ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

ADI solution for RF test instruments

Eric Cai

Jay Huang

Industry-Leading Financial Profile with **Scale**, **Scope**, and **Diversity**

$87B
market cap as of end of fiscal Q1 2023

26%[2]
year-over-year revenue growth

125k+[2]
customers across diverse markets and geographies

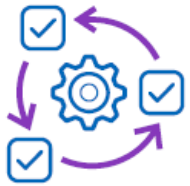
~80%[2]
of revenue derived from products that individually contribute 0.1% or less

1. Industrial automation, healthcare, aerospace, instrumentation and measurement, and energy management.
2. Information as of end of fiscal year 2022

Instrumentation segment snapshot

Market leader in high performance signal chains across precision, micromodule power, isolation, high-speed, & RF

- **20,000+** customers
- **~30,000** SKUs
- **Strong Technology leverage**
  Aligned with all secular mega-trends



AUTOMATED TEST EQUIPMENT (ATE)

Semiconductor
Portable devices
System level test

ELECTRONIC TEST & MEASUREMENT (ETM)

Wireless & optical coms
Satcon & aerospace
Automotive

SCIENTIFIC INSTRUMENTS

Life sciences
Environmental monitoring
Geological exploration

SYSTEMS APPLICATIONS

Reference Designs, Signal Chains, Technical Support

R&D and Field Deployed Measurement

CHALLENGES

- Higher working voltages and switching speeds
- New battery chemistries
- Increasing measurement throughput
- Ever higher speeds and wider bandwidths

COMS

5G (low/mid/mmW) deployment, 6G research, Terabit optical links

Automotive

Advanced digital twins – HIL RF/mmW for ADAS test
Accelerating battery manufacturing

Key ADI Technologies

Power
High efficiency instrumentation, High margin attach

Precision with speed
Bolt & Bullseye platforms

HS Mixed Signal
5G, 6G Signal generation

RF/mmW Signal Chains

Embedded Digital Processing and Control

High Voltage & ISO
Edison & Everest Platforms

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Technology focus area

ADI RF & Microwave Technology Supports Full Signal Chain Sell

Frequency Generation

Clocks & Synthesizers

Low Jitter (<25 fs rms)

Higher Fundamental Frequency (26.5 GHz)

PLL
Low Jitter with High FOM (-234 dBc)

Higher Integration

RF & Optical Power Detection

RF Sampling
Wider Bandwidth (4000MHz IF)

Higher Sampling Rates (>10Gsps)

Optical
Higher Dynamic Range (140 dB)

Shorter Response

Frequency Conversion & Tunable Filters

Mixers
Ultra Wideband (67GHz+)

Lower Conversion Loss

Filters
Multi Octave (30MHz-32GHz)

Switches, Attenuators & Beamformers

High Switch/Atten Frequency (70GHz+)

Lower Loss Switching (<1dB) & High-Power Handling (>80W)

Wider Multi-Octave Operating Bandwidths

COMM's Mkt. Beamforming from 8 to 48 GHz

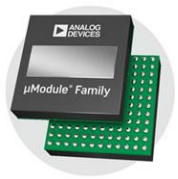
RF Amplifiers

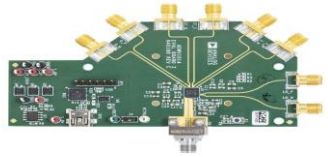
Higher Frequency (95 GHz)

Wider Bandwidth

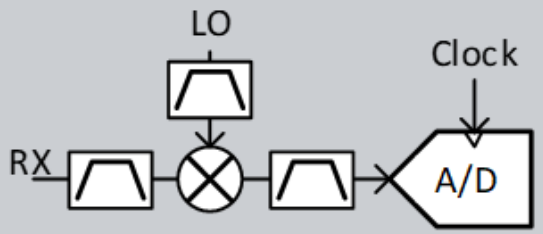
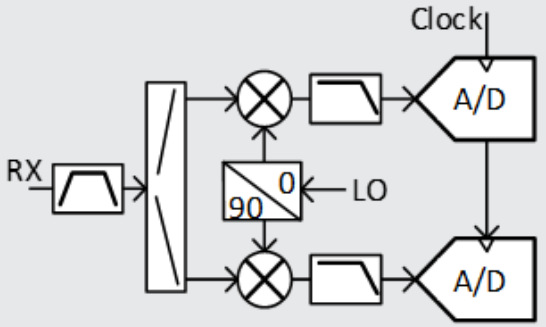
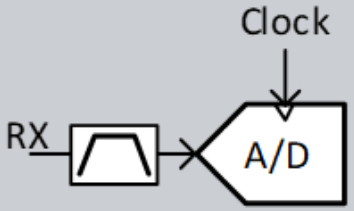
Higher Power

Integrated Switch & Amplifier Functions in Single Package (SIP)





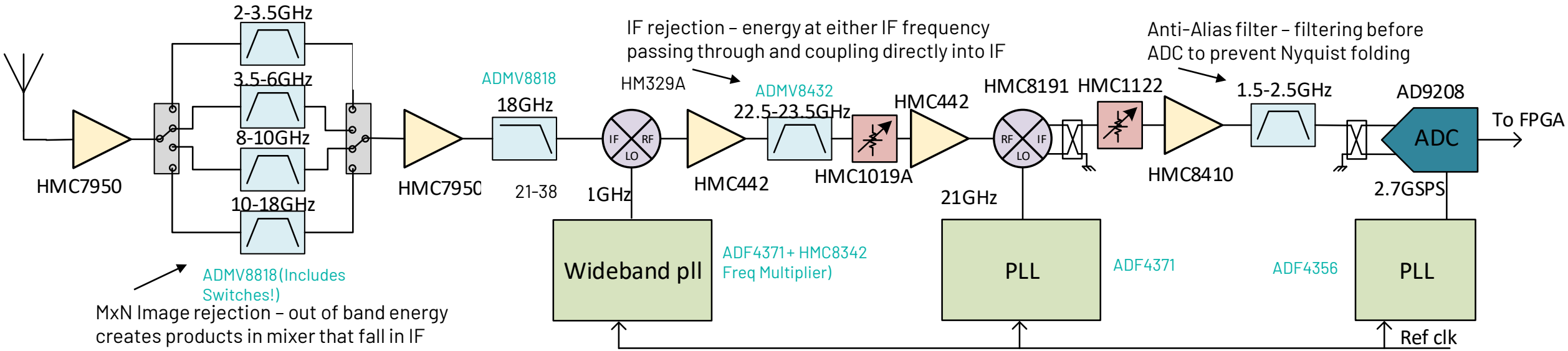

RF Architectures

Type	Configuration	Benefits	Challenges
Heterodyne		• Proven/Trusted • High Performance • Optimum Spurious • High Dynamic Range • EMI Immunity	• SWaP (Size, Weight, Power) • Many Filters (some cannot be integrated) • Image Rejection
Direct Conversion (Zero IF)		• Maximum A/D BW • Simplest WB option • Low Cost & Power Consumption • Less Filtering (mostly integrated on chip) • LO Leakage • Image Rejection	• Image Rejection -IQ Imbalance • In-band IF harmonics • LO Radiation (centered in band) • EMI Immunity (IP2) • DC and 1/f noise
Direct Sampling		• No Mixing • Practical at L/S Band	• A/D Input BW • Gain not distributed across Frequency • Requires High Speed Sampling Data Converters

Fill In Wideband RX Super Heterodyne Signal Chain

- Populate rest of signal chain with frequency appropriate amplifiers, switches, filters, mixers, PLL/VCO

- Add any desired features such as digital step attenuators
  - Can be used for gain leveling and Automatic Gain Control (AGC)



Precision Technology

>250 problem solvers, >1,500 solutions

Ultralow N

>300 Active Patents

Where the Data is Born –

Source of data and bridge in connecting physical to digital world

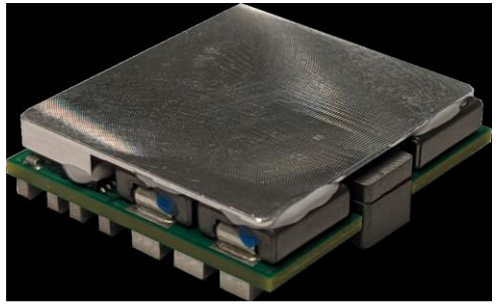
Standard Precision Products –

Technology Leadership for 40+ years with the most advanced precision ADC and DAC cores as well as complete analog signal chains such as amplifiers, voltage references and signal chain umodules

ADI Internal IP Provider –

Develop break through converter cores that advance figure of merit as well as many system value adds such as low power, fast precision & high voltage operation.

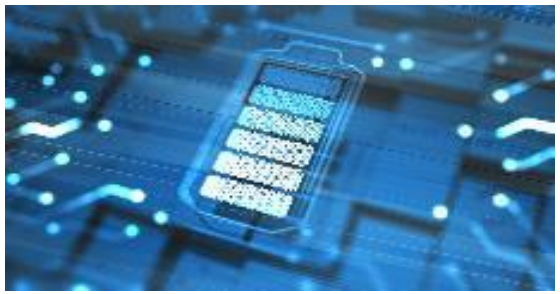
Industry Leading power Technologies



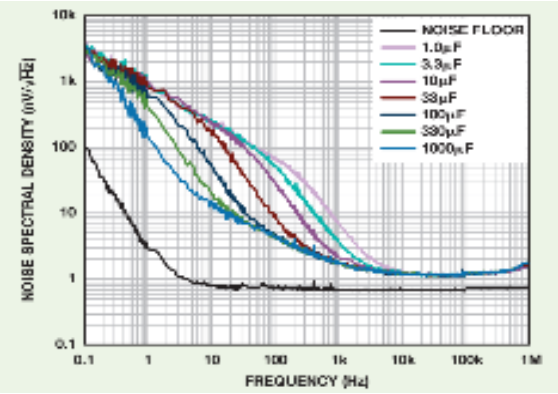
µModules

LTSpice & tools

Silent Switcher® 3



nanoPower



Ultralow Noise LDOs

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

ADI products and solutions in RF instruments

Communications Test Application Examples

Wireless Communications Test

- Highly integrated for 5G, WiFi Test
- 5G Signaling Test; 5G call with DUT
- RF characteristics, protocol compliance

High Speed Benchtop Equipment

- Spectrum Analyzers, VNAs
- Signal Generators
- Channel Emulators
- RF to mmWave measurements

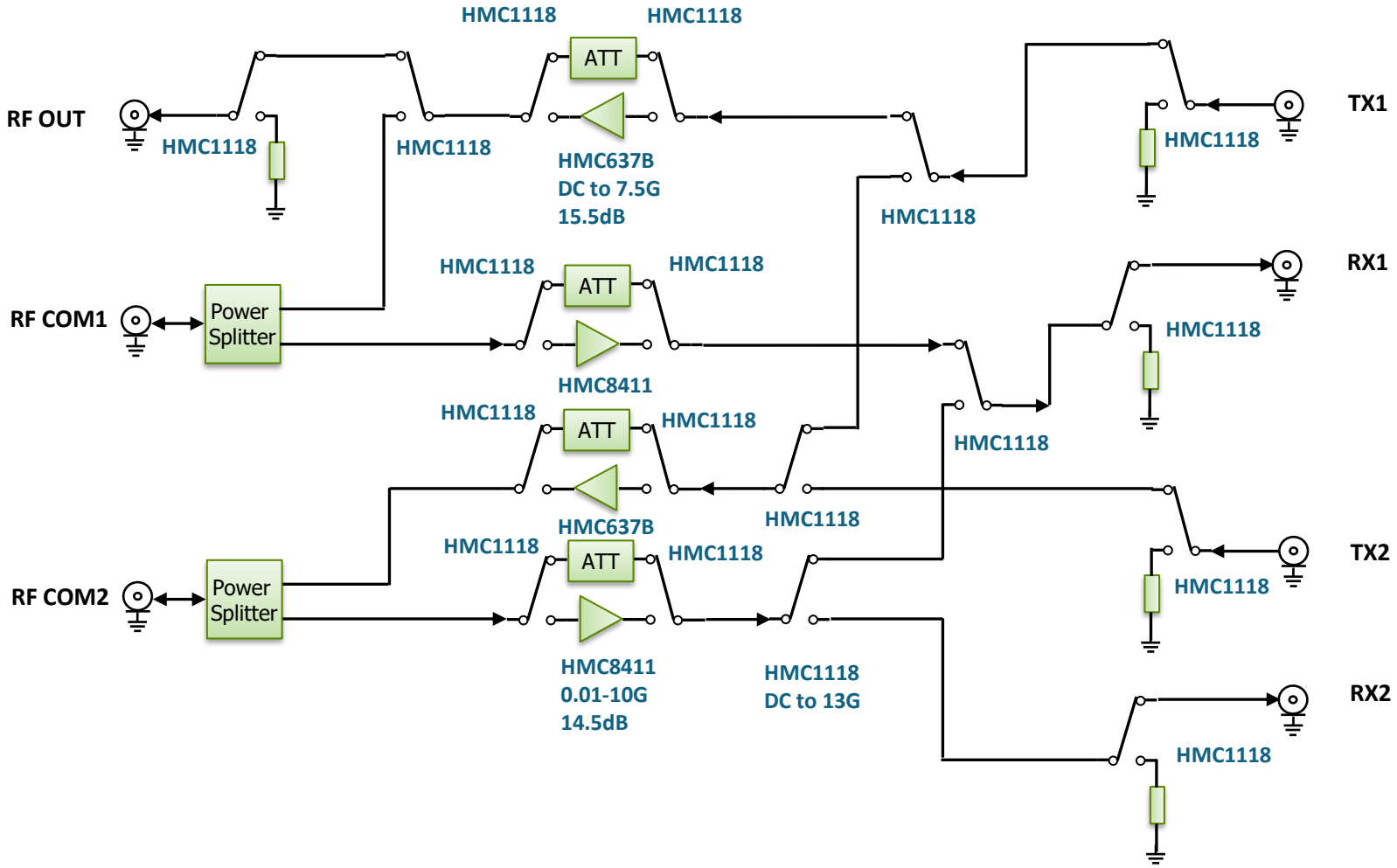
Portable Testers

- Handheld Spectrum Analyzers, VNAs
- Field Deployed
- Low Power dissipation, small footprint

Wired Communications Test

- Time domain, High Speed Data (PCIe, GbE)
- Datacenters, High Speed Computing
- Oscilloscopes, Digitizers, Bit Error Rate Testers
- OTDR & Protocol Analyzers

Universal Wireless Tester --- Front End Signal Path

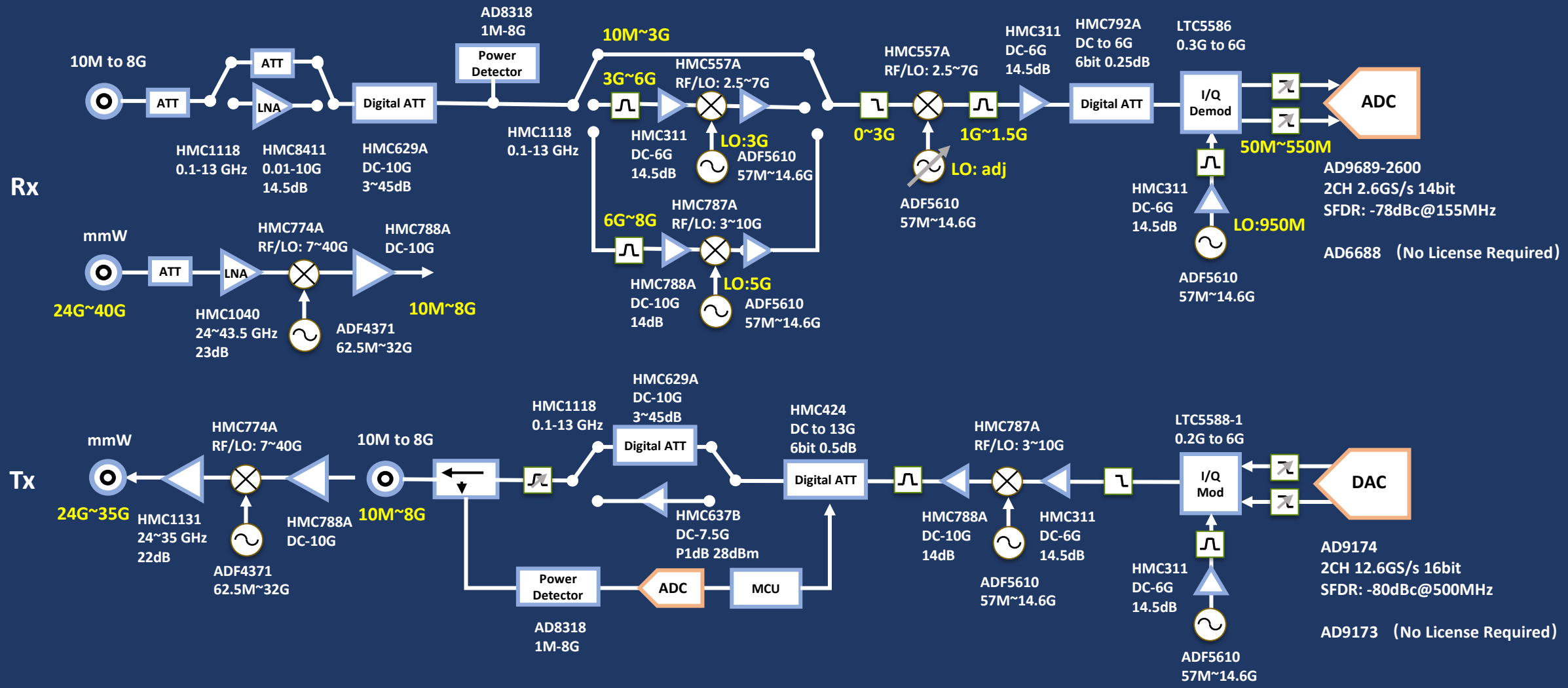


IN/OUT PORTS

10dbm max

To Internal PORTS

5G Universal Wireless Tester --- ADI 500M BW Sub 8GHz / mmW Signal Chain



LO Design --- Strengths of DDS & PLL

Some Strengths of both techniques

- **PLL**
  - Can achieve GHz frequencies
  - Fractional-N design achieves good frequency resolution
  - Can be very low power
  - Does not require reconstruction filter
  - Reference frequency lower than output frequencies

- **DDS**
  - Extremely high frequency resolution
  - Agile – no settling time or overshoot for frequency shifts
  - Can be phase and amplitude modulated
  - Multiple DDSs can be synchronized
  - Inherently digitally controlled

LO Design --- Limitations of DDS & PLL

Some Limitations of both techniques

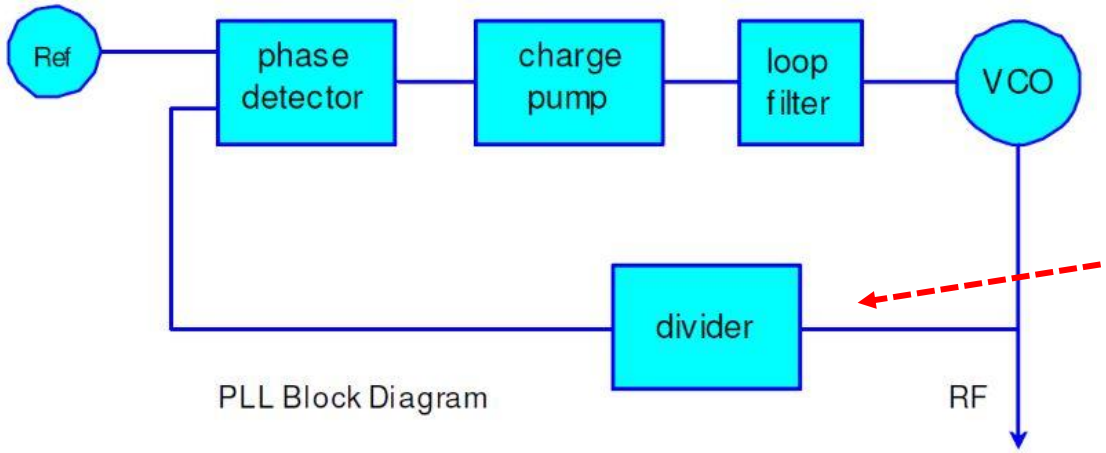
- **PLL**
  - VCO is a critical component
  - Integer-N PLL design limits frequency resolution
  - Loop settling characteristics affect settling time and overshoot during frequency shifts
  - Loop multiplication factor increases phase noise of RF

- **DDS**
  - Requires DDS clock more than 2X desired output frequency
  - Requires external reconstruction filter
  - Higher frequency operation requires more power
  - Output frequency limited to less than half of DDS clock frequency

Combining Strengths – Overcoming Limitations

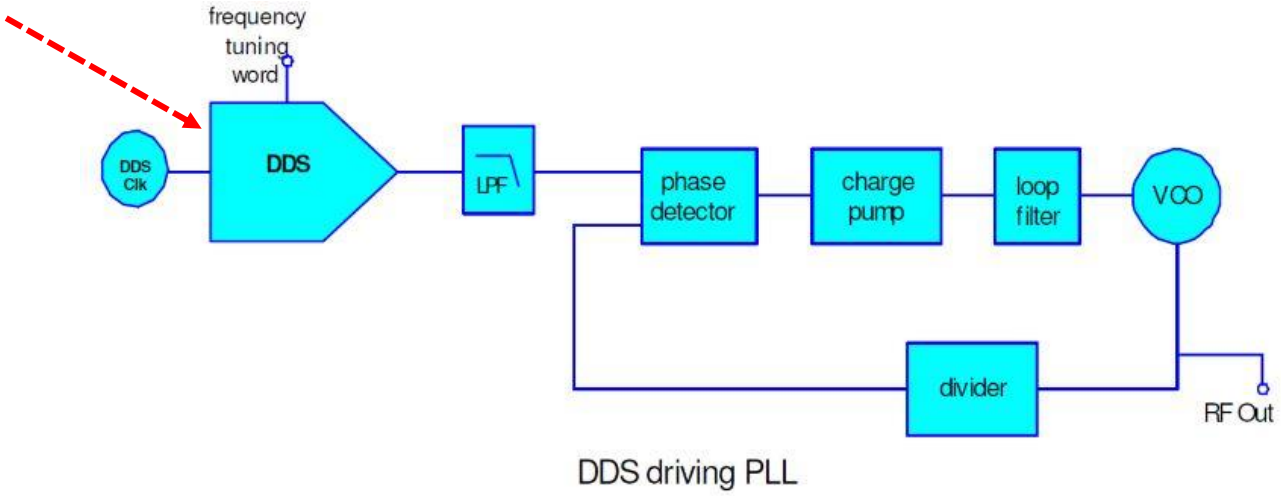
- PLL and DDS techniques can be combined to achieve what neither one alone can manage
- Combining a DDS with a PLL in an RF synthesizer design allows the frequency resolution and controllability of the DDS, and the frequency range of the PLL
- In some architectures the DDS allows for a lower frequency multiplication factor, enhancing phase noise performance
- The PLL can reduce DDS spurs
- Together, PLL and DDS enable high performance RF synthesizer designs

Frequency Synthesizer： with DDS added



1. **Limited Fractional-N and Resolution.**
2. **Divider cause more noise, the fractional is worse.**
3. **This divider can be replaced by DDS.**

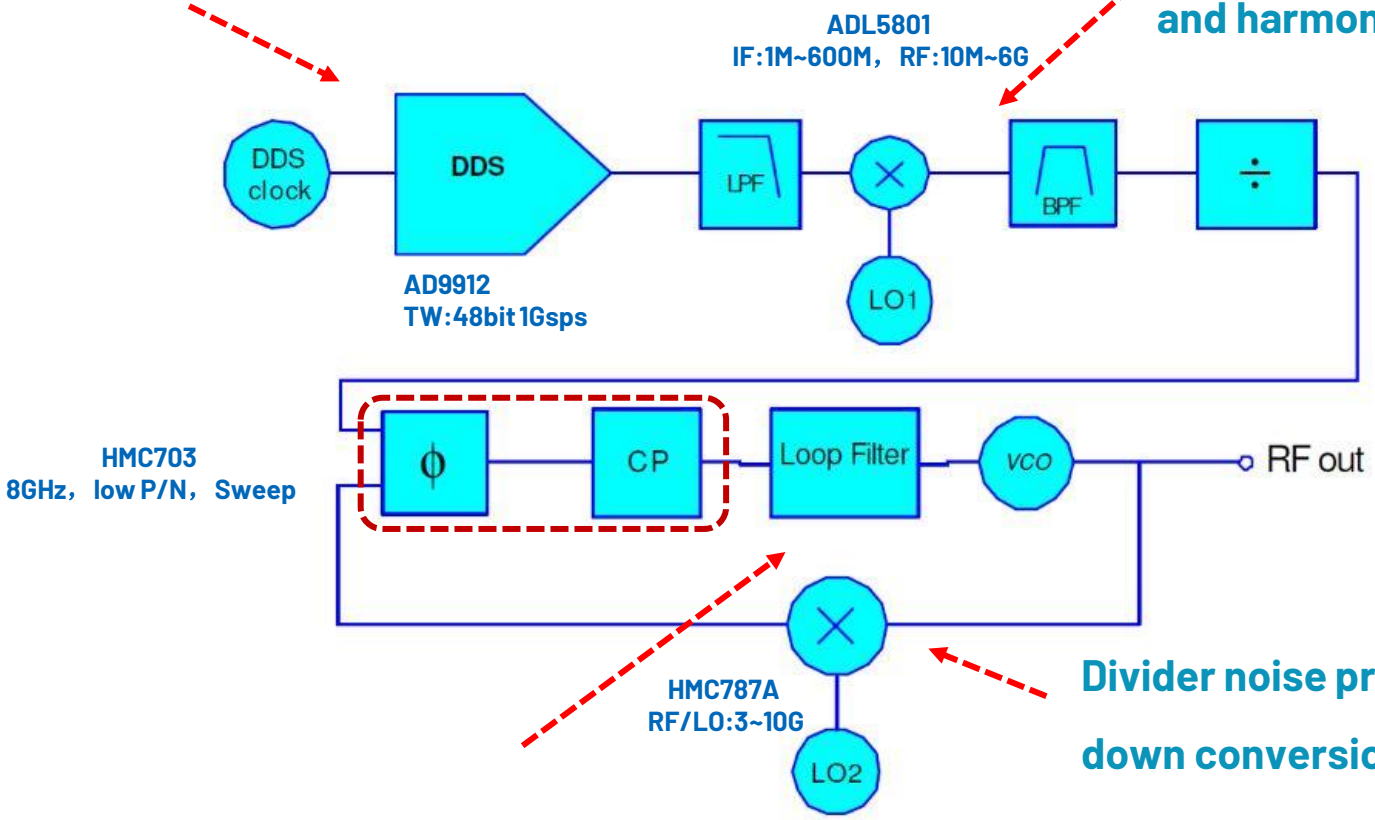
The frequency resolution is improved.



High Performance Frequency Synthesizer： The 1st stage LO of RX

Improved frequency resolution, and fast hopping.

Enhanced higher frequency band，
and harmonic and spur are suppressed.



Divider noise problem is resolved , it also can do down conversion and support higher frequency.

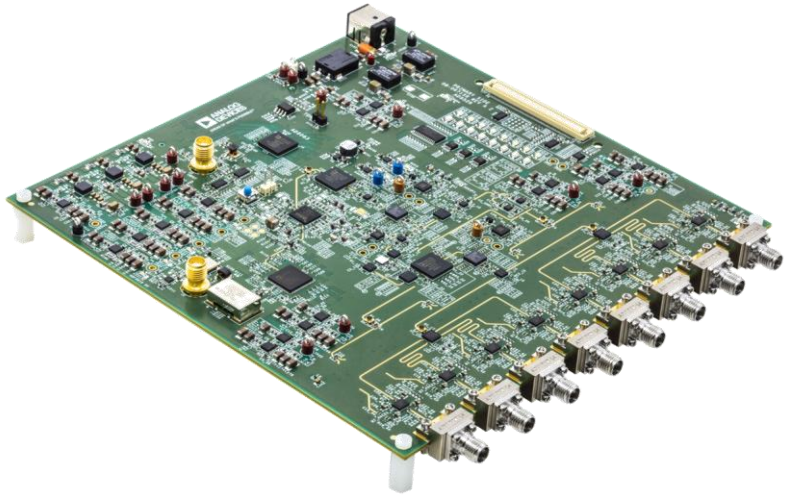
1. Lock time is based on loop bandwidth and VCO calibration speed.
2. It can save lock time if use manual VCO band config or use a stand alone VCO.

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

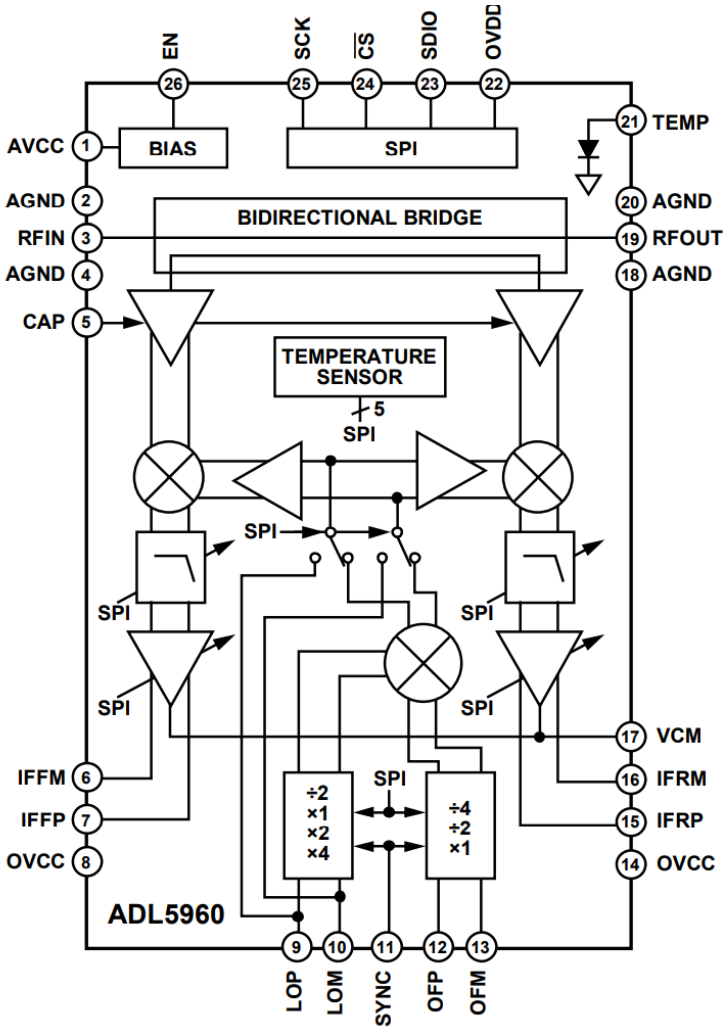
VNA solution

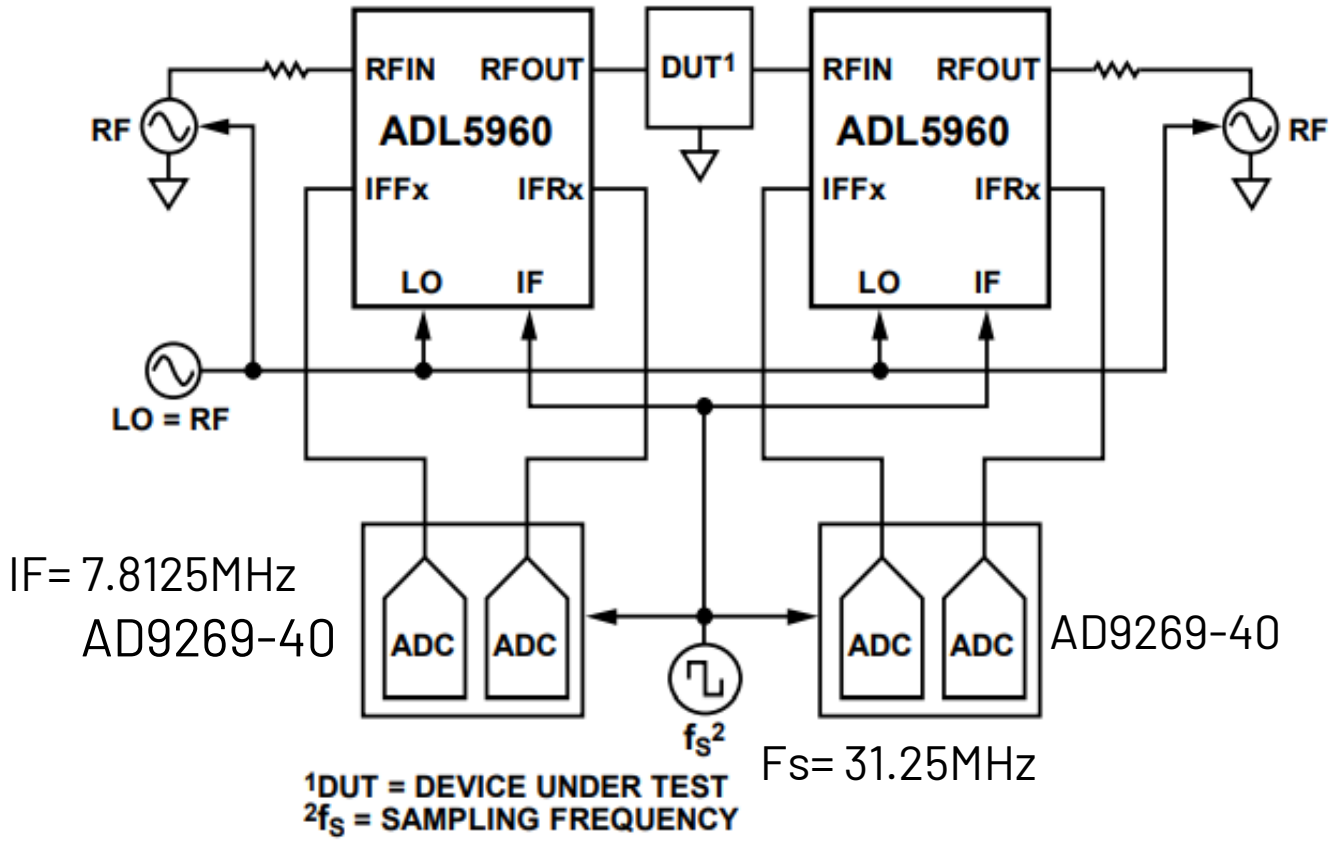
8-Port VNA (Vector Network Analyzer)

- Wide Bandwidth and Small Solution Size
  - 10MHz to 20GHz
  - 7in x 6.5in board
- Fully functional for turnkey evaluation
  - Plugs into Xlinx ZCU102 development board
  - Complete software, firmware and GUI
- Programmable IF Filters and Amplifiers
- LO Frequency Multiplier and Divider
  - 6GHz frequency synthesizer as local oscillator to measure 20GHz
- Offset Frequency Mixer and Divier
  - RF and LO interfaces requires only a single high frequency source



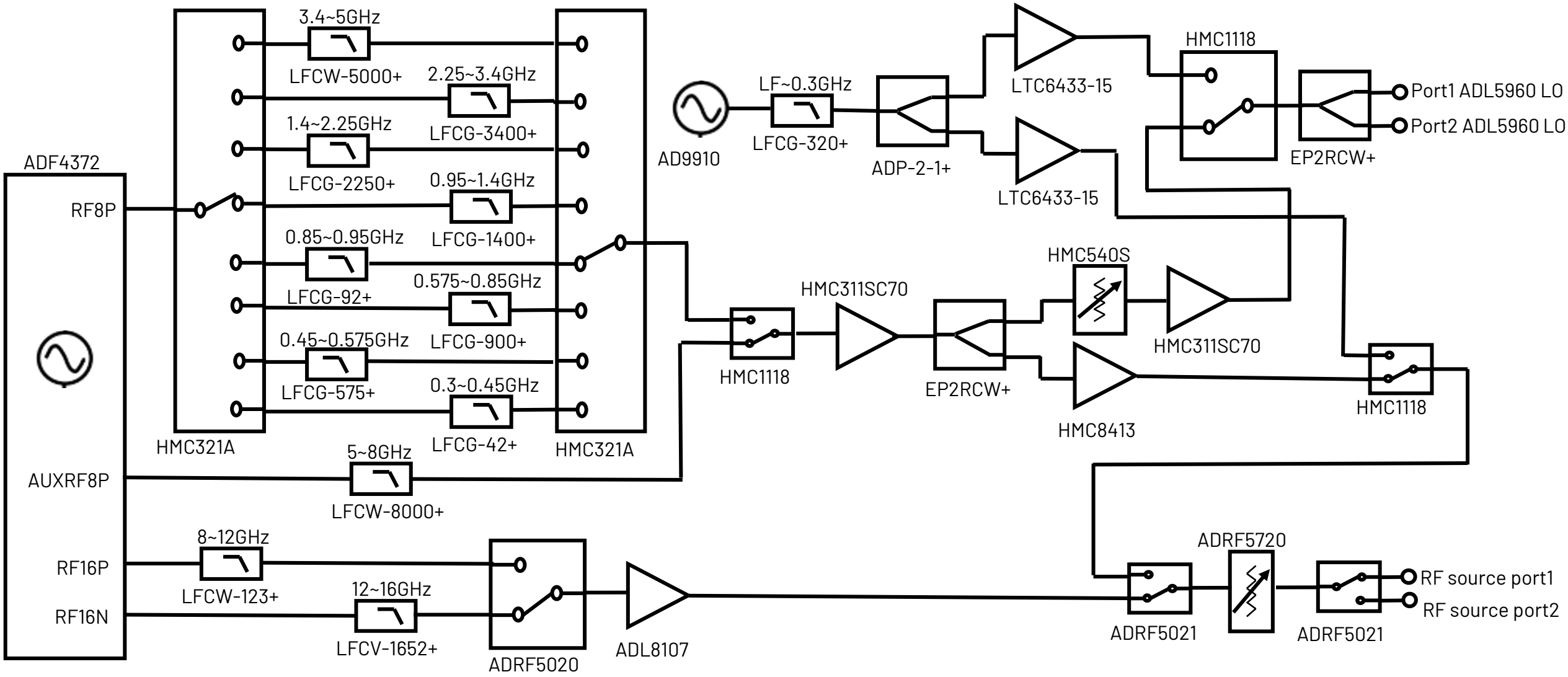
ADL5960 and ADL5960 based VNA block diagram





*: ADL5960 offset mode and internal LO doubler will be used.

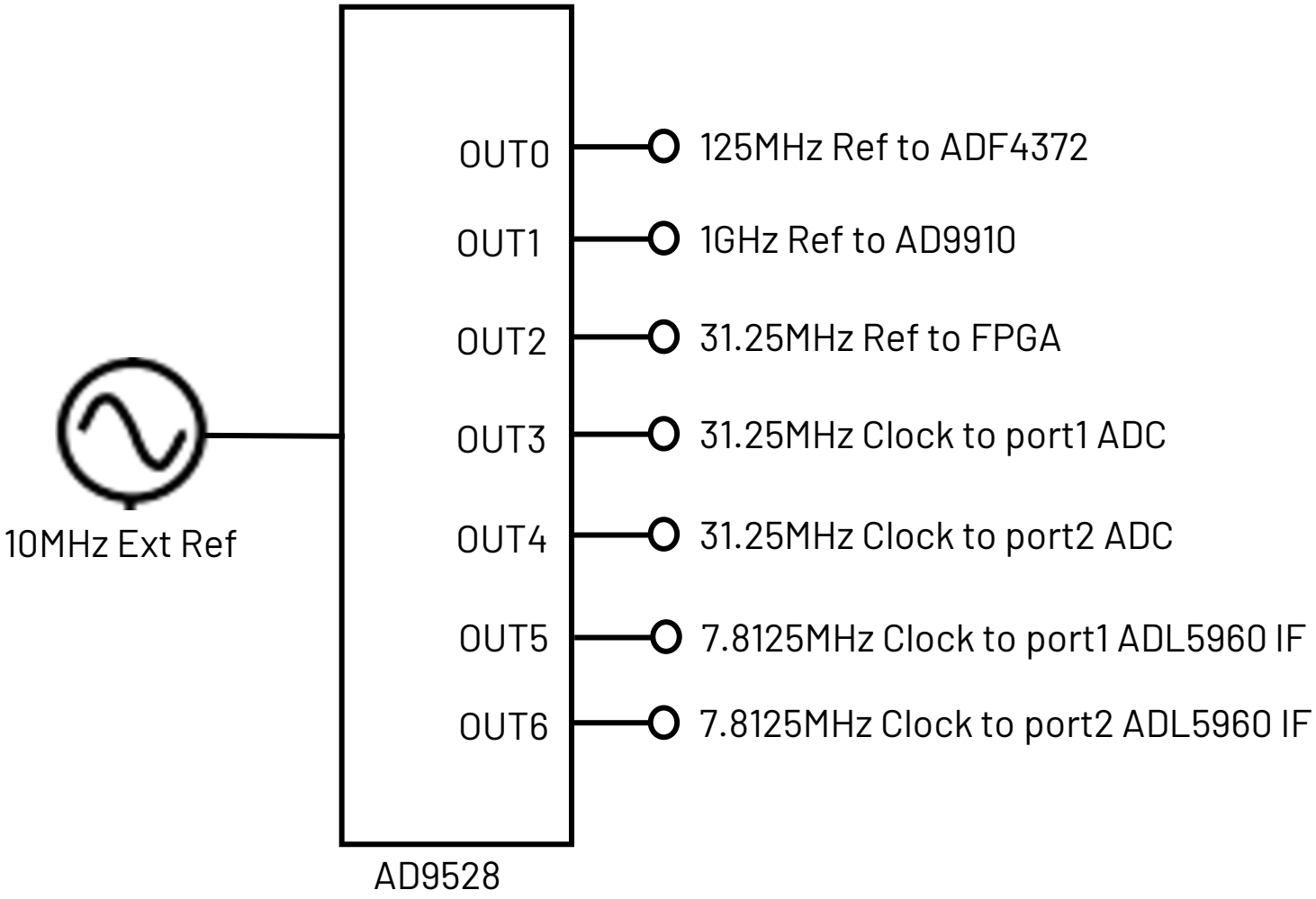
RF source implementation



*: HMC8413 and ADL8107 second harmonic performance could be a concern.

Need to measure on Eva board.

Clock implementation



Thanks