wide Band RF Transceivers Community**
  - **Software on Linux Drivers Community**

* Values per July 30.2014

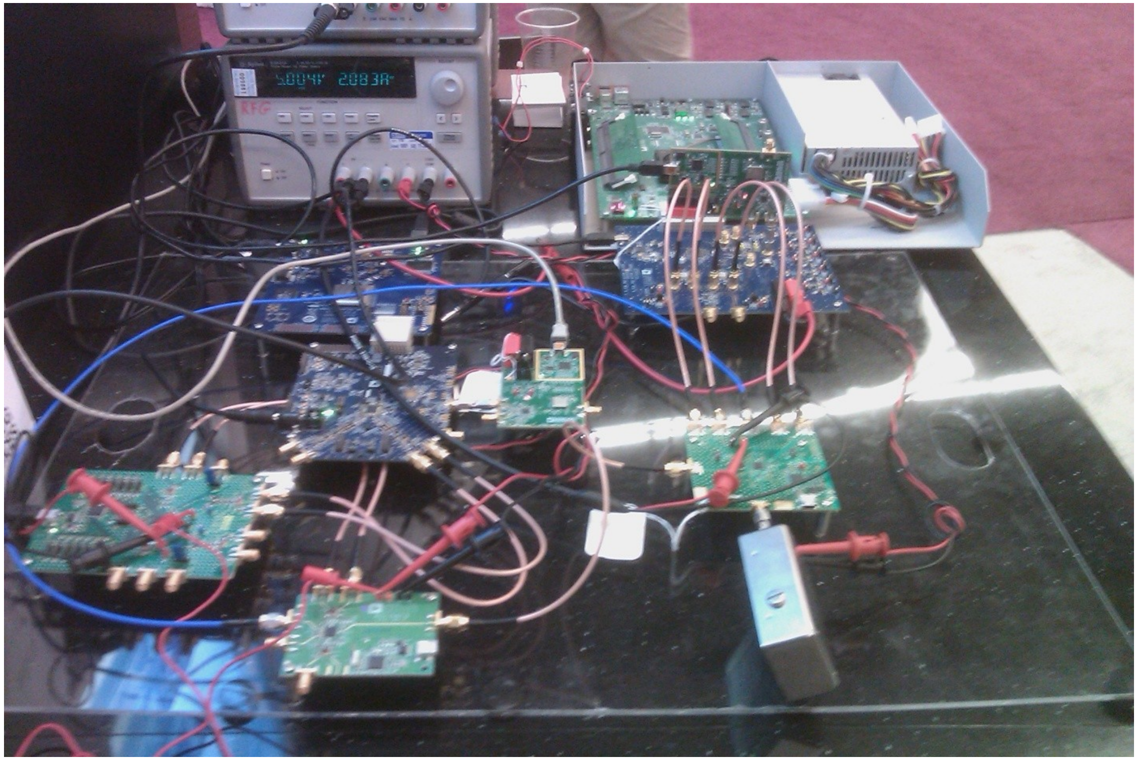
Steps for using Filter Design Wizard & Matlab

1. Download the Filter Design wizard http://www.mathworks.com/matlabcentral/fileexchange/45843-ad9361-filter-design-wizard
2. Instructions are at the ADI wiki http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms2-ebz/software/filters
3. Request a MATLAB trial license from Mathworks website http://www.mathworks.com/products/dsp-system/
4. Refer to webinar: Digital Filter Design Made Easy http://www.mathworks.com/videos/digital-filter-design-made-easy-81883.html

DEMO SETUP EXPLAINED

Traditional RF Evaluation Platforms (Antenna to Bits)

- Discrete single product evaluation boards, connected with wires
- 6 power supplies
- 4 different USB applications
- Not easy to replicate, or use as part of a SDR prototyping solution
- Needed small form factor, open design



ANALOG DEVICES

Reference Designs

- **HDL:**
  - **ML605 (Microblaze)**
  - **KC705 (Microblaze)**
  - **VC707 (Microblaze)**
  - **ZC702 (ARM)**
  - **ZC706 (ARM)**
  - **Zed Board (ARM)**

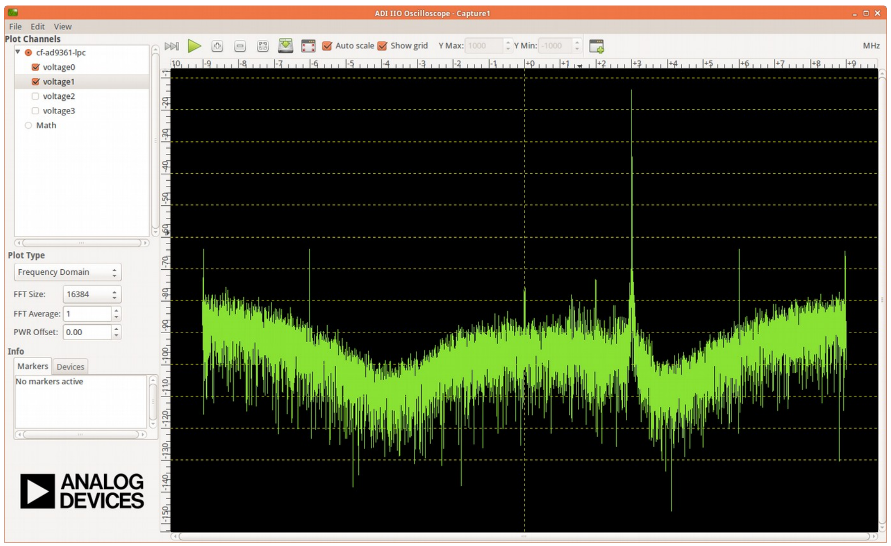
Lowest Cost FPGA Eval.Bd.
Get it from Xilinx or AVNET

- **Software:**
  - **Linux for FMCOMMS1**
    - Recommended solution
    - Drivers for all programmable parts (AD9122, AD9548, AD9523-1, ADF4351, AD9643, AD8366)
    - Streams data over network for Microblaze platforms
    - GTK+ based application for ARM based platforms
  - **No-OS**
    - Basic drivers

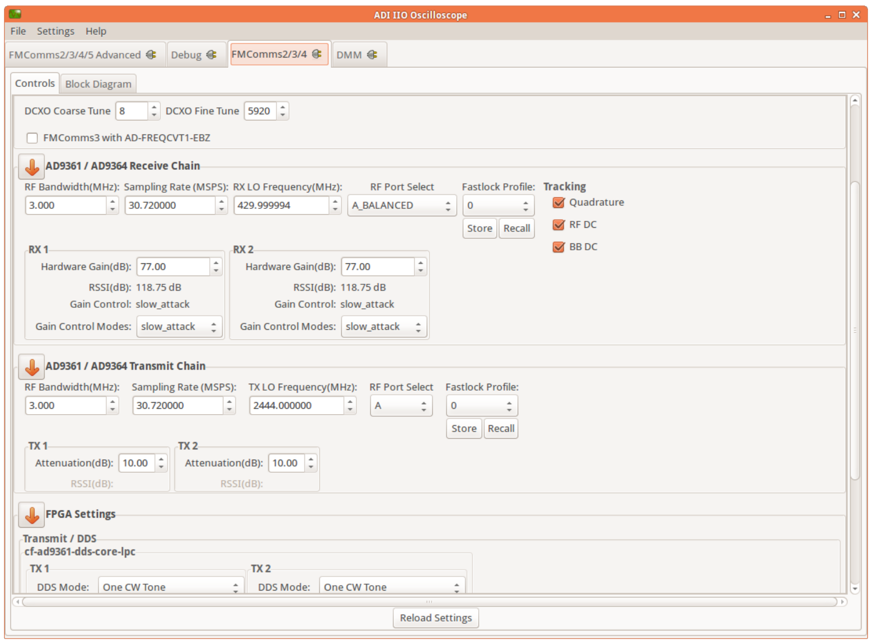
http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms1-ebz/reference_hdl

Goal: Run IIO Scope Linux Application

- Visualize Data:



- Control Things from GUI:



Boards

- **Supportet Carrier Boards**
  - **http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms2-ebz/reference_hdl**
    - AD-FMCOMM2,3,4,5,
    - ZC702, ZC706, ZED BOARD, (KC-705, VC707)
  - http://www.zedboard.org/ ← Lowest cost entry model for evaluation purpose
  - http://www.xilinx.com/products/boards-and-kits/EK-Z7-ZC706-G.htm
- **Wiki site for AD-FMCOMMS2-EB**
  - **http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms2-ebz**
- **Wiki site for AD-FMCOMMS3-EB**
  - **http://wiki.analog.com/resources/eval/user-guides/ad-fmcomms3-ebz**
- **Xilinx FPGA Boards**

Setup/Upgrade

GNU RADIO

http://wiki.analog.com/resources/tools-software/linux-software/gnuradio#gnuradio

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This version (25 Mar 2015 15:41) was *approved* by rgetz.
The Previously approved version (17 Nov 2014 15:33) is available.

GnuRadio

GnuRadio comes pre-installed on the SD card image that ships with the AD-FMCOMMS2-EBZ, AD-FMCOMMS3-EBZ, AD-FMCOMMS4-EBZ, ARRADIOand AD-FMCOMMS5-EBZ, as well as the FMCOMMS-2 IIO blocks. GnuRadio can also be compiled for a host PC.

Although the GNURadio block is called "FMCOMMS-2", it will work with the any of the AD-FMCOMMS[2345] or arradio boards. The FMCOMMS-2 IIO blocks can run on the network. By setting the "hostname" parameter to the IP address of a ZedBoard, you can stream samples from/to the remote board. It should be preferred when possible:

- it's easier to setup (you only need to compile GnuRadio on your PC)
- It's faster, as the ZedBoard does not have the processing power of your PC.

Table of Contents

Compiling GnuRadio

Full build

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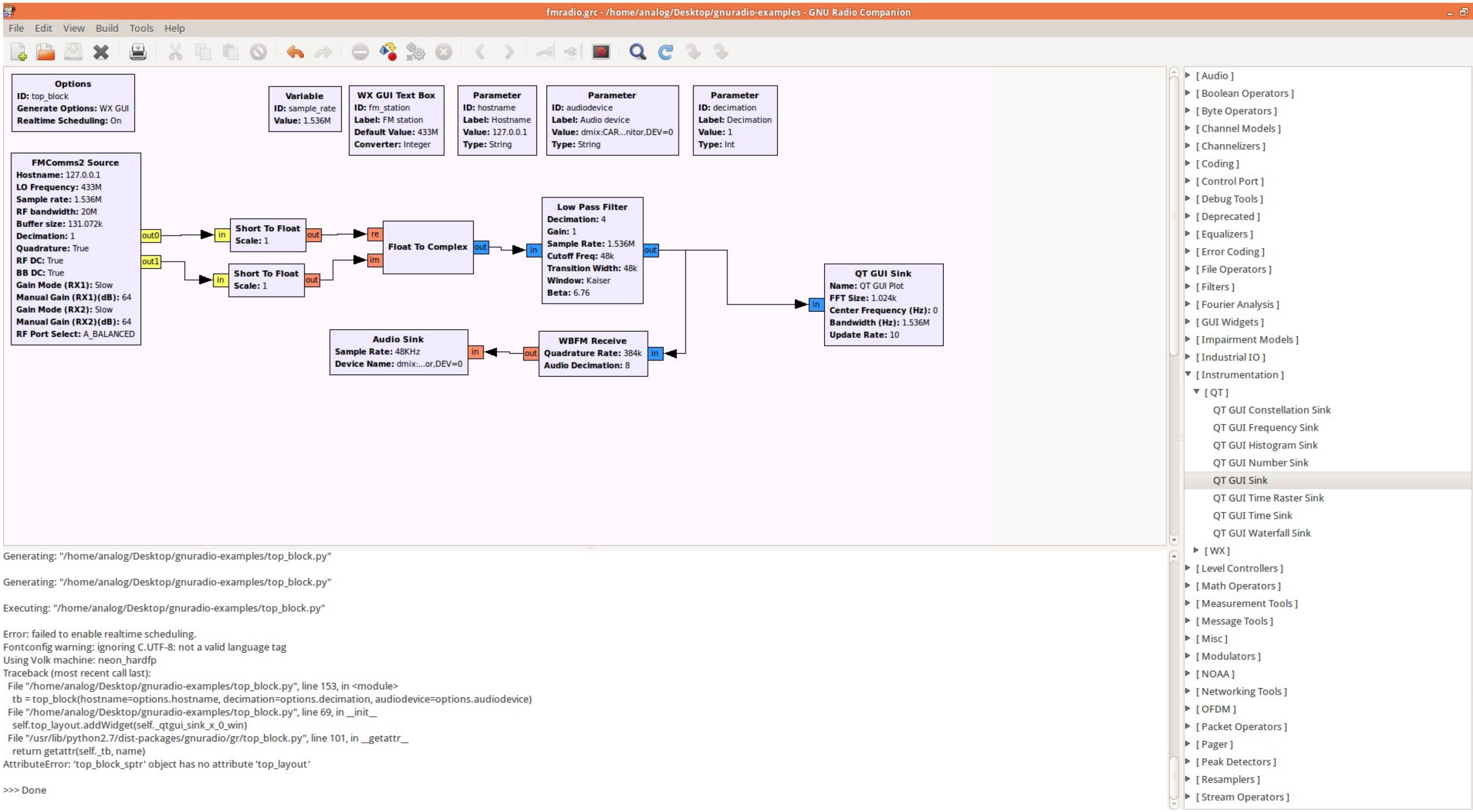
GNU Radio UI

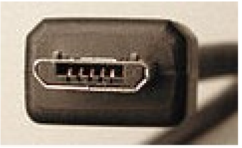

fmradio.grc - /home/analog/Desktop/gnuradio-examples - GNU Radio Companion
File Edit View Build Tools Help
Options
ID: top_block
Generate Options: WX GUI
Realtime Scheduling: On
Variable
ID: sample_rate
Value: 1.536M
WX GUI Text Box
ID: fm_station
Label: FM station
Default Value: 433M
Converter: Integer
Parameter
ID: hostname
Label: Hostname
Value: 127.0.0.1
Type: String
Parameter
ID: audiodevice
Label: Audio device
Value: dmix:CAR...nitor,DEV=0
Type: String
Parameter
ID: decimation
Label: Decimation
Value: 1
Type: Int
FMComms2 Source
Hostname: 127.0.0.1
LO Frequency: 433M
Sample rate: 1.536M
RF bandwidth: 20M
Buffer size: 131.072k
Decimation: 1
Quadrature: True
RF DC: True
BB DC: True
Gain Mode (RX1): Slow
Manual Gain (RX1)(dB): 64
Gain Mode (RX2): Slow
Manual Gain (RX2)(dB): 64
RF Port Select: A_BALANCED
out0
out1
in
Short To Float
Scale: 1
out
in
Short To Float
Scale: 1
out
re
im
Float To Complex
out
in
Low Pass Filter
Decimation: 4
Gain: 1
Sample Rate: 1.536M
Cutoff Freq: 48k
Transition Width: 48k
Window: Kaiser
Beta: 6.76
out
in
QT GUI Sink
Name: QT GUI Plot
FFT Size: 1.024k
Center Frequency (Hz): 0
Bandwidth (Hz): 1.536M
Update Rate: 10
Audio Sink
Sample Rate: 48KHz
Device Name: dmix:...or,DEV=0
in
out
WBFM Receive
Quadrature Rate: 384k
Audio Decimation: 8
in
[Audio]
[Boolean Operators]
[Byte Operators]
[Channel Models]
[Channelizers]
[Coding]
[Control Port]
[Debug Tools]
[Deprecated]
[Equalizers]
[Error Coding]
[File Operators]
[Filters]
[Fourier Analysis]
[GUI Widgets]
[Impairment Models]
[Industrial IO]
[Instrumentation]
[QT]
QT GUI Constellation Sink
QT GUI Frequency Sink
QT GUI Histogram Sink
QT GUI Number Sink
QT GUI Sink
QT GUI Time Raster Sink
QT GUI Time Sink
QT GUI Waterfall Sink
[WX]
[Level Controllers]
[Math Operators]
[Measurement Tools]
[Message Tools]
[Misc]
[Modulators]
[NOAA]
[Networking Tools]
[OFDM]
[Packet Operators]
[Pager]
[Peak Detectors]
[Resamplers]
[Stream Operators]
Generating: "/home/analog/Desktop/gnuradio-examples/top_block.py"
Generating: "/home/analog/Desktop/gnuradio-examples/top_block.py"
Executing: "/home/analog/Desktop/gnuradio-examples/top_block.py"
Error: failed to enable realtime scheduling.
Fontconfig warning: ignoring C.UTF-8: not a valid language tag
Using Volk machine: neon_hardfp
Traceback (most recent call last):
File "/home/analog/Desktop/gnuradio-examples/top_block.py", line 153, in <module>
tb = top_block(hostname=options.hostname, decimation=options.decimation, audiodevice=options.audiodevice)
File "/home/analog/Desktop/gnuradio-examples/top_block.py", line 69, in __init__
self.top_layout.addWidget(self._qtgui_sink_x_0_win)
File "/usr/lib/python2.7/dist-packages/gnuradio/gr/top_block.py", line 101, in __getattr__
return getattr(self._tb, name)
AttributeError: 'top_block_sptr' object has no attribute 'top_layout'
>>> Done

QUICK-VERSION

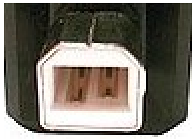
SETUP ZED BOARD & AD-FMCOMMS-2 OR FMCOMMS-3

List of Hardware

- Zedboard
- AD-FMCOMMS2 or AD-FMCOMMS3 evaluation board
  - Note: Since Feb.2014. Analog Devices ships the SD-BOOT card with the AD-FMCOMMS3-EBZ
- 8 Gbyte programmed SD Card holding Linux and applications
- USB Hub
- USB Mouse
- USB Keyboard
- Micro USB Type B – USB B
- Power supply for Zedboard
- Power supply for USB-Hub
- SMA bridge RF Cable
- HDMI Cable
- Full HD TV (1980 x 1080)
- SMA-SMA Cable (for looping back the TX Signal)



Micro USB Type B



USB-B

ANALOG DEVICES

CREATING YOUR OWN BOOT SD-CARD

http://wiki.analog.com/resources/tools-software/linux-software/zynq_images

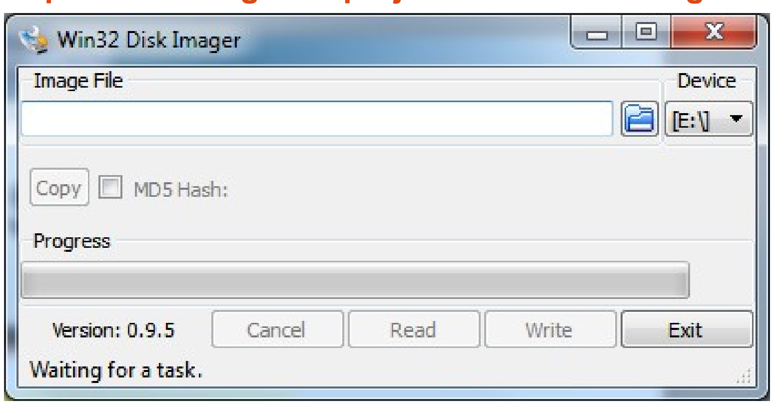
- **6 February 2015 release (2014_R2)**
- Actual file: http://swdownloads.analog.com/cse/2014_R2-2015_02_06.img.xz
- Checksum 2014_R2-2015_02_06.img.xz bb76031fcd68fd9b1a175a2f7fd3e053
- Checksum 2014_R2-2015_02_06.img 132d03a2888db34f10f0ebbcb3100ae7

On MS-Windows create the SD Card with:

http://wiki.analog.com/resources/tools-software/linux-software/zynq_images/windows_hosts#gui_using_win32diskimager

Works with: Win32 Disk Imager

http://sourceforge.net/projects/win32diskimager/files/latest/download?source=navbar



ANALOG DEVICES

On Linux Machines

http://wiki.analog.com/resources/tools-software/linux-software/zynq_images/linux_hosts

Write the file (input file or if) to the storage device (output file or of):

```
rgetz@brain:~/newest$ time sudo dd if=2014_R2-2015_02_06.img of=/dev/mmcblk0 bs=4194304
[sudo] password for rgetz:
0+60640 records in
0+60640 records out
7948206080 bytes (7.9 GB) copied, 571.766 s, 13.9 MB/s

real    7m54.11s
user    0.29s
sys     8.94s
```

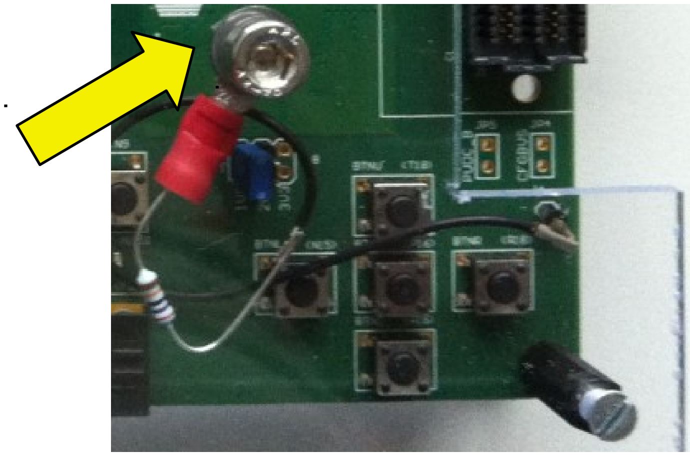
Prepare the SD CARD

Preparing the image

The SD card includes a few images on it's BOOT partition. One of these images needs to be selected before the system will boot properly. In order to run any of these images, just copy the images from the subdirectory into the base directory, and then boot it.

Make your ESD Protection

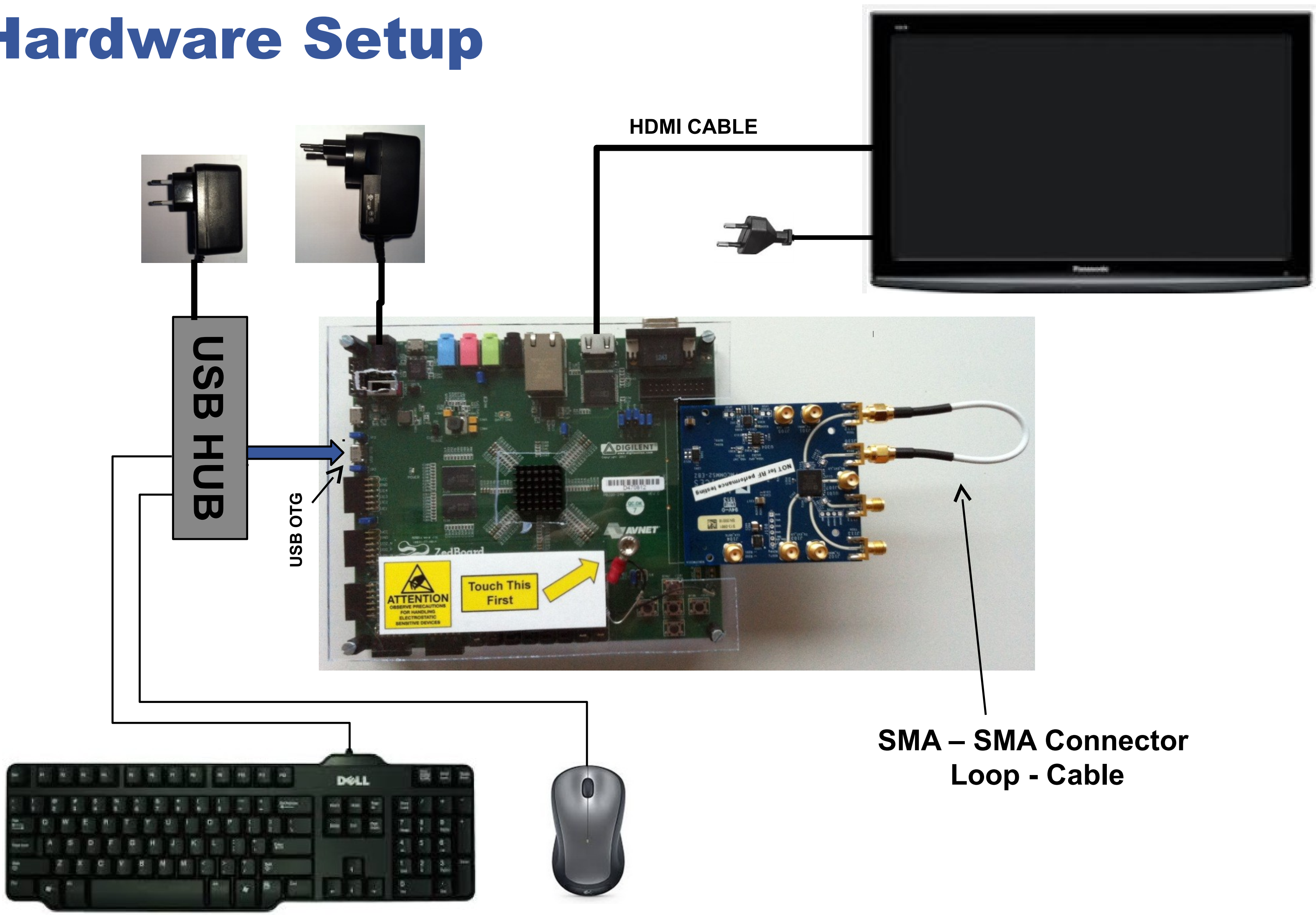
Touch This First



Before touching anything else of your setup, discharge your body on this screw! (keyboard, mouse, usb-hub, cable connect/disconnect Zedboard)

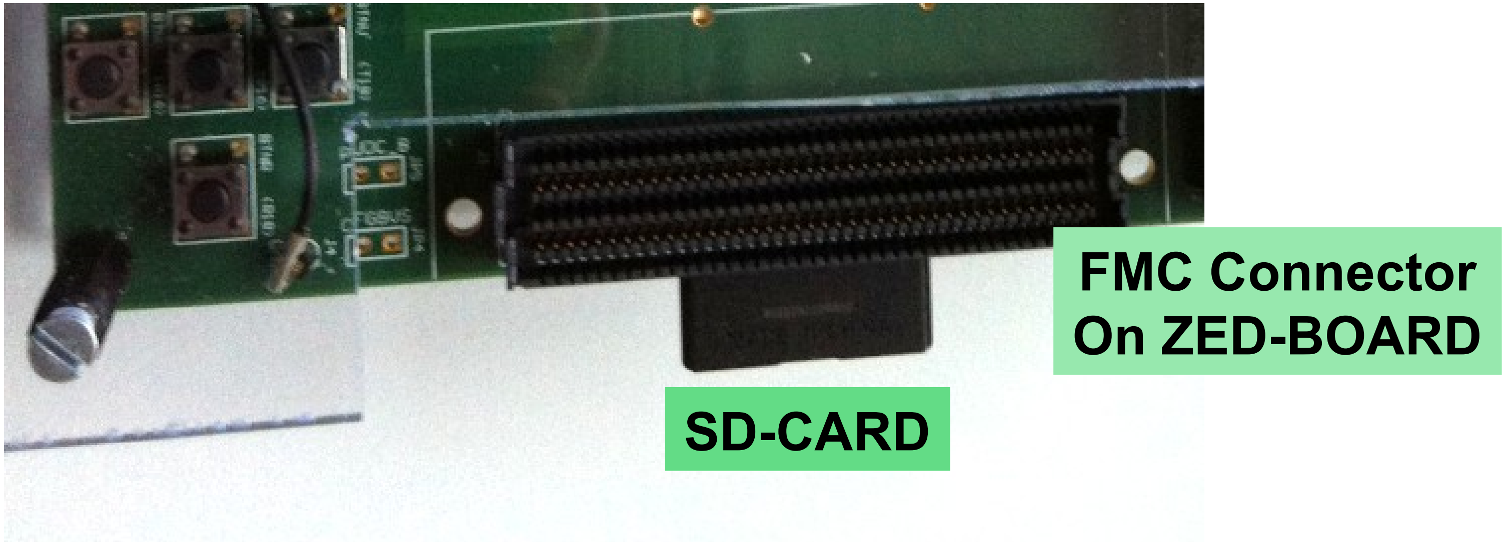
Background:
The demo setup consists of a TV, which is connected to the Zedboard via the HDMI Cable. TVs are not grounded any more and can accumulate charge. Your body charges in Airconditioned rooms, winter, wearing plastic shoes on plastic floor. Touching the HDMI cable shield of the Zedboard, to discharge your body, causes a big spark, pain in the finger, and finally a softwarecrash of the Zedboard's FPGA. The TV represents quite a capacitance or in some cases a galvanic ground connection. A full body discharge on a „ground" potential, can cause up to 4A peak, at 10kV-30kV body voltage. The screw is here for a controlled discharge. It is connected via a 270kOhm resistor to GND of the Zedboard. No spark, no pain, no crash!
A 4A pulse discharge is potentially dangerous to destroy sensitive semiconductor components on the Zedboard. Either thru a voltage spike, or thru Electromagnetic field generation and induction in wires.

Hardware Setup



Software

- Software for running the FMCOMMS2 Demo is on the SD-CARD
- 8GByte
- The SD-CARD preprogrammed is part of the FMCOMMS-3 Evaluation board.



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Connecting and Power-up

- Insert the SD – Card
- Connect the AD-FMCOMMS2 board to the Zedboard FMC Connector
  - RF Feedback cable mounted as shown on the picture.
- Connect all the USB Cables.
  - You can use any USB socket on the hub. (it has 4 sockets)
    - Mouse & Keyboard
  - Connect the mini-USB socket to the Zedboard
  - The other USB-B Plug (the big one), into the hub.
    - Adapters are already part of the cable.
- HDMI Cable to the TV
  - TV must be full HD, and you need to visualize the picture till to the edge. Search for that option in the TV Menue.
  - Turn on the TV and make sure the right HDMI input is selected
- Powersupply: Note the difference of the supply units!
- Power-up the USB Hub
- Finally plug in the Supply for the ZED-Board
  - The power switch on the Zed-board is already turned ON.

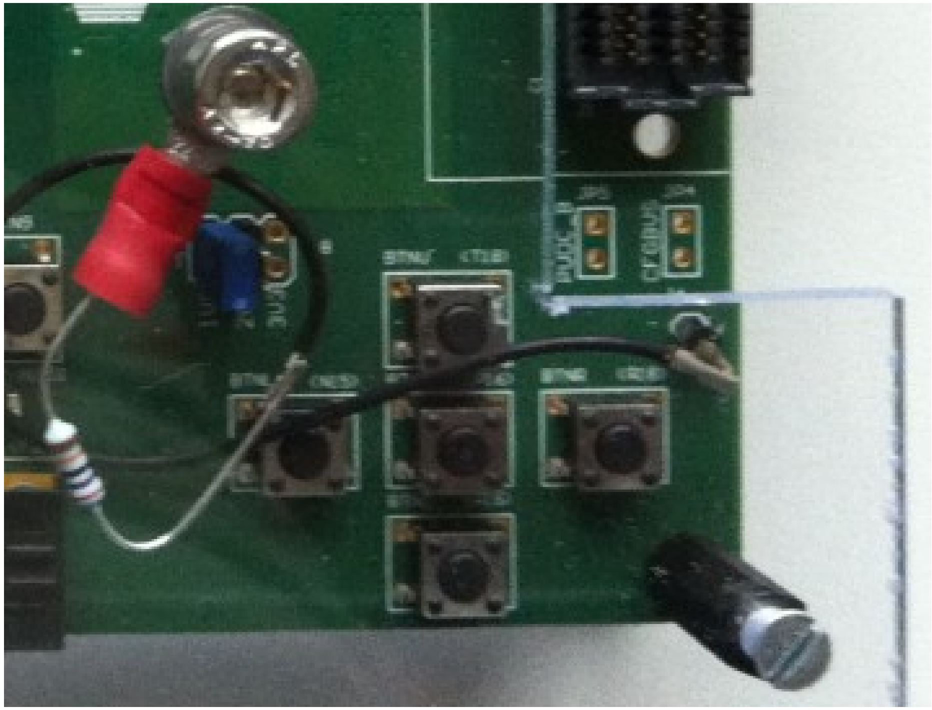
Power-Up

- After you plugged in the supplyconnector to the Zedboard, the FPGA starts to boot from the SD-Card.
- LEDs on the Zedboard turn on.
- It takes about ½ Minute, then you see on the top-left corner 2x the Linux TUX (Penguin)
- Some booting text shows up.
- The Zedboard fully boots and starts with the FMCOMMS2 application.
- Use the mouse and keyboard to operate the application.
  - Showing spectrum is impressive
  - Play with settings
- After usage & demo, shutdown the OS.
  - Right top corner menue contains shutdown.


Applications Menu
[Pictures - File Manager]
01 Jan, 01:14
BOOT
ADI Update Tools
ADI Update Boot
Log Out
Trash
File System
Home
ADI IIO Oscilloscope
Terminal Emulator
GnuRadio Companion
gnuradio-examples
ANALOG DEVICES
Amplifiers and Linear
Analog-to-Digital Converters
Digital-to-Analog Converters
Audio/Video Converters
Broadband Products
Clock and Timing Products
Fiber Optic Products
Interface
MEMS and Sensors
Power Management Products
RF/IF ICs
Switches/Multiplexers
Other Products
For more information, visit analog.com

ESD Discharge

- Do not forget to discharge yourself.
- Touch the Screw whenever you ***walk to the board.***
- No fear, it does not arc. And no spark!



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Other Tips

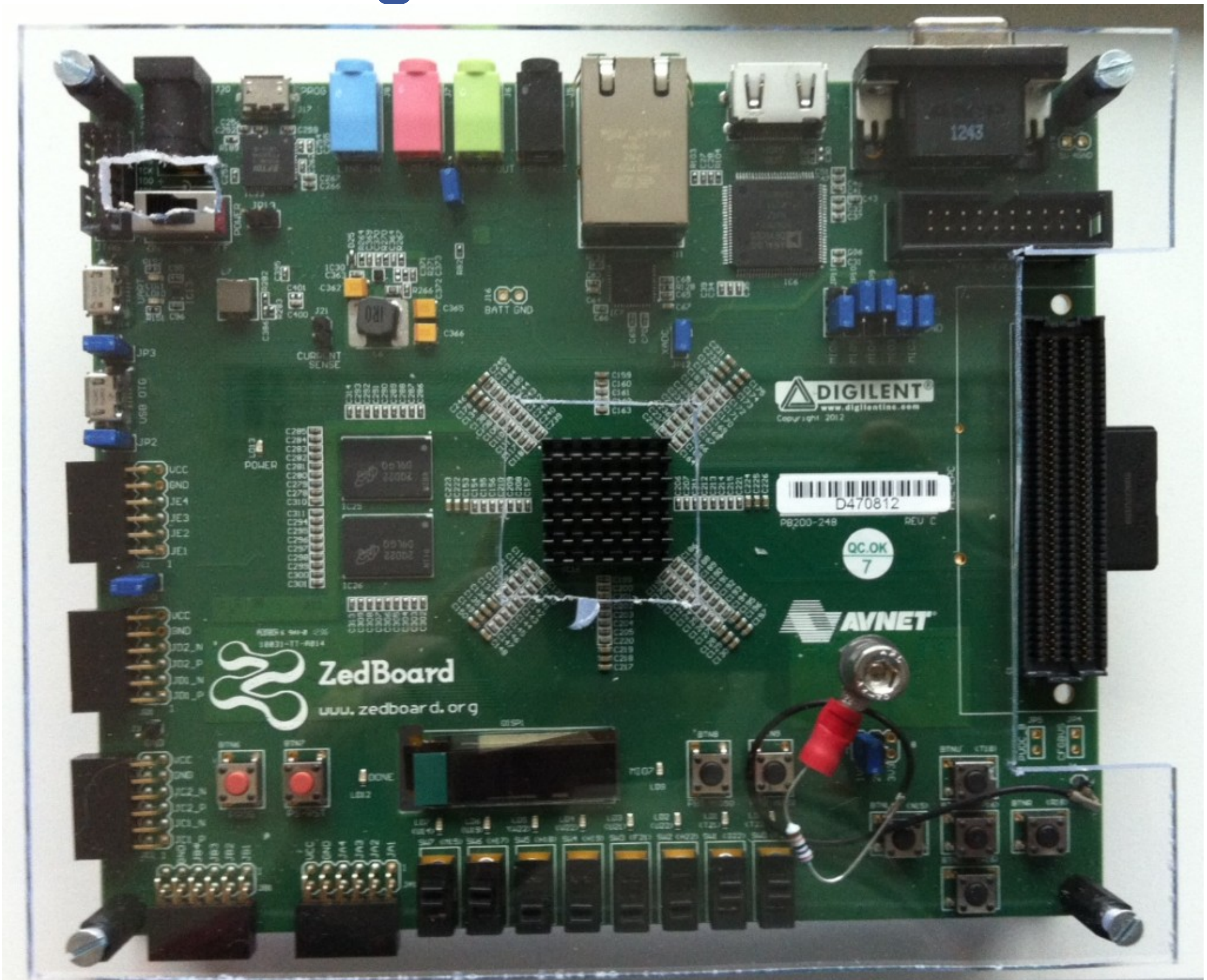
- When you need to mount or unmount a RF cable or receiving Antenna to the SMA Connectors of the FMCOMMS2 board, shutdown the board and power it off.
  - When handling the FMCOMMS2, it may get easily unplugged from the FMC Connector, which can damage the boards!
- Do not put any cover on top of the board while operating it.
  - The cooling of the FPGA would get less effective, causing overheat and damage of the FPGA.
- The installed SMA cable is a loopback cable.
  - So you can monitor the generated signal by the AD9361

Display-Tip

- Use a full HD TV.
- We do not support any other resolution than full HD.
- Select a TV 42 inch (106 cms) or larger.
  - Smaller TV screens are typically NOT full HD. (unless otherwise noted in their specification)
- The TV should allow „Overscan = ON“
  - Otherwise the TV Frame crops the picture. Loss of Linux specific buttons.
  - Panasonic TX-L42B6E
    - Supports full HD & Overscan

ANALOG DEVICES

Switch settings



Alternative Demo

- Handheld Mobile Radio
  - PMR Europe: 446MHz
  - FRS USA: 462/467MHz
- Wavelength: 70cm

- You can with FM Transmissions
  - Verify Frequencies
  - Learn about AD9361 direct conversion
  - Verify sensitivity (if you have a 2nd Transceiver)

- Amateur Radios allowed to replace Antennas

ANALOG DEVICES

Helpful Q&A

- Main differentiation of the AD-FMCOMMS3-EBZ
  - http://ez.analog.com/message/135288#135288
- IIO Scope Tool & LTE
  - http://ez.analog.com/thread/39161
- LTE Setup questions
  - http://ez.analog.com/thread/40694

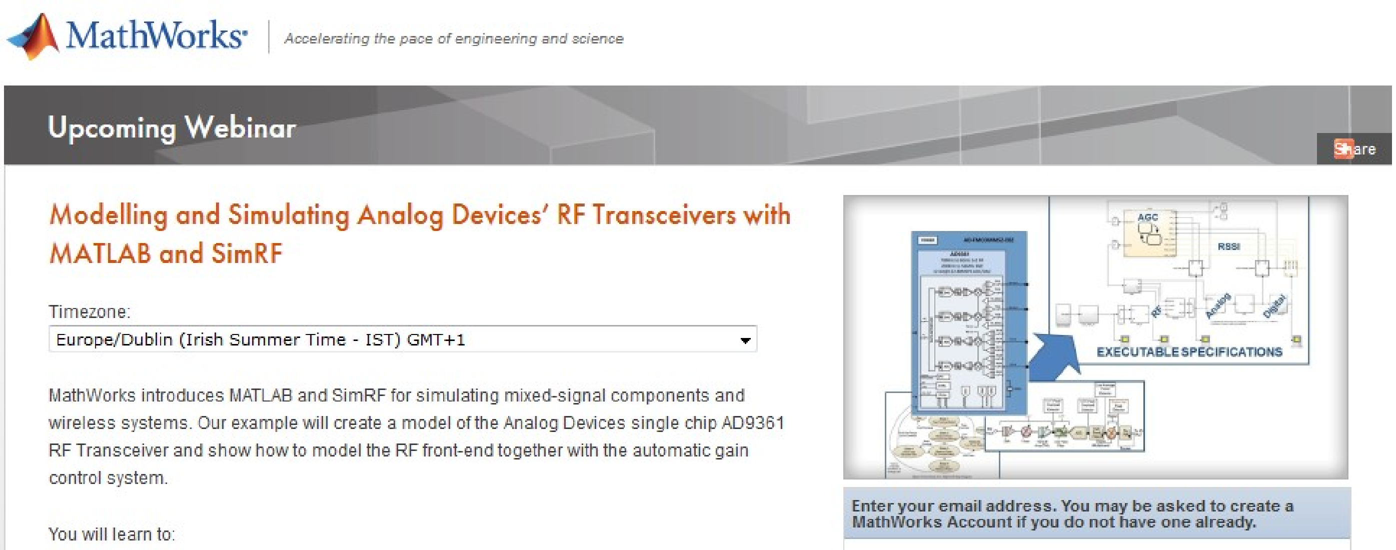
Q&A cont.

- **Can I use the AD9361 for a HF SDR?**
  - **In general: no. The lowest Frequency specified is 70MHz.**
- **Alternatives:**
  - **Using an upconverter**
    - https://code.google.com/p/opendous/wiki/Upconverter
  - **Alternative SDRs**
    - http://www.taylorkillian.com/2013/08/sdr-showdown-hackrf-vs-bladerf-vs-usrp.html

Q&A Cont

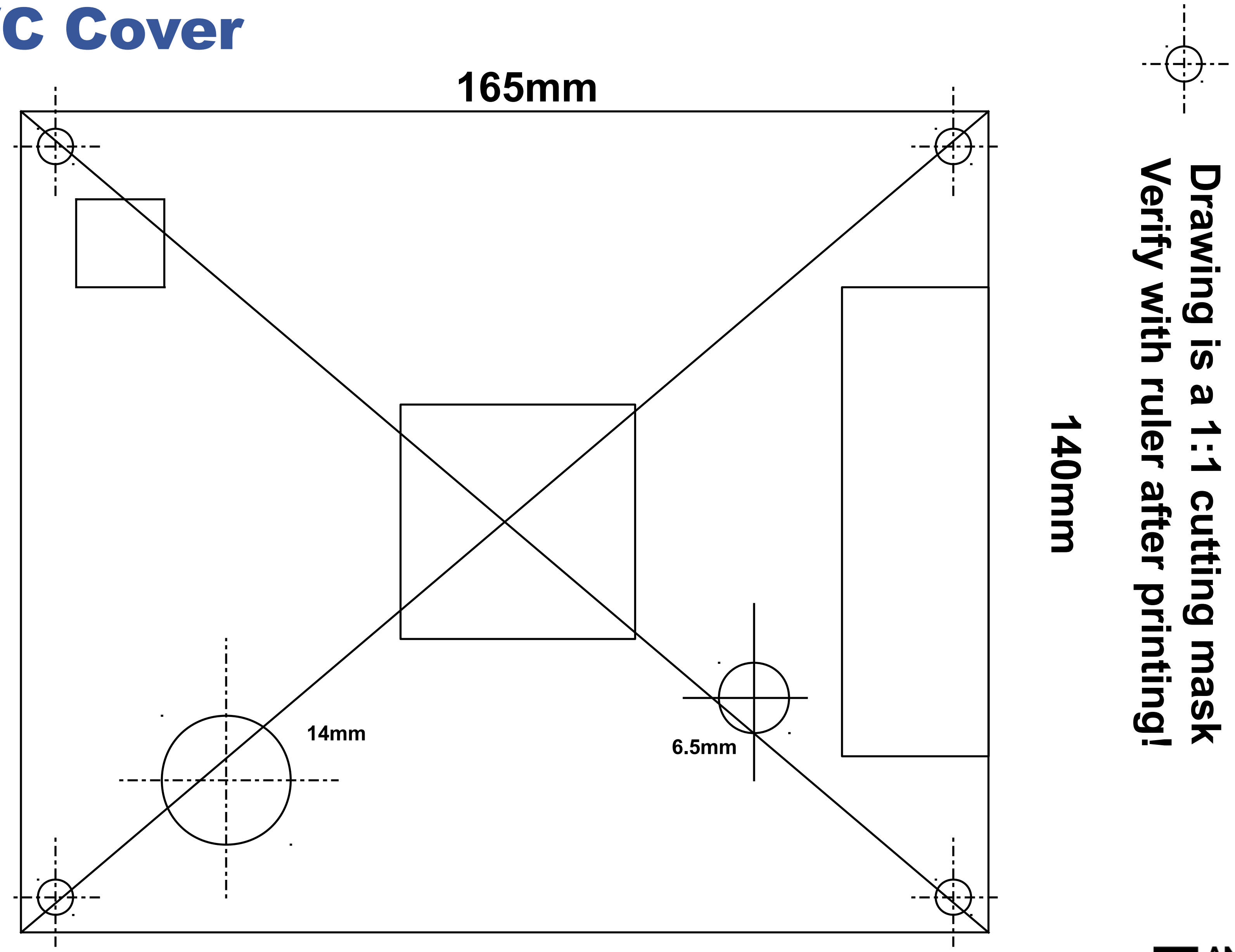
- **Does Matlab support the AD9361?**
- **Check this URL:**
  - **https://www.mathworks.com/company/events/webinars/wbnr89002.html?seq=1&s_cid=em_en_us**

  - **The filter wizard is part of the larger model shown in the webinar**



ANALOG DEVICES

PVC Cover



© Analog Devices

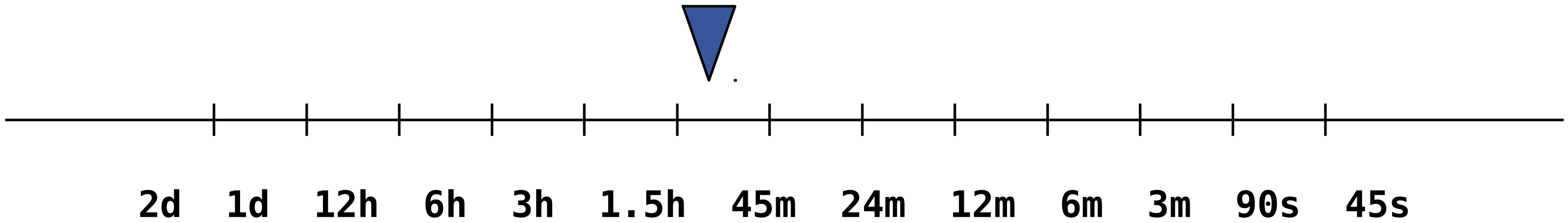
Bonus Question „Make an educated guess“

- **Problem/Task:**
- **National Security Bureau (NSB), asks your customer for decoding an unknown RF Signal**
- **24 hour monitoring & storing for 1 week.**
- **Between 87MHz…108MHz, random transmitions**
  - **Modulation type: Could be anything**
    - AM, FM, WBFM, QAM, PSK, SSB (USB, LSB), QPSK, OOK, CW
- **What is needed, to capture it on HD for post tuning?**
- **How many 1 TB Hard-Disks the customer needs to store 1 week?**

- **1st GUESS:**
- **How long can I record on 1TB Hard-Disk?**

ANALOG DEVICES

How long 1TB HDD allows to record the FM Radio Band?



Estimation

- Smallest BW: CW, 50Hz.
- Full BW: (108-87)MHz=21MHz
- Capture BW: 22MHz
- Sampling: 56MSPS @ 12Bit (Nyquist) (1Hz Resolution)
  - For 50Hz resolution, 1MSPS would be sufficient
- I & Q output: 56MW(12Bit) each /sec. ➔ 1.344Gbit/s 168MB/s
- 1e12Byte/168e6Byte/s = 5952s == 1h 39‘ 12“

- You need 14.5x 1TB HD per Day to capture the FM Radio Band. @ 1Hz resolution.
  - Hint: Using Compression improves the situation

- To have a 50Hz resolution out of 21MHz Bandwidth
- FFT: 1M pt FFT 2*(21M/50) (complex FFT)
- 1M samples in 17.8ms. 56FFTs/sec
- First Approach: AD9364

Mini Quiz

Prior to 1923 it was called 750kcs (kilocycles) rather than 750kHz.

The SI unit hertz (Hz) was established in his honor by the IEC in 1930 for frequency, an expression of the number of times that a repeated event occurs per second. It was adopted by the CGPM (Conférence générale des poids et mesures) in 1960, officially replacing the previous name, "cycles per second" (cps).

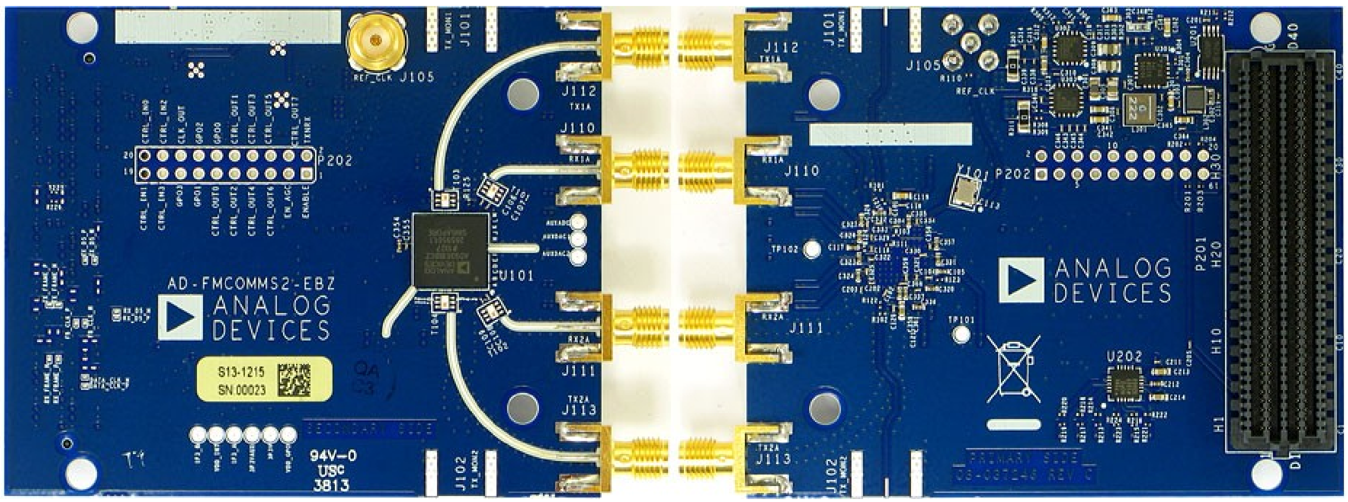
Why in 1920 they could not calculate the exact wavelength?

299 792 458 m/s, 1975

Prior that time, the problem was also in the definition of 1metre.

END

Sources:
http://en.wikipedia.org/wiki/Heinrich_Hertz
http://en.wikipedia.org/wiki/Speed_of_light#Early_history



LIVE-DEMO