The Future of Digital RFICs

Robin Getz

Engineer, Analog Devices

https://ez.analog.com/university-program

@robinlgetz

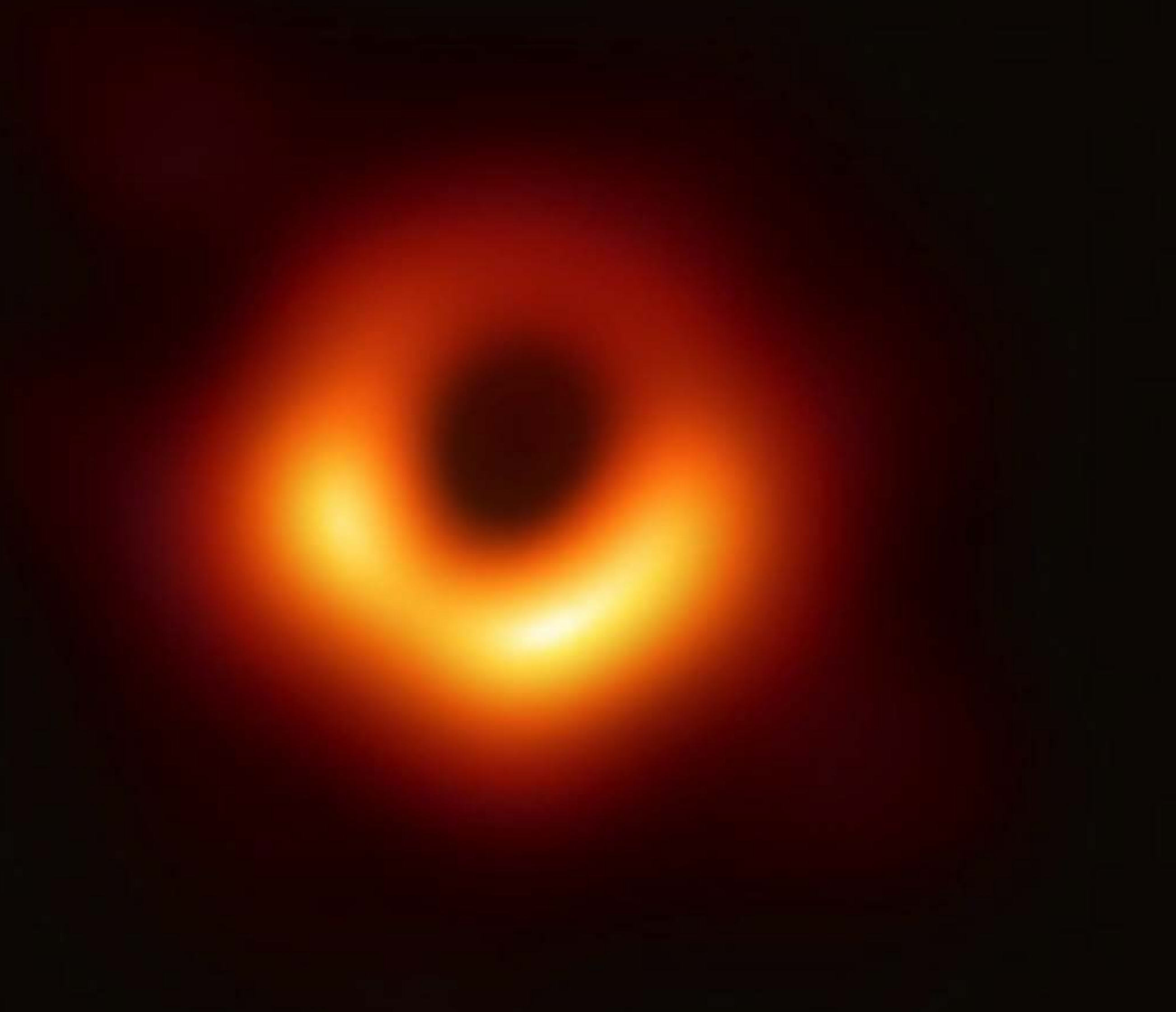
ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

GNURadio

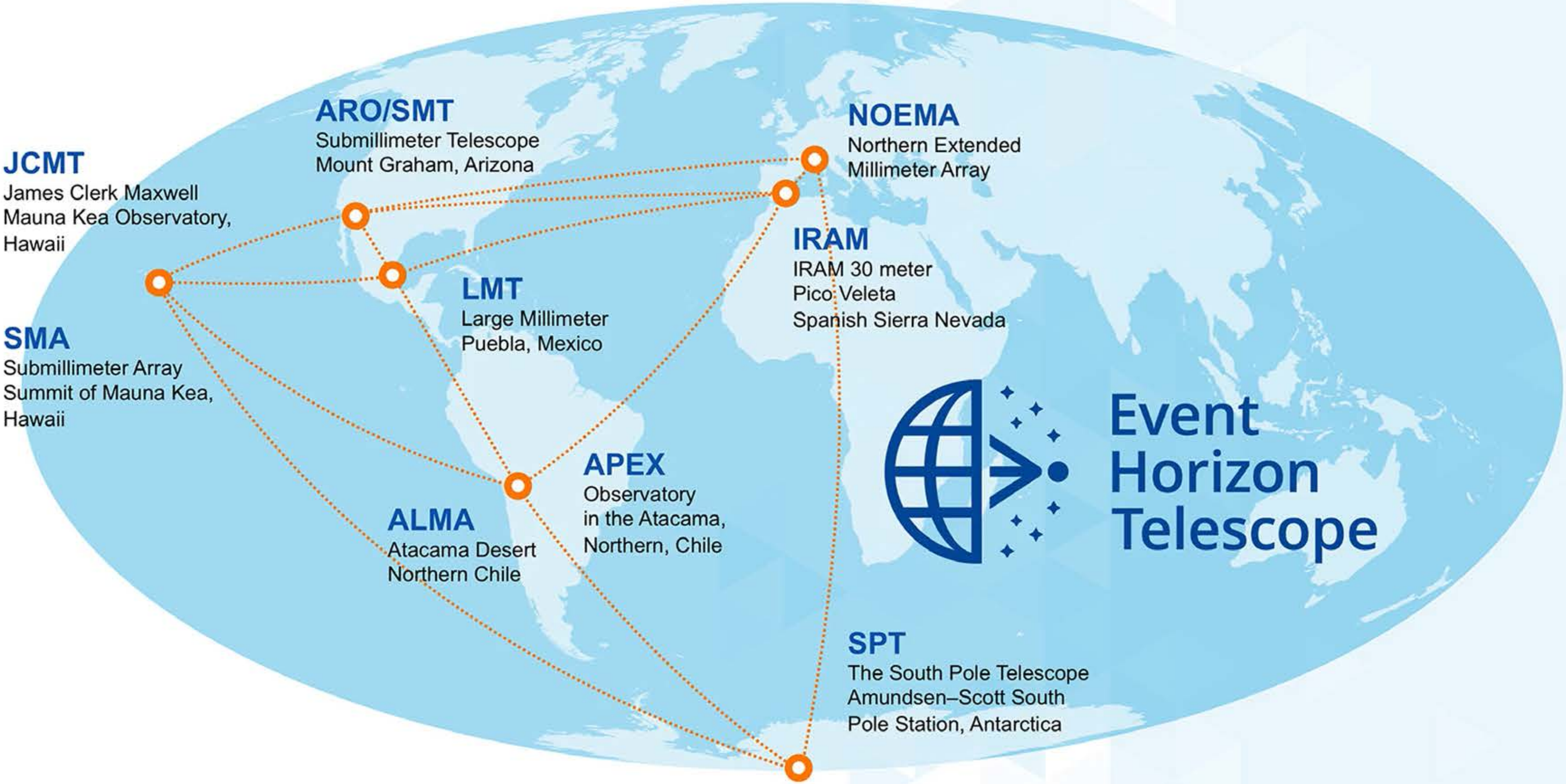
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

Seeing the Unseen



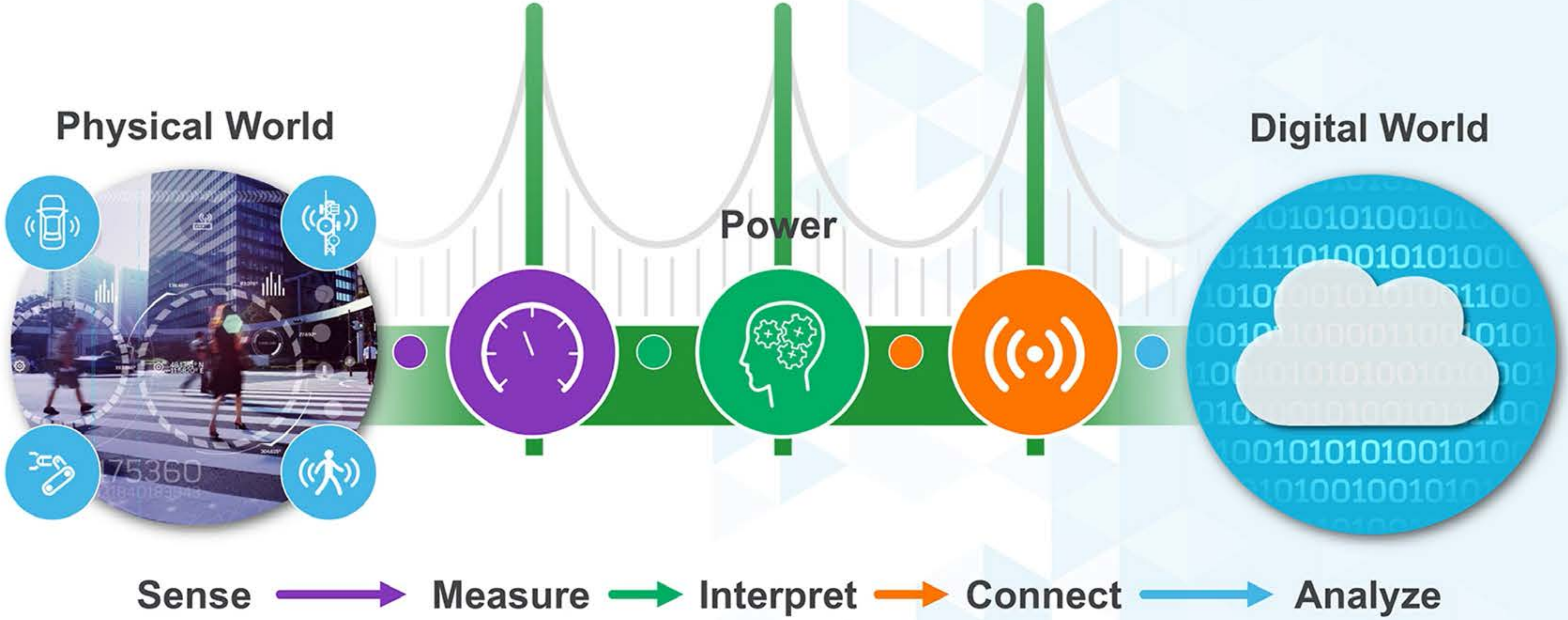
Credit: EHT Collaboration

https://eventhorizontelescope.org/



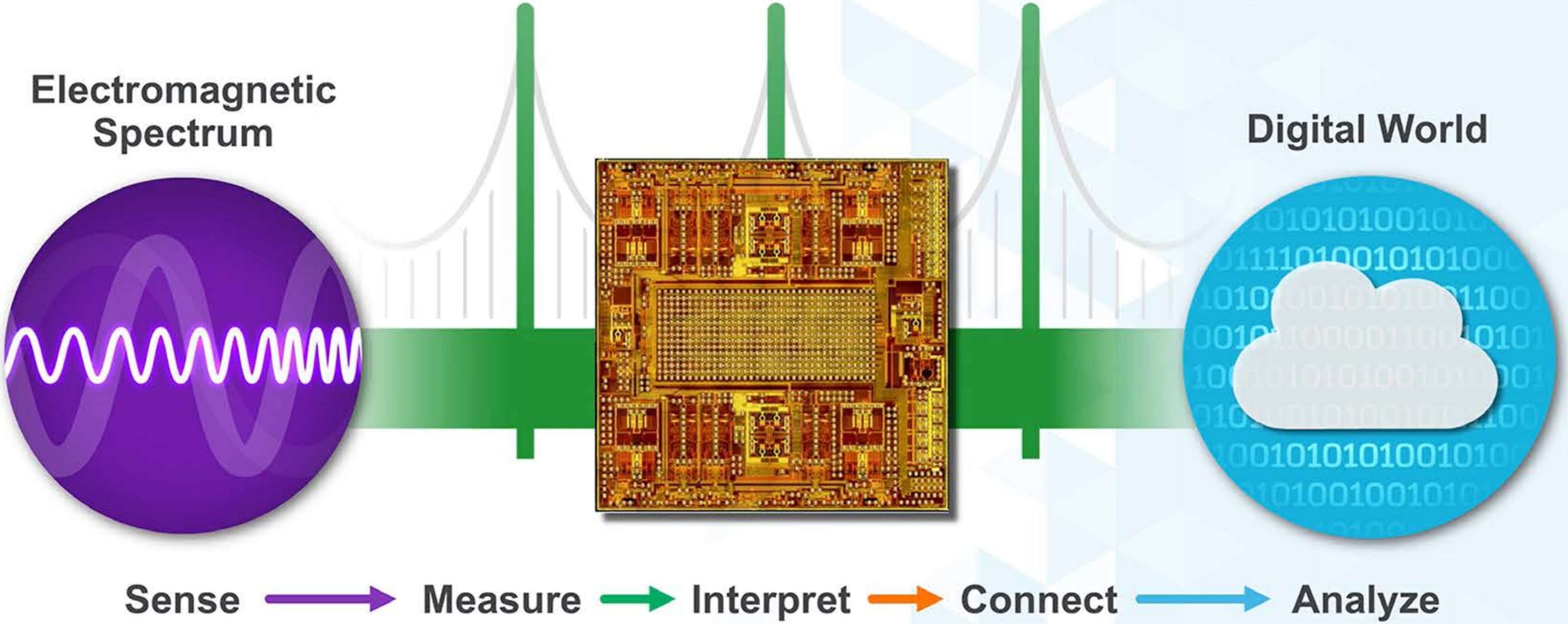
Analog Devices

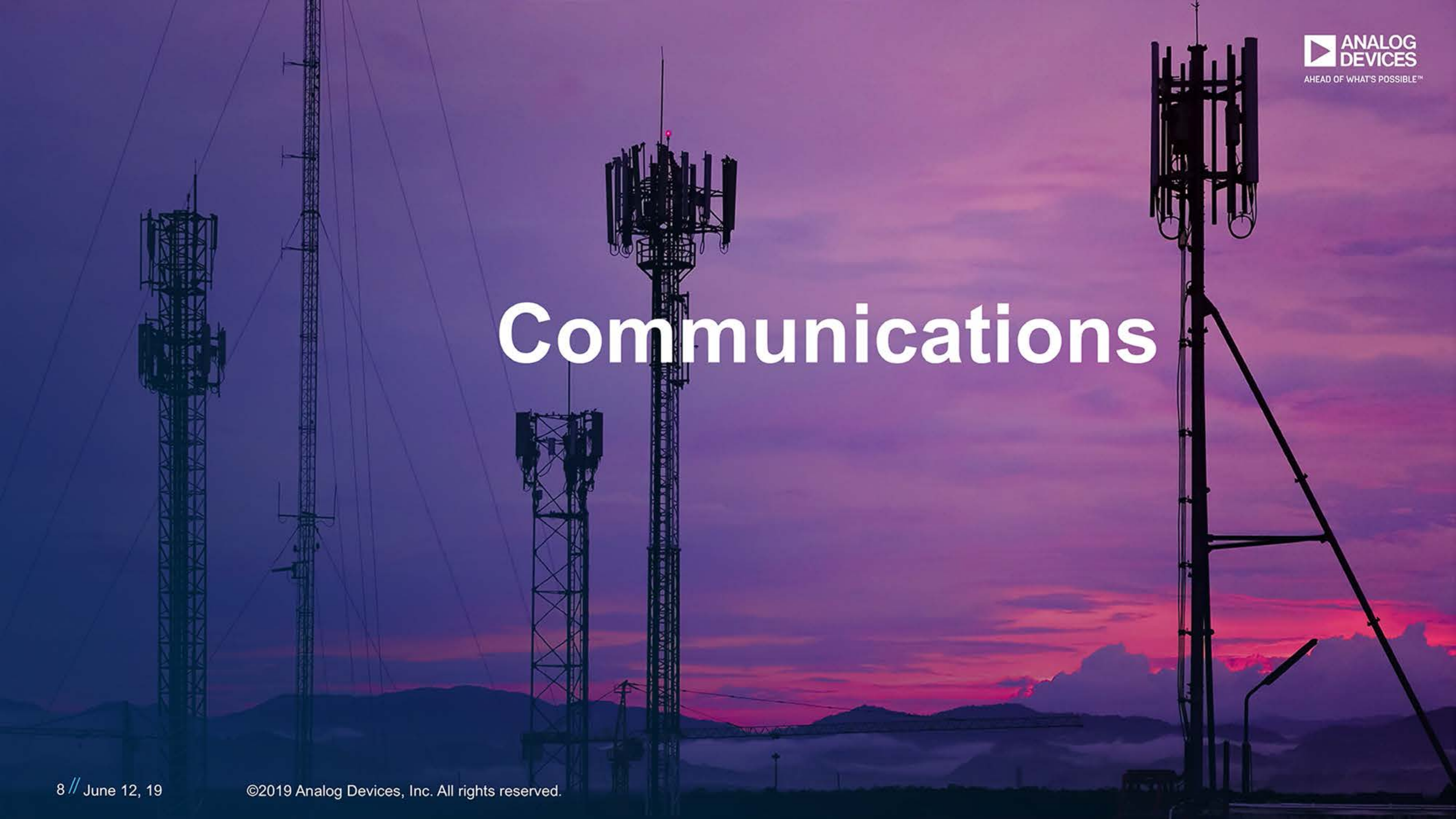
Connecting the Physical and Digital Worlds



RFIC

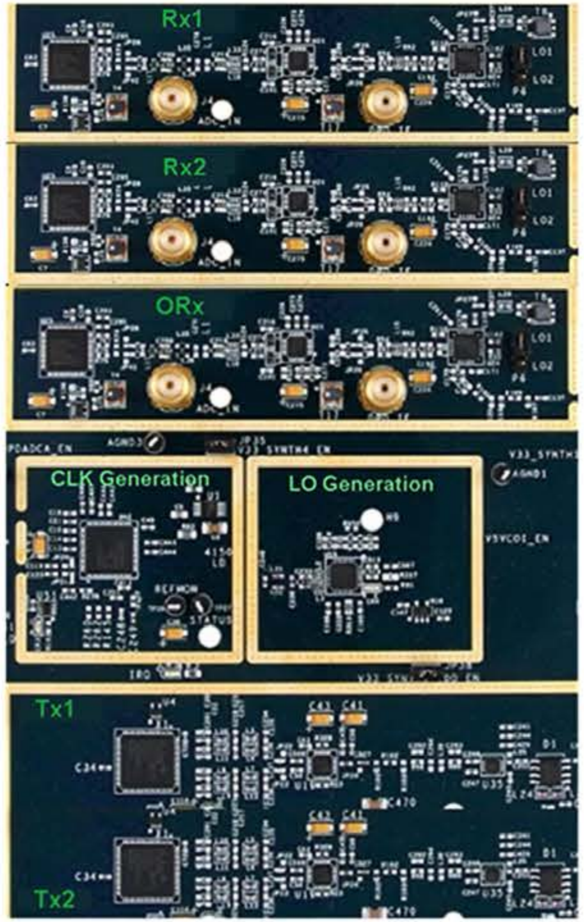
Connecting EM Spectrum to Digital World

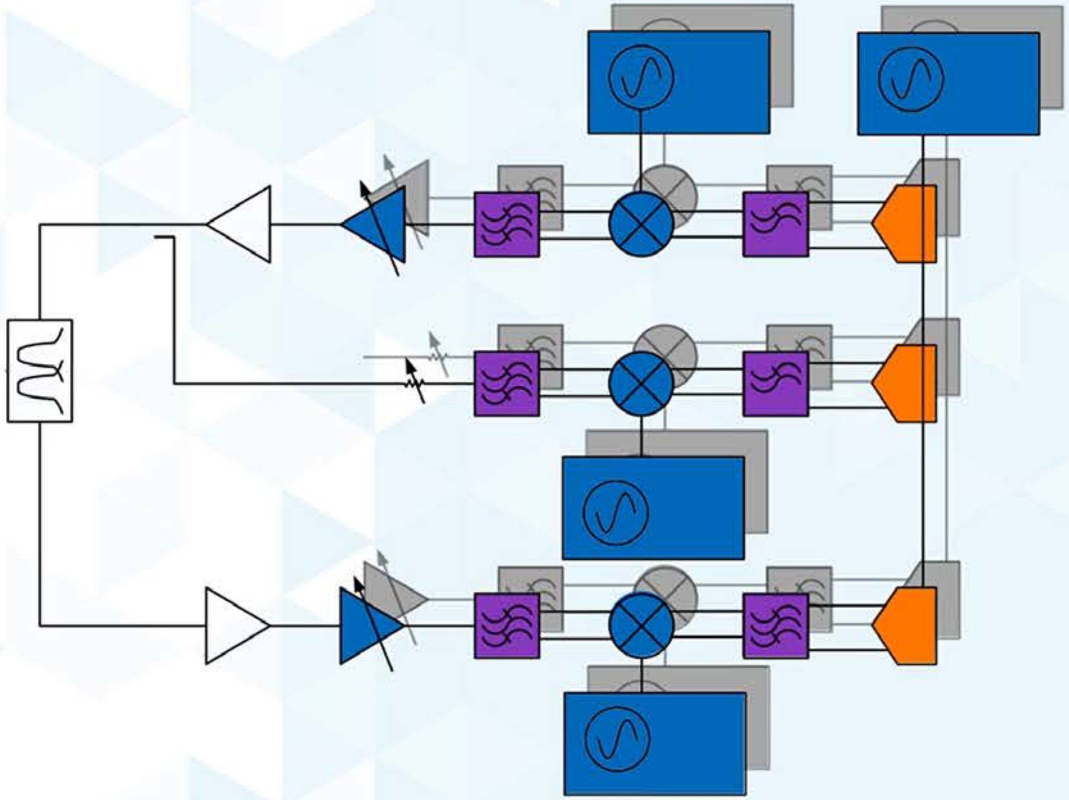




Communications

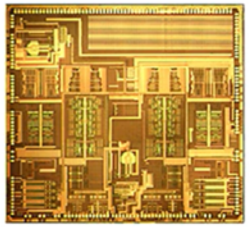
LTE Base Station Radio Architecture ~ 2013



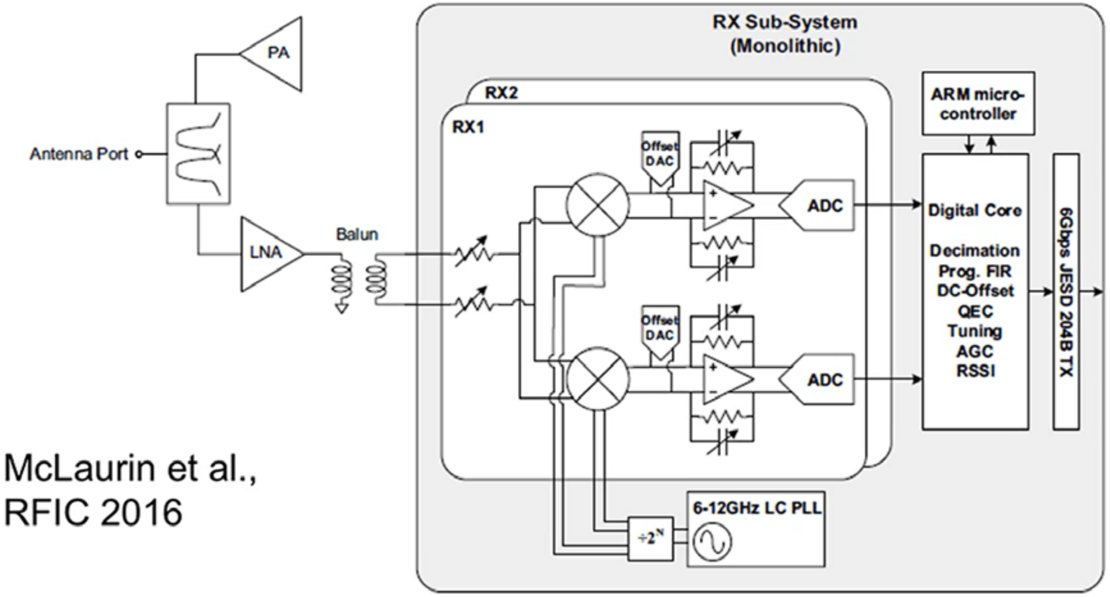


Base Station Radio Architecture Evolution ~ 2016

~2013

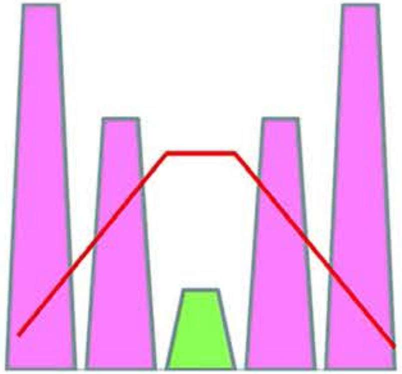


~2016



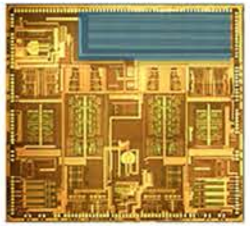
McLaurin et al., RFIC 2016

Single Carrier to Full Band



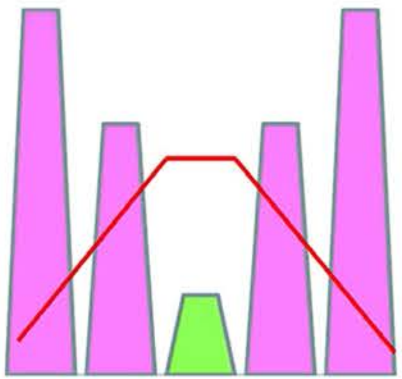
Single-carrier LTE

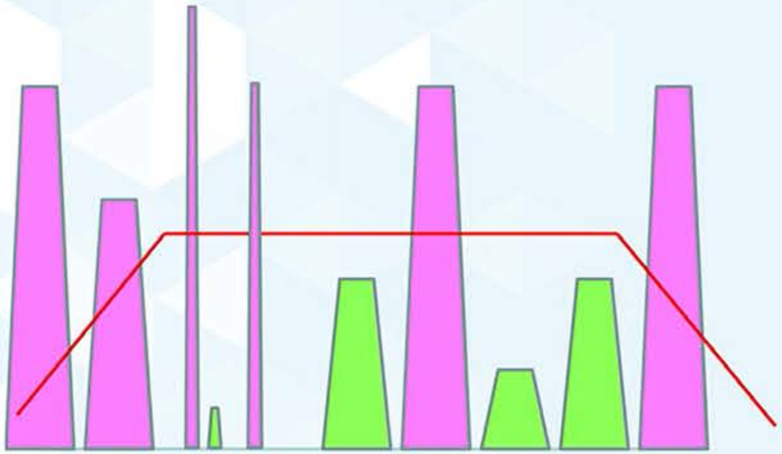
Modest dynamic range requirements



65nm 2T2R single-carrier ZIF TRX

Single Carrier to Full Band





Single-carrier LTE

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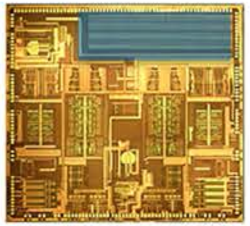

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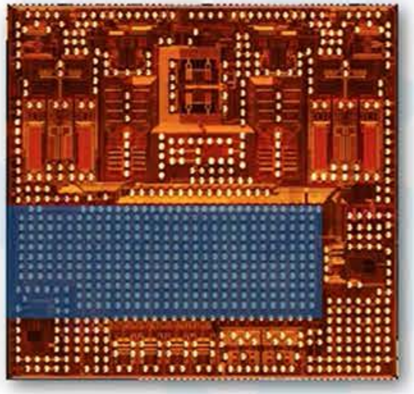
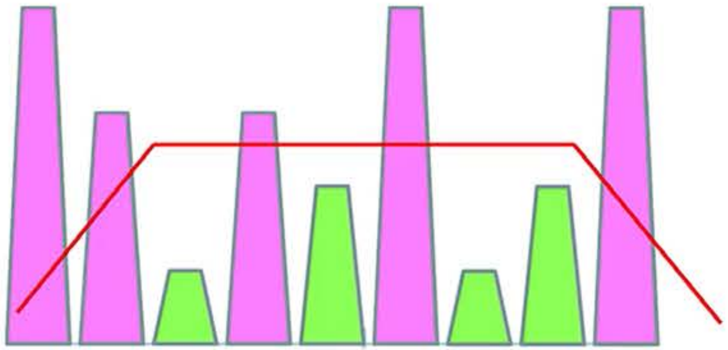


65nm 2T2R multi-carrier GSM/LTE ZIF TRX

GSM/LTE multi-carrier

Need ~ 50dB SFDR improvement for multi-carrier GSM
~30dB SNR improvement
~ 8X digital content

More Antennas to Multi-bands

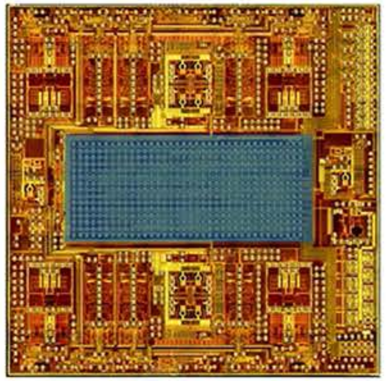


Massive MIMO

30dB higher dynamic range than single carrier but far more (64 or more) antennas.

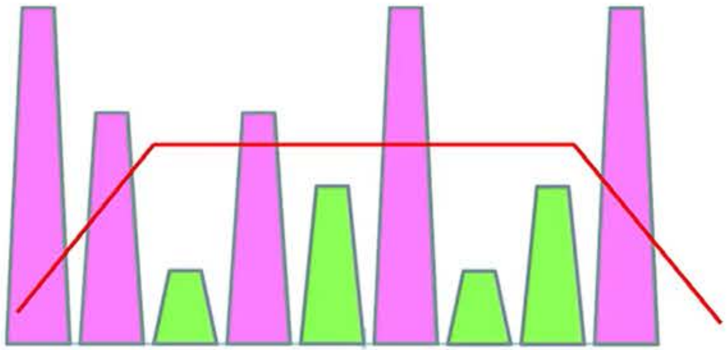
Power-efficient PA linearization

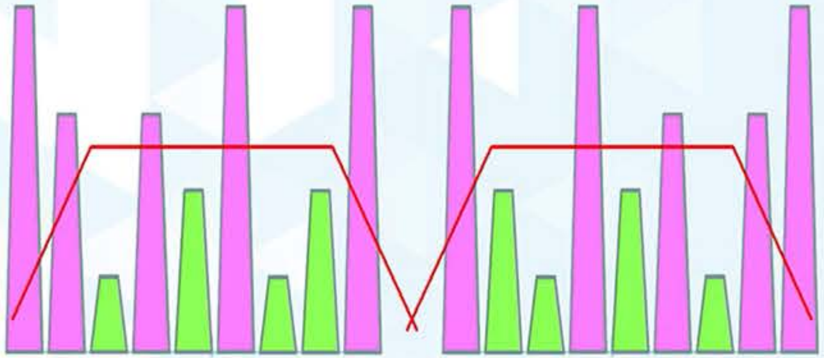
Need higher channel density and power optimized



28nm 4T4R ZIF TRX with DPD

More Antennas to Multi-bands





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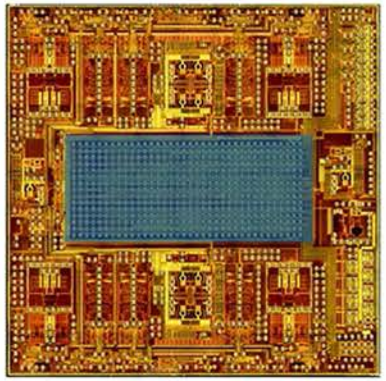
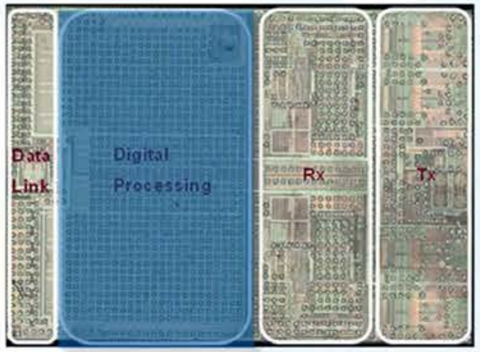


28nm 4T4R ZIF TRX with DPD

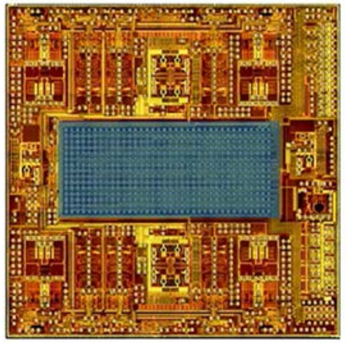


28nm 4T4R RF converter

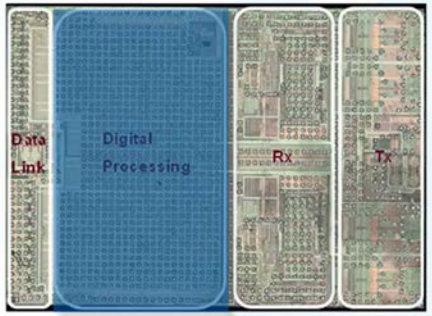
Multi-band

Similar to multi-carrier but over much wider bandwidth

Evolution

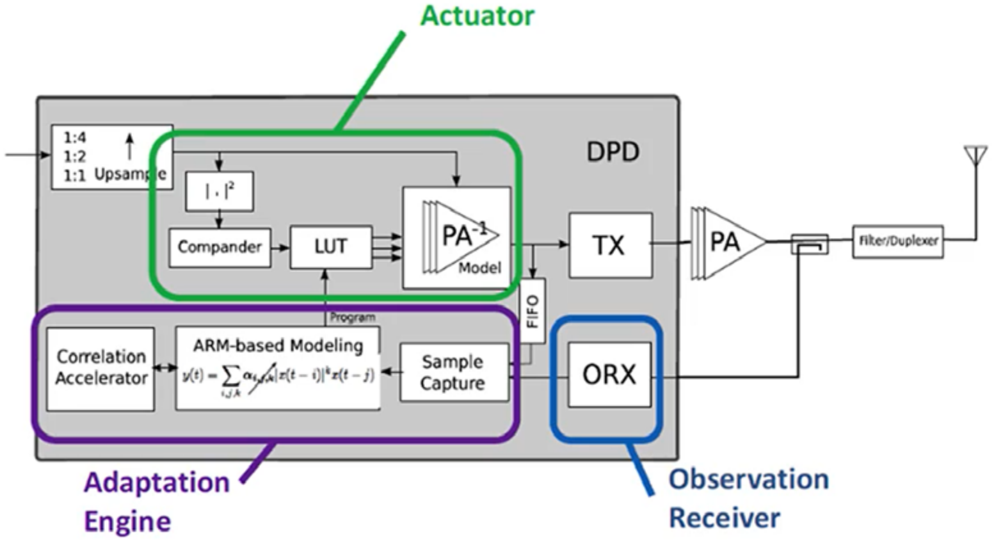


28nm 4T4R ZIF
TRX with DPD



28nm 4T4R RF converter

Digital Enables New System Level Capabilities



Mayer et al., RFIC 2016

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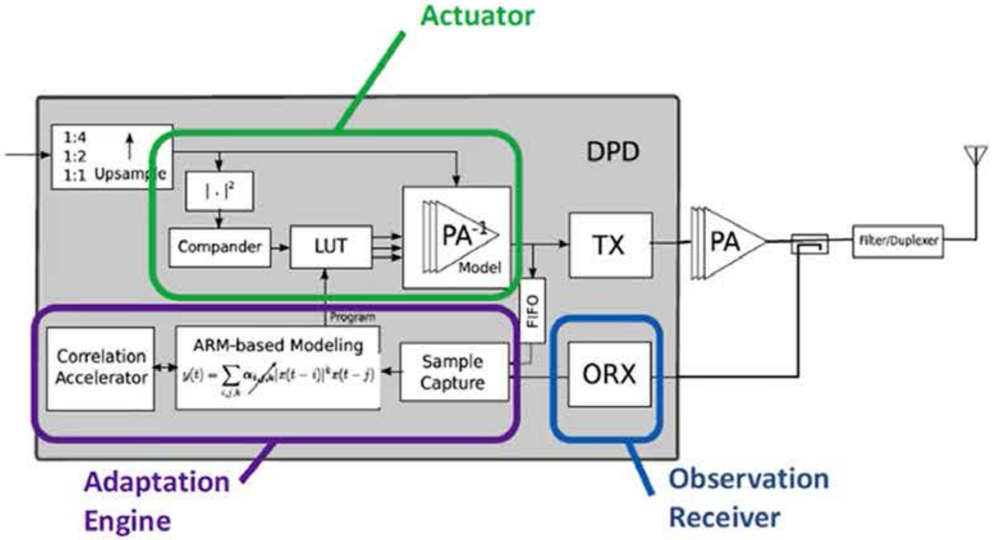

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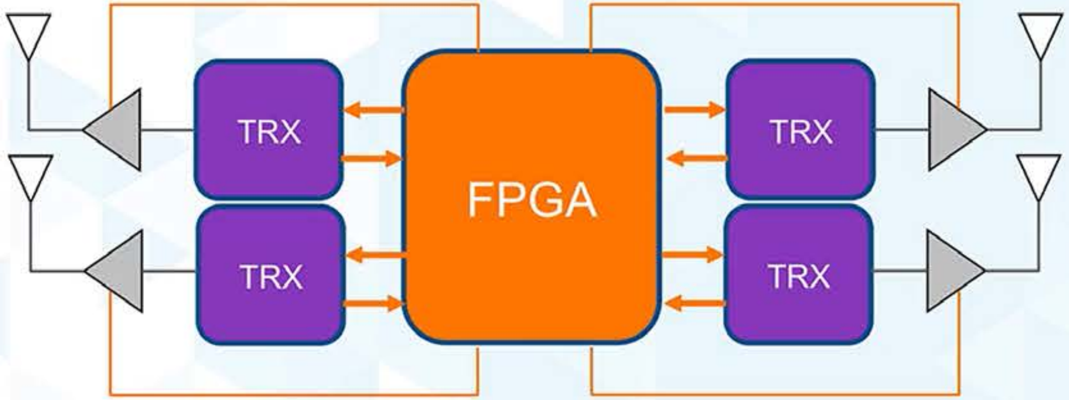
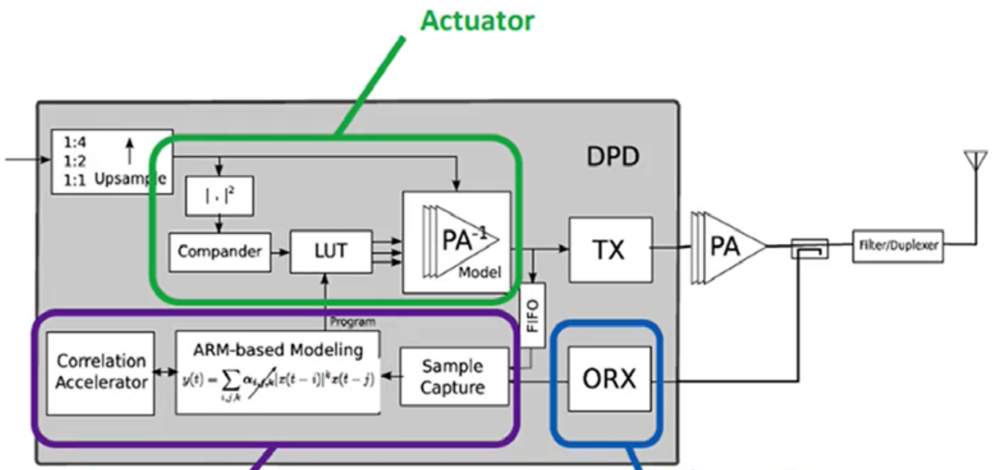
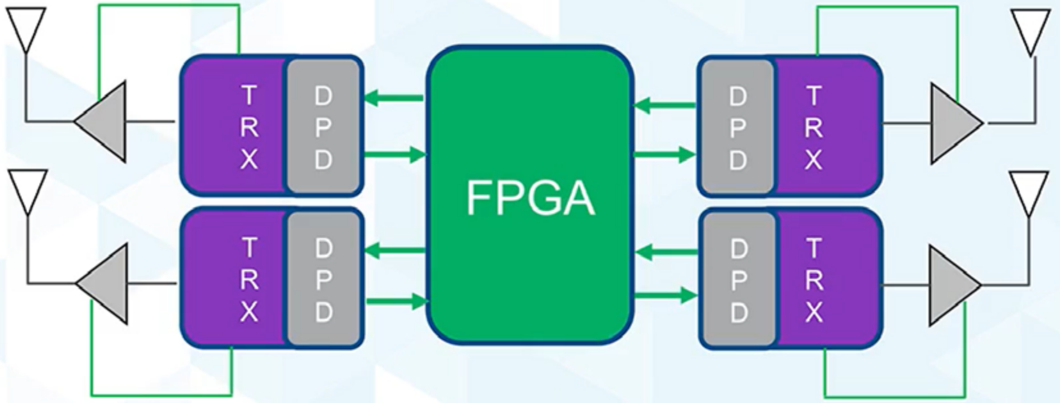


System with Central DPD

Digital Enables New System Level Capabilities



Mayer et al., RFIC 2016

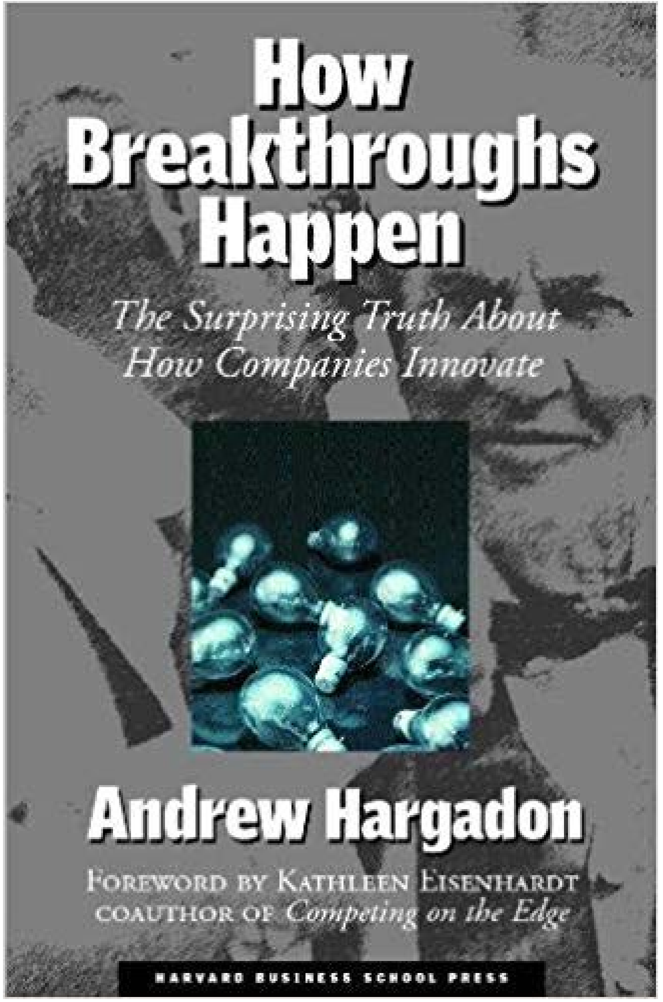


System with Transceiver DPD

Digital Predistortion (DPD) improves PA efficiency:

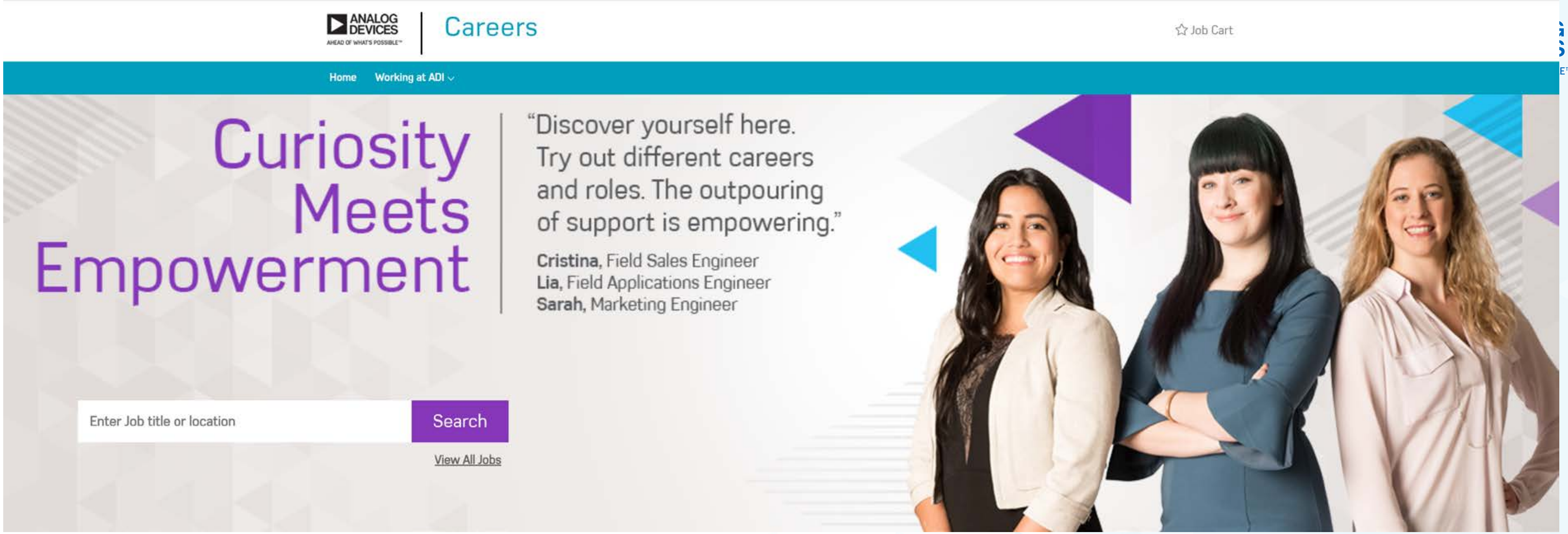
- 2/3 the FPGA size
- 110W savings per 64T64R system

Recombinant Innovation



University of California, Davis | UCD · Graduate School of Management

- Existing technologies are unique combinations of three elements.
  - The objects are hardware and software.
  - The ideas are an understanding of how to interact with those objects.
  - The people are those who know the ideas and objects. Their experiences give them the tacit knowledge that makes the ideas and objects work effectively together.
- Innovators are no smarter, no more courageous than the rest of us – they are simply better connected. They find ways to exploit the networked landscape. So they are able to innovate continuously by seeing and making connections between people, ideas, and objects from across the broader landscape.


ANALOG DEVICES
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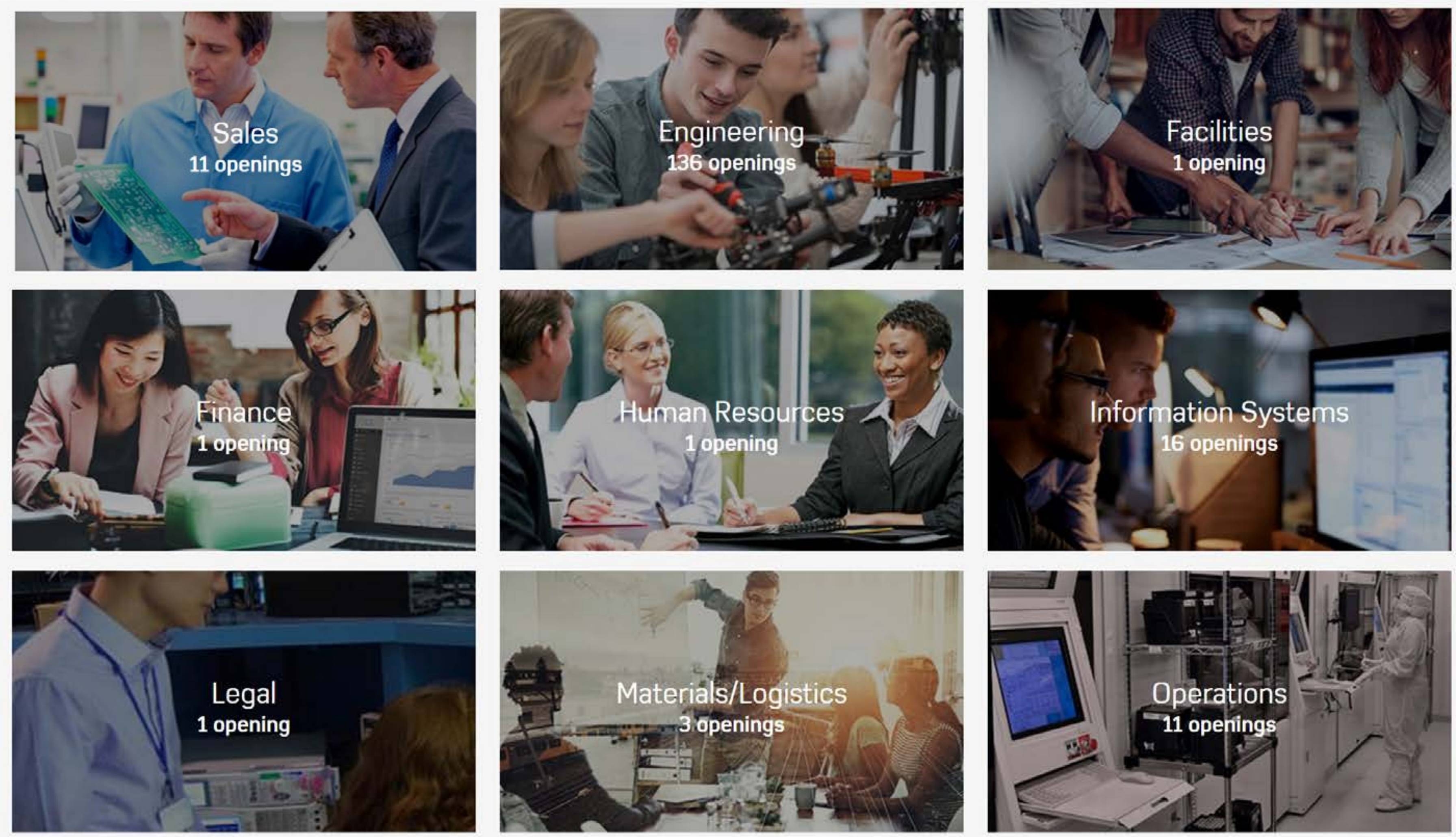
Careers
Job Cart
Home
Working at ADI
Curiosity Meets Empowerment
"Discover yourself here. Try out different careers and roles. The outpouring of support is empowering."
Cristina, Field Sales Engineer
Lia, Field Applications Engineer
Sarah, Marketing Engineer
Enter Job title or location
Search
View All Jobs

GRCon

https://careers.analog.com/



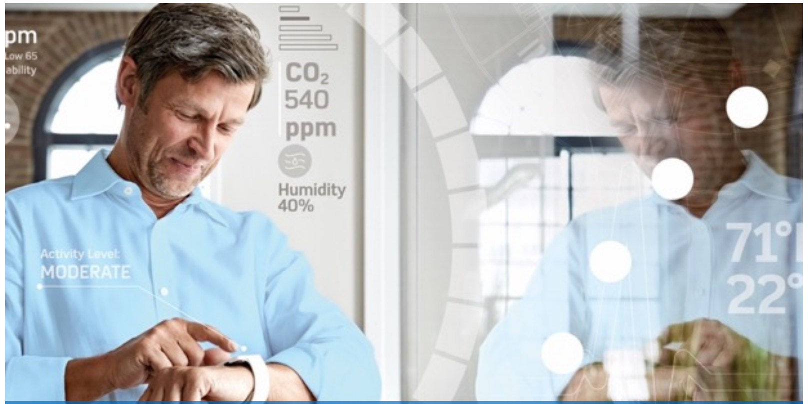
- ☐ United States (65)
- ☐ India (22)
- ☐ Philippines (17)
- ☐ Ireland (12)
- ☐ China (8)
- ☐ Romania (5)
- ☐ Germany (3)
- ☐ Great Britain (1)
- ☐ Italy (1)
- ☐ Japan (1)
- ☐ Taiwan (1)

Technologies for Today’s and Tomorrow’s Innovations

Autonomous Transportation and Machines

Automotive Electrification

5G and Next-Gen Connectivity



Digital Health

Industry 4.0 and Smart Energy

Immersive Consumer Experiences

Commitment to Innovation

Founded	**1965**
Headquarters	**Norwood, MA**
Employees	**~15,000**
Countries	**20+**
Products	**~45,000 SKUs**
Customers	**125,000**
Publicly Listed	**NASDAQ:ADI** Part of S&P 500 and NASDAQ 100
Design Centers	**~45**
Global Manufacturing	**U.S. (Massachusetts, California, Washington), Ireland, Philippines**

Over 4700 patents and $4 billion R&D investment in the past 10 years.

ADI at GNU Radio Conference 2019

https://www.analog.com/gnu

- Monday
  - 11:15-11:45
    - Mega Hertz, Mega Samples, Mega bits, Mega Confusing
  - 15:45-16:15
    - Determining Optimized Radio settings for specific waveforms
- Tuesday
  - 14:00-14:30
    - The Future of Digital RFICs
  - 16:30-17:00
    - Building a radio with ADALM2000 (m2k) and spare parts
- Wednesday
  - 10:30-11:00
    - gr-iio: Nuances, Hidden Features, and New Stuff
  - 13:30-17:00
    - ADALM-PLUTO Workshop (Discovery Room)
  - 14:30-15:00
    - Multichannel phase coherent transceiver system with GNU Radio interface
- Thursday
  - 11:00-11:30
    - Enabling Precise Timing Control in SDRs
  - 13:30-17:00
    - ADALM-PLUTO Workshop (Discovery Room)

GNU Radio Demos

- **ADRV9009-ZU11EG 4 Rx, 4 Tx Phase Coherent System on Module**
  - A complete multi-transceiver system will 4 transmit and 4 receive fully phase aligned will be demonstrated. This is a single system-on-module (SOM) solution, ideal for phased array applications and is even expandable so multiple SOMs can be synchronized together to build large channel count systems.

- **ADALM-PLUTO Fosphor (FFT done inside FPGA)**
  - A hardware-accelerated implementation of everyone's favorite out-of-tree module gr-foshor. Inspired by the RFNoC variant, this version has been specifically designed for the ADALM-PLUTO.

- **ADALM2000 Ring Oscillator for HF Radio Reception**
  - Powered with GNU Radio and with a few external components, the ADALM-2000 (M2K) can be turned into a direct sampling or direct conversion SDR RF receiver. This demo will introduce a simple LNA, active mixer and PLL frontend circuits for the M2K and show how they can be controlled from the GNU Radio flowgraph.

- **Enabling AD9361 Fast Frequency Hopping with GR-IIO**
  - Learn how custom IP cores can be created and controlled through the ADI ecosystem leveraging both IIO and GNU Radio, enabling high-speed control over the fast frequency hopping mode of the AD9361 transceiver.

- Amplifiers
- Analog Functions
- A/D Converters (ADC)
- Audio & Video Products
- Clock & Timing
- D/A Converters (DAC)
- High Speed Logic & Data Path Management
- Industrial Ethernet
- Interface & Isolation
- Optical Communications & Sensing
- Power Management
- Power Monitor, Control, & Protection
- Processors & DSP
- RF & Microwave
- Sensors & MEMS
- Switches & Multiplexers


Aerospace and Defense


Analog Garage


Autonomous Transportation


Systems Development


Automotive Electrification and Infotainment

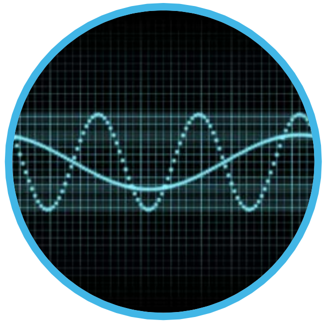

Communications


Consumer


Energy


Healthcare


Industrial Automation


Instrumentation


Power

ADRV9009 : Released ~2018

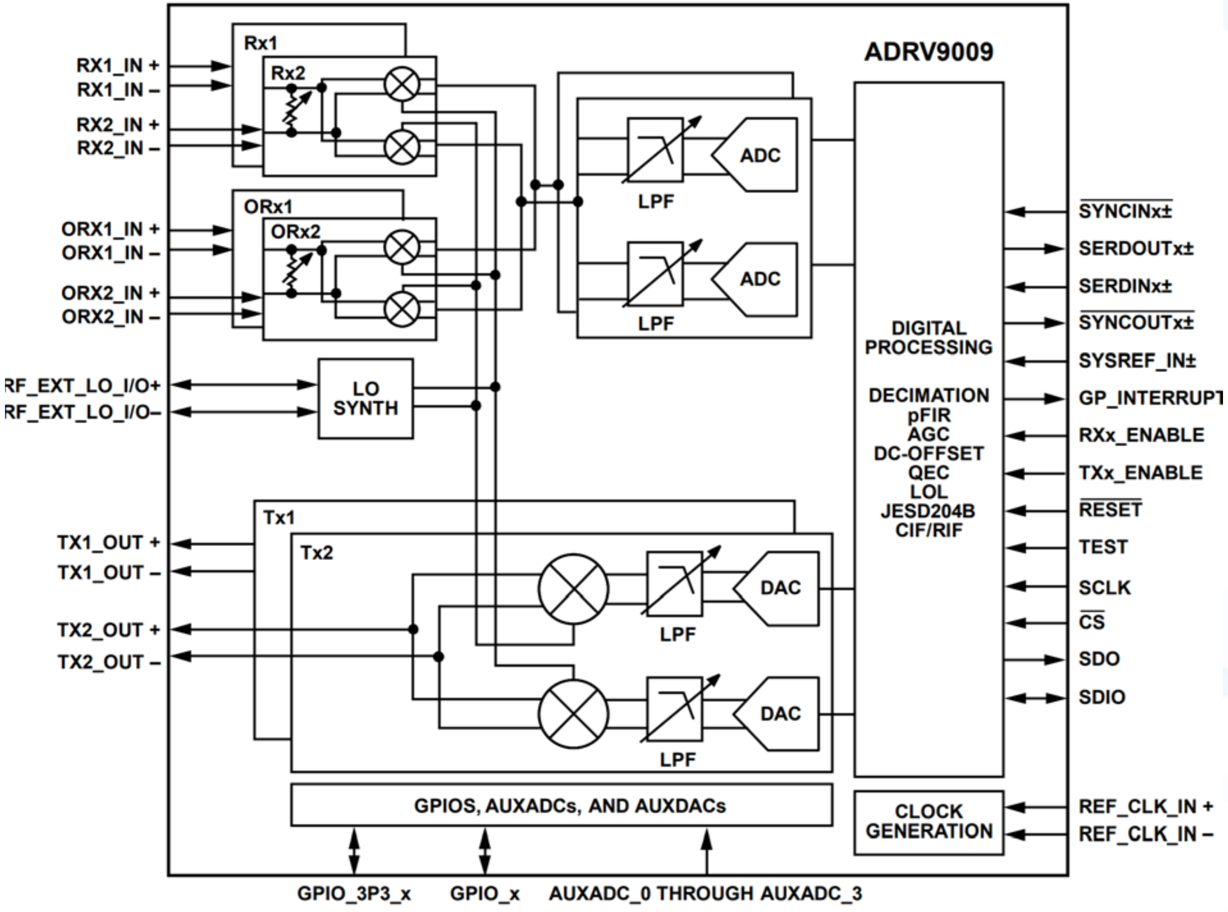
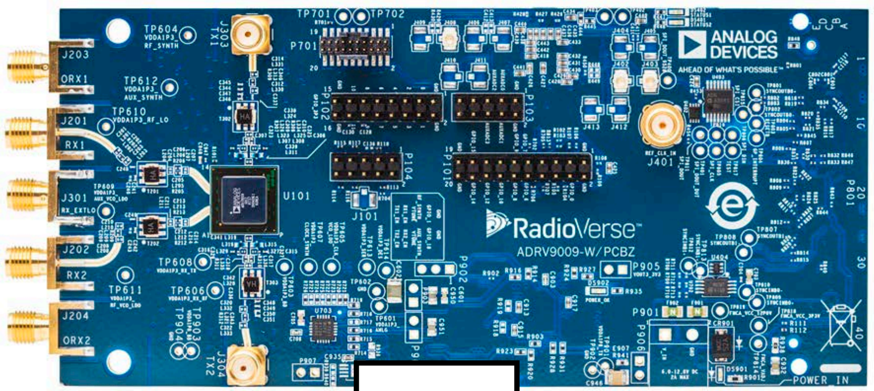
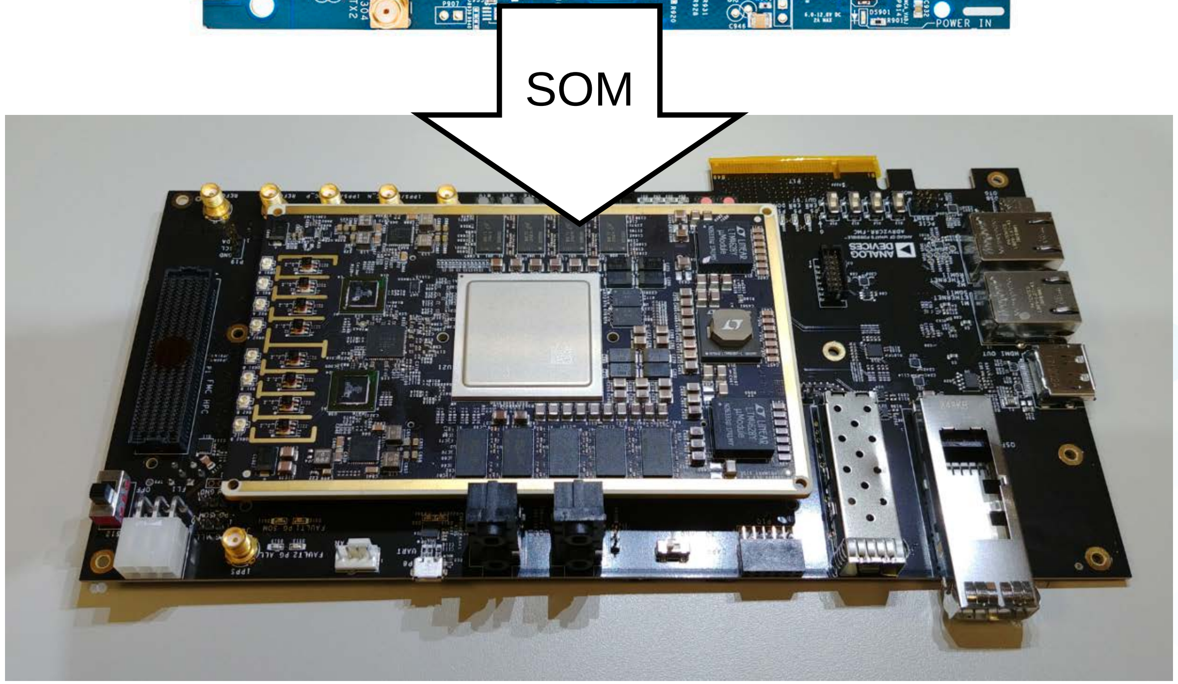


Figure 1.

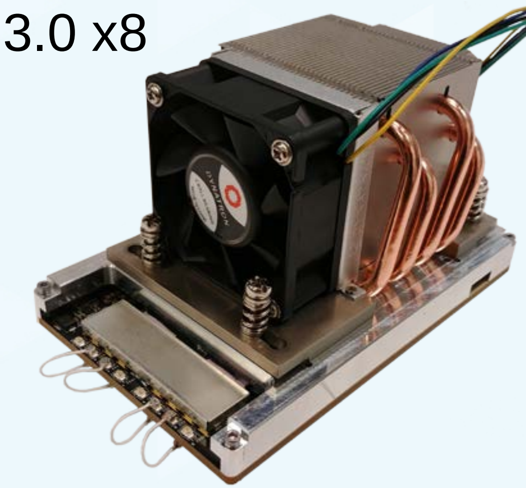
- Dual transmitters
- Dual receivers
- Dual input shared observation receiver
- Maximum receiver bandwidth: 200 MHz
- Maximum tunable transmitter synthesis bandwidth:
- 450 MHz
- Maximum observation receiver bandwidth: 450 MHz
- Fully integrated fractional-N RF synthesizers
- Fully integrated clock synthesizer
- Multichip phase synchronization for RF LO and baseband
- clocks
- JESD204B datapath interface
- Tuning range (center frequency): 75 MHz to 6000 MHz

Next Generation RFSOM: ADRV9009-ZU11EG





- Dual ADRV9009 + Expandable daughterboard
  - 4T and 4R or 8T and 8R (with daughterboard)
- Xilinx Ultrascale+ ZU11EG
  - 653K logic cells
  - 2,928 DSP slices
- 4 GB DD4 ECC for PS
- 2x 2 GB banks dedicated for PL
- SFP+, QSFP+, USB3, PCIe 3.0 x8
- Available Q1 2019



Analog Devices RF SOM (System on Module)

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Production Ready Module, MIL-202 qualified (projected)

ADRV9009-ZU11EG RF SOM : $7999

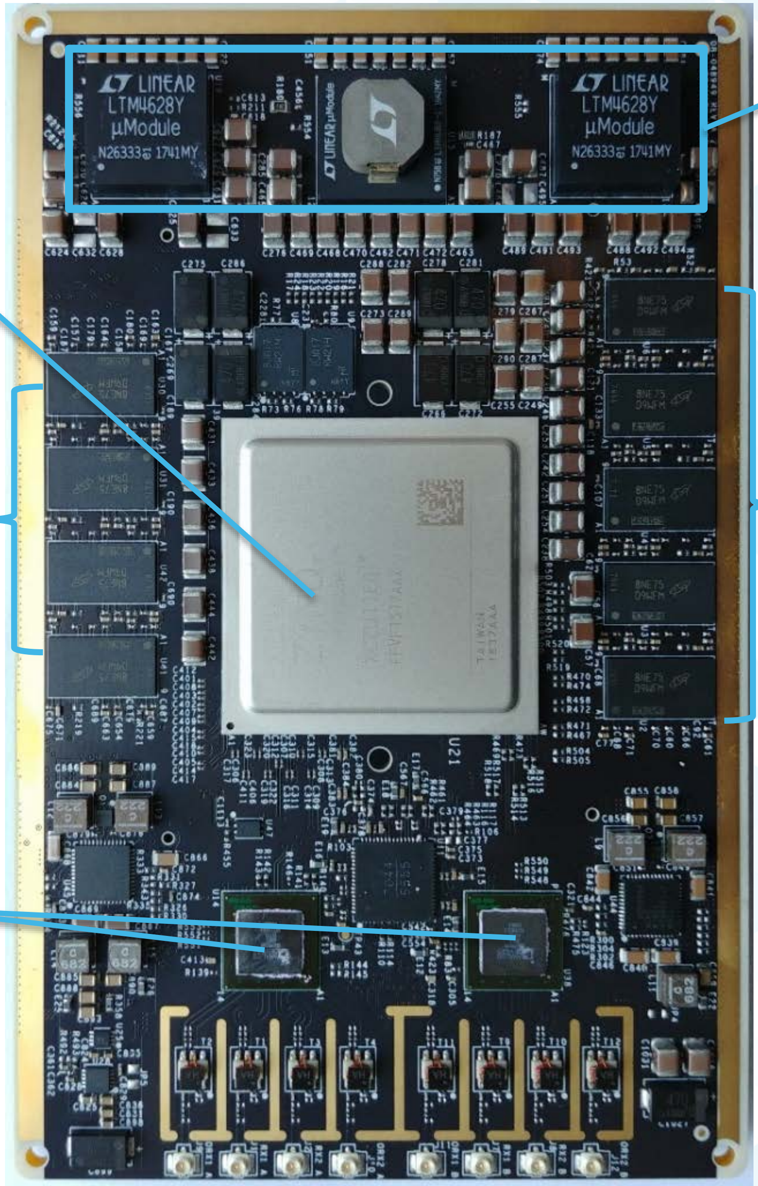
- Processor
  - Quad Core ARM Cortex A53 (1.5 GHz each)
  - L1 cache : 32 KB Instruction, 32 KB Data
  - L2 cache : 512 KB
- Processor
  - Dual ARM R5 (600 MHz each)
  - L1 cache : 32 KB Instruction, 32 KB Data
  - 128KB Memory per core
- GPU : Mali-400 MP2 up to 667MHz
  - L2 Cache 64KB
- FPGA
  - Kintex Ultrascale+ Fabric
  - 653k Logic Cells
  - 52.7 Mb Block RAM
  - 2,928 DSP Slices
  - Vivado license required

Xilinx ZU11EG

- 2 Banks of 2 Gbyte (x32) DDR4 for PL (Radio)
- 128 Mbyte SPI Flash
- MicroSD Card (lockable)

- ADRV9009 RF Transceiver
  - 245.76 MSPS Rx (200 MHz Bandwidth)
  - 491.52 MSPS Tx (450 MHz Bandwidth)
  - 491.52 MSPS Observer (450 MHz Bandwidth)
  - 128-tap FIR Filters for equalization
  - Multi-chip phase synchronization for RF LO and baseband clocks
  - 75 – 6000 MHz tuning range
  - 2 Rx, 2 Tx, 2 Tx Monitor (per device)

ADI ADRV9009

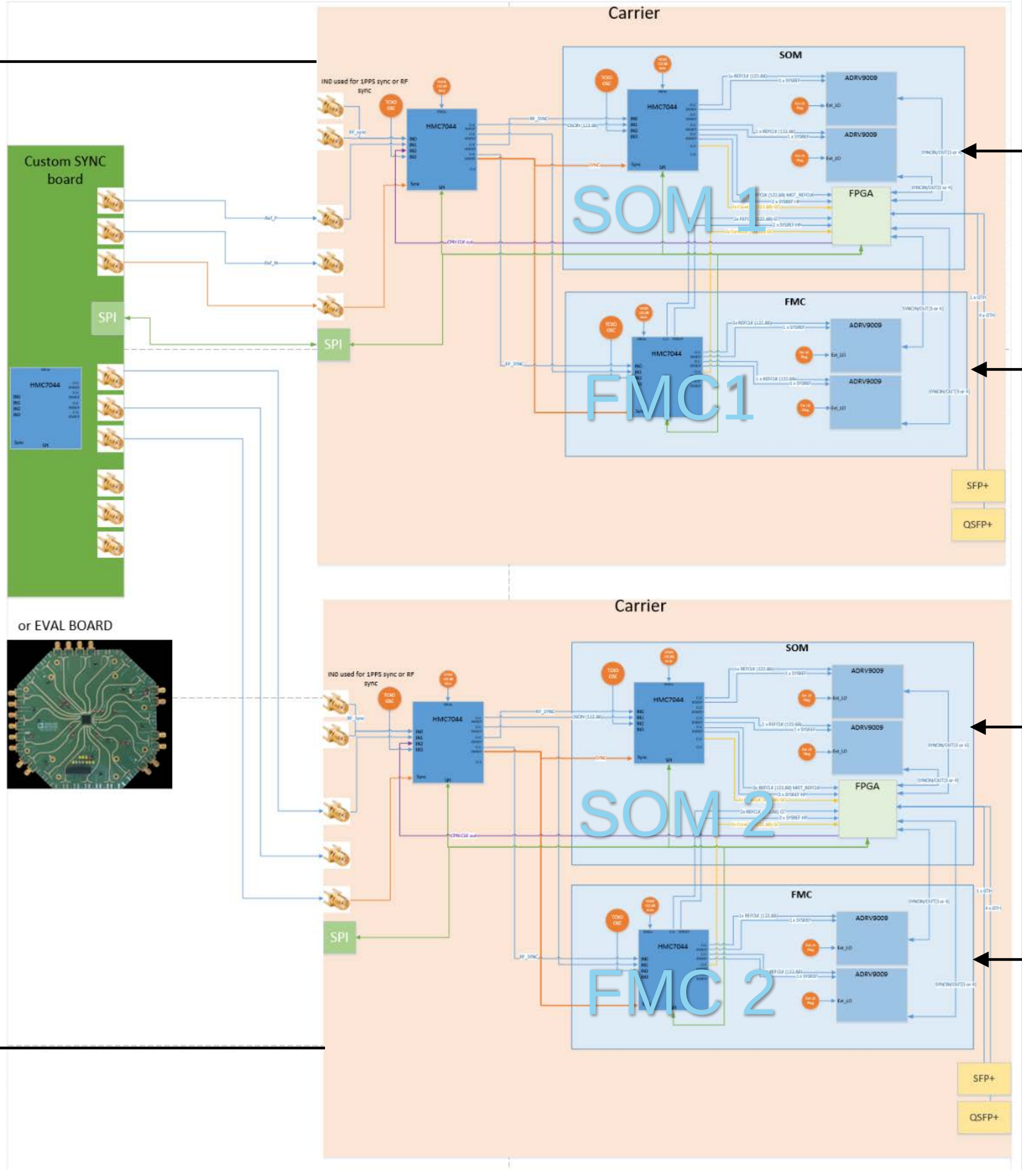


- Power Modules (2x16A, 1x40A)
  - 12V input
- 4 Gbyte DDR4 + ECC for Processors
- 128 Mbyte SPI Flash
- USB 2.0 (OTG Controller + Phy)
- 4 x GTR share amoung:
  - PCIe® Gen2 x4,
  - 2x USB3.0,
  - SATA 3.1,
  - DisplayPort,
- 4x Tri-mode Gigabit Ethernet
  - 1 x 10/100/1000 Ethernet Phy
- 2xUSB 2.0
  - 1 USB 2.0 Phy
- 2x SD/SDIO
  - 1x MicroSD Card (lockable)
- 2x UART,
- 2x CAN 2.0B,
- 2x I2C,
- 2x SPI,
- 4x 32b GPIO
- 24 x GTH (12.5 Gb/s)
  - 2x 100G Ethernet MAC/PCS w/RS-FEC
  - PCI Express® Gen 3 (x16)
  - External JESD204B ADRV9009 Devices

- Full Linux based reference design
- Fully integrated and tested system
- Common connector: HPC FMC
- Digital I/O pins :
- U.FL connectors : 15

Multi-SOM Sync
scalable up to 8 cards x 8 channels = 64 Rx, 64 Tx

PCIe



4 x Rx
4 x Tx

4 x Rx
4 x Tx

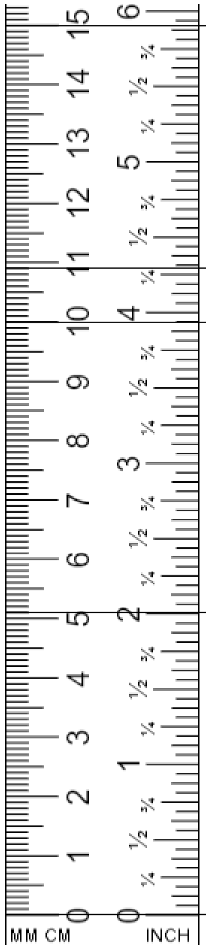
4 x Rx
4 x Tx

4 x Rx
4 x Tx

PCIe

Size comparison

To Scale (as good as you can get in powerpoint)



51 x 30 mm
15.3 cm^2

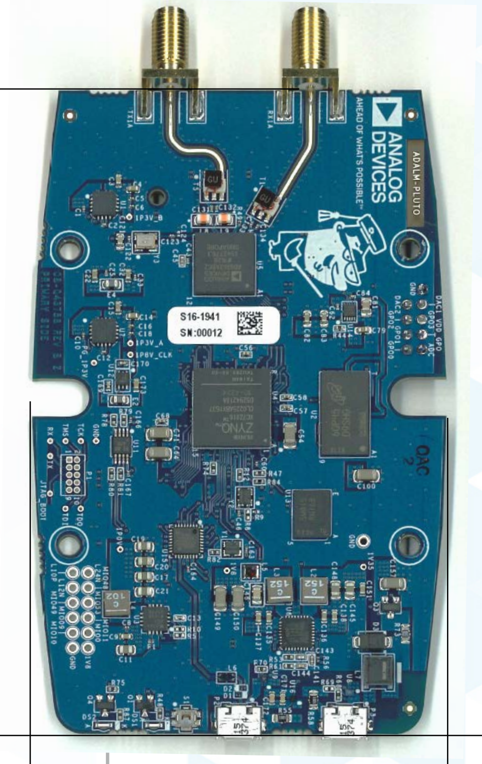
Epiq Solutions
Sidekiq Z2

100 x 62 mm
62 cm^2

ADRV9364-Z7020
ADRV9361-Z7035

109.14 x 69.55 mm
75.9 cm^2

ADALM-PLUTO



150 x 94 mm
141 cm^2

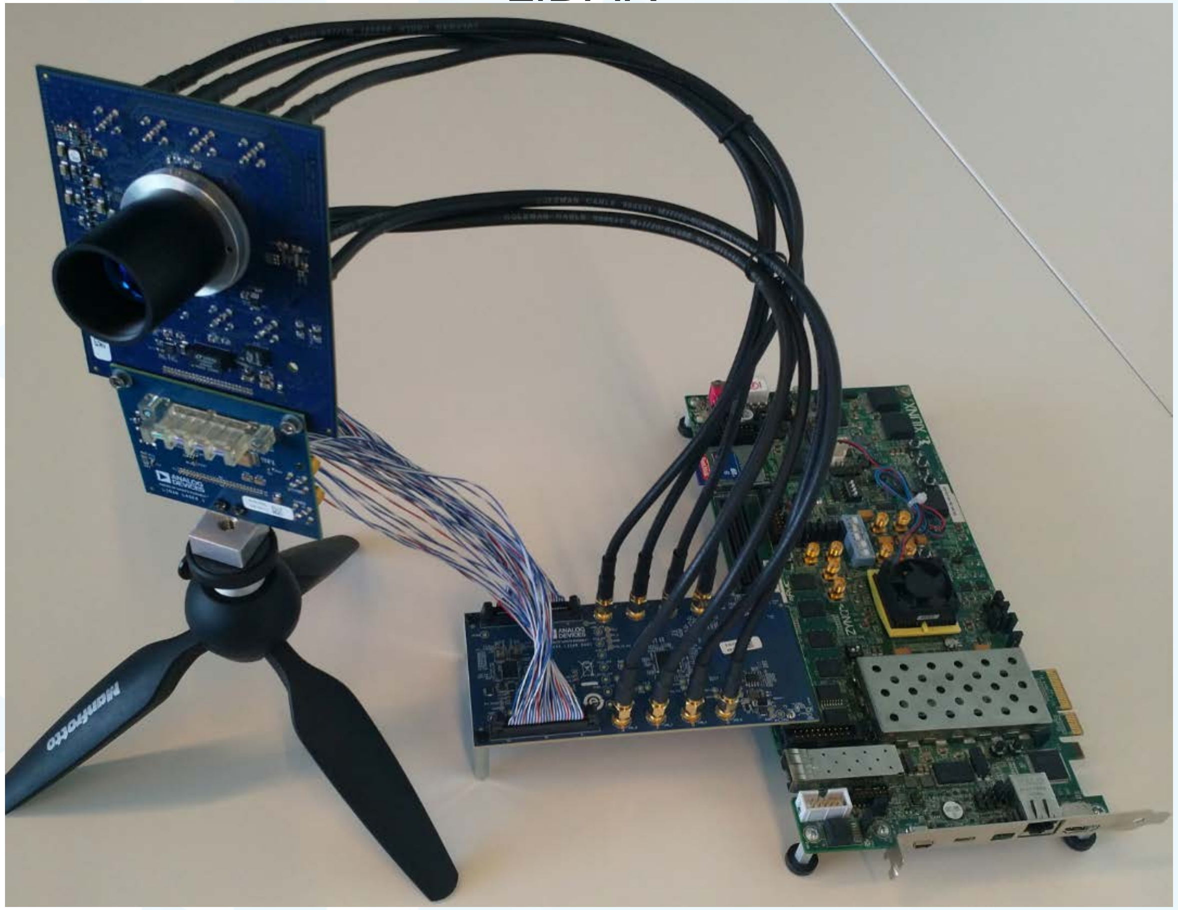
ADRV9009-ZU11EG

Others

3DToF

AD-96TOF1-EBZ

LiDAR



AD-FMCLIDAR1-EBZ

Sensing Technology Landscape (ADI have solutions in these areas)

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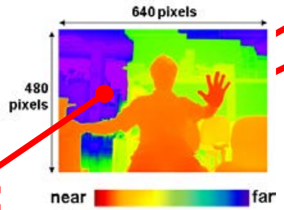
	Depth LIDAR	LIDAR	RADAR
SPECS	CCD Sensor, VGA Depth Image Wide FOV Accurate at short Ranges 5cm at 5M Frame Rate 10-60Hz	Lidar 16 Point TIA 16 Pixel Image Narrow FOV Accurate over longer ranges 5cm at 40M	24GHz Chipset FOV 120 degree Accurate at long range 60cm @ 150 M
POS/NEG	Ambient Light Rejection Interference Cancellation Sensitive to Environment	Ambient Light Rejection Interference Cancellation Sensitive to Outdoor Envir	Works well in Harsh Environ Scalable Designs
APPS	3D Scanning Navigation People Counting	Object Detection Angular Position. Distance Measurement	Road-Railway Sensors Intelligent Lighting Building Security – Occupancy Detection Surveillance – IP Network Camera



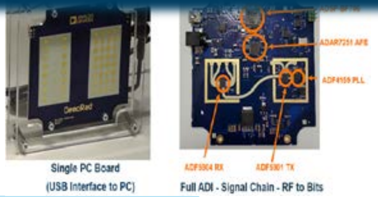
10 m

Depth LIDAR

60 m

LIDAR

150 m



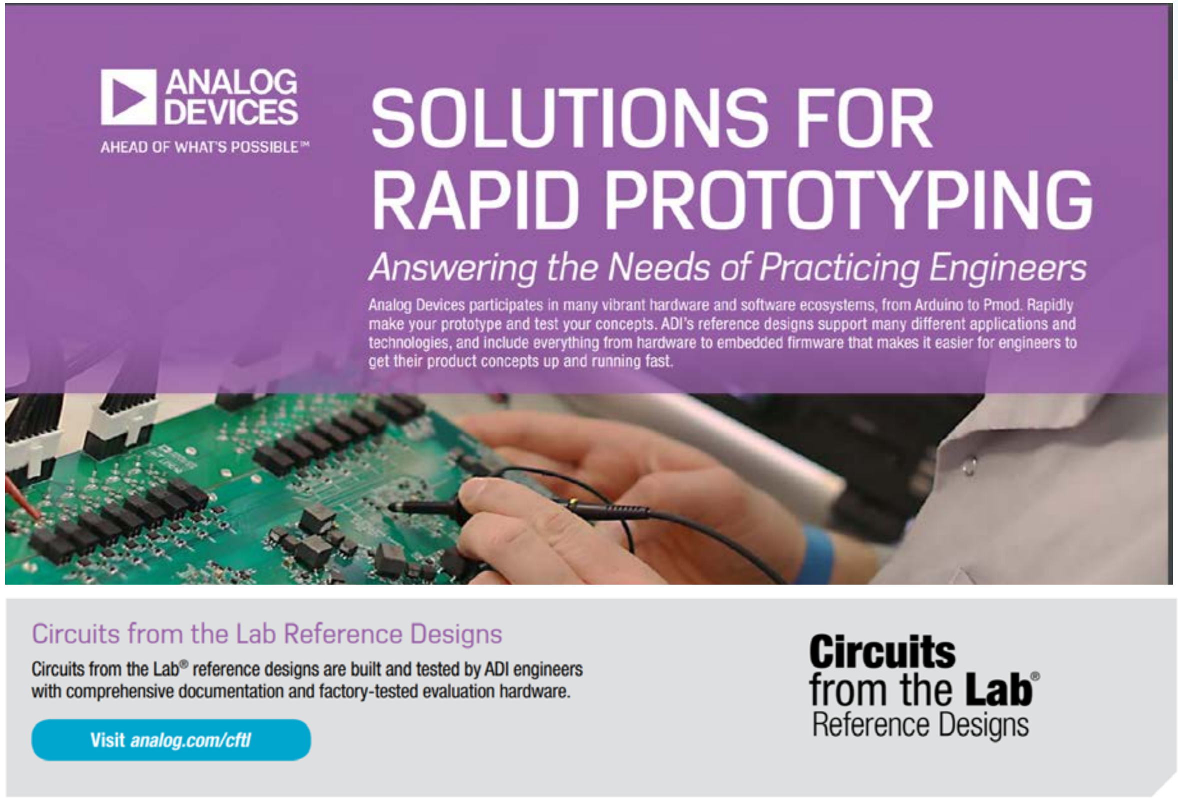
RADAR

S

RANGE/DISTANCE

INDOOR → OUTDOOR

GRCon



Dual RF RMS Power Detector

- Measure forward and reverse rms power
- Good up to 7 GHz
- SMA input connector
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RF/Microwave RMS Power Detector

- 100 MHz to 40 GHz
- SMA input connector
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RF Gain and Phase Detector

- Low frequency to 2.7 GHz
- SMA input connector
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TruPWR™ RMS Detector

- 50 MHz to 9 GHz
- SMA input connector
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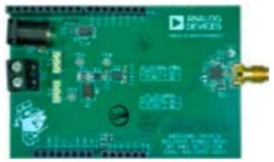


https://www.analog.com/media/en/news-marketing-collateral/solutions-bulletins-brochures/Solutions-for-Rapid-Prototyping.pdf

Active Learning

Hands on active learning transforms educational process

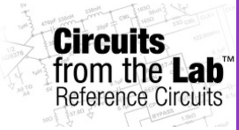
Collaborating with faculty to create inspirational curricula

- Trusted partner for technology initiatives
- Modular courseware material allows dynamic educational content
- Affordable kits and instruments available for students and the classroom

Courseware:

- Engineering Discovery
- Circuit I & II Lab Activities
- Electronics I & II
- Electronics I & II Lab Activities
- Online Teaching Materials
- Virtual Classroom - Questions and support for courseware and modules.

Explore **Build** **Communicate**



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