

This white paper is an executive summary of a webcast of the same title released on November 16, 2015, sponsored by Analog Devices and Avnet.

FULL RF SIGNAL CHAINS FROM 0 Hz TO 110 GHz

Introduction

Since the acquisition of Hittite Microwave in 2014, Analog Devices, Inc. (ADI) has expanded its RF capabilities in the full signal chain, including companion products, in the full bandwidth from 0 Hz to 110 GHz. ADI is now #1 in RF semiconductors worldwide, and remains #1 in analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), as well as #1 in linear semiconductor components. This white paper provides examples of the wider frequency spectrum covered by ADI, and explains that true dc is important. Off signal chain performance is also critical, and this paper shows how low noise, high stability control, and power components are important to overall RF signal performance.

ADI solutions range from industrial to communications infrastructure, all the way to automotive. In the industrial space, they include test and measurement, aerospace, and defense. In communications infrastructure, our solutions include cellular infrastructure (smartphones and the infrastructure behind them), microwave, broadband, and fiber optic networks. And in automotive, ADI's portfolio includes advanced driver assistance systems such as radar and other types of equipment.

The frequency spectrum ADI now covers ranges all the way from 0 Hz to 110 GHz, with a wide variety of applications ranging from CATV and magnetic resonance imaging, all the way up to scientific imaging and measurement. And in between is everything from satellite radio and military countermeasures, to industrial imaging and telematics—a massive spectrum—and all the solutions required for this to address the megatrend of ubiquitous connectivity, also known as the Internet of Things (IoT).

Complete Signal Chain Solutions

ADI provides reference designs that integrate standard ICs. Systems-in-package (SIP) integration takes standard components and packages them, fully tested and verified, as a complete subsystem solution. In system on-chip technology, the silicon die itself is the integration platform. ADI also makes available connectorized modules, which are very important in high frequency applications.

ADI components span from sensors to amplifiers and LNAs, all the way through signal conditioning technology, as well as ADCs, digital signal processing devices, DACs, power amplifiers, and output products.

Figure 1 shows a generic RF signal chain. In the upper left corner are the LNA, the RF switches, and RF attenuators going into frequency conversion, which could be upconversion or downconversion, depending upon what's required. The chain then goes to the ADC drivers and the ADC for conversion to bits—the RF to bits. In the middle are the frequency generation blocks, which can be driven from a variety of sources and distributed around the system with timing management. The timing management frequency generation blocks would be shared with the output side or the transmit side of the generic signal chain. On the output side, the DAC goes into an amplifier for the mixer, which is frequency conversion, and filters and switches out. The key point to note here is that ADI's signal chain coverage has increased from only about 20% to almost 100%, making ADI #1 in this space.

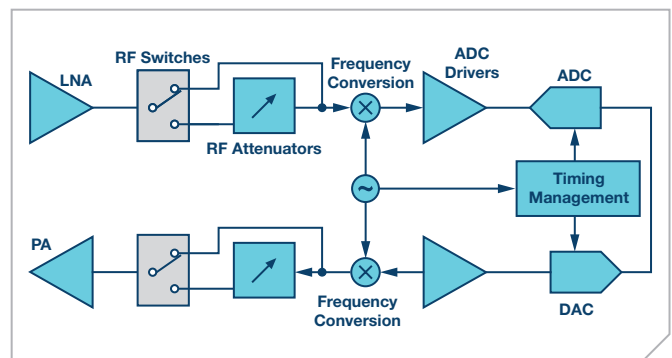


Figure 1. A generic RF signal chain.

An Expanded Portfolio

ADI has a greatly expanded portfolio of components and solutions. These include, but are not limited to:

- ▶ Switches that are smaller, with lower insertion loss and higher isolation
- ▶ LNAs that are lower power, lower noise frequency, and have better gain balance
- ▶ Passive mixers and filters
- ▶ Passive mixer local oscillator (LO) drivers and postamplifiers
- ▶ IF amplifiers that are lower power
- ▶ RF gain blocks
- ▶ Digital step and fixed attenuators
- ▶ Phase-locked loops (PLLs)
- ▶ Wideband and narrow-band voltage controlled oscillators (VCOs)
- ▶ Doublers and triplers

Test equipment is a key growth area for ADI, including backhaul test equipment and the cellular standards—2G, 3G, 4G, and the upcoming 5G. There is a lot of work being done in R&D and prototyping in 5G development. Next is the IoT and multistandard radio test. On the same system, there can be many different radio standards to test. There is also Wi-Fi or WiGig 40 GHz short range communications test for that type of system. And lastly, there is automotive radar, which is heading up towards 77 GHz. The IoT is suggesting a very large—tens of billions of units—market that needs to be low cost with better and wider bandwidth test capabilities. That's one of the most stringent, high volume test needs in the marketplace. They are all extremely aggressive in terms of performance.

A smartphone is an example of a piece of equipment that requires testing to multiple standards such as: Bluetooth®, cellular 2G/3G/4G LTE, Wi-Fi, and GPS variants.

There are a multitude of standards that would be applied across the electronic test and measurement spectrum, ranging from precision and audio testing at a very low frequency, to land mobile radio, which would have lower frequencies for longer transmission distances; to digital broadcast analyzers, handset test equipment, microwave point-to-point test equipment, automotive collision avoidance test equipment, and 5G research.

For all of these spectrums or bands, for the components that go into these systems, the components themselves have to be tested at these high frequencies, the modules they go into have to be tested, the completed printed circuit boards have to be tested, and the systems themselves have to be tested, and that occurs at various stages of life. At the beginning, those stages could be at R&D in the lab. There is compliance testing of all this equipment, then there's the production test, and then the final factory test. There are many different stages of testing for all of these bands, so there is a wide variety of different needs and applications across a very wide spectrum of frequencies.

Enabling Innovation in Electronic Testing

All of these new applications are generating a number of different needs and trends in the marketplace. Unlimited appetite for data is driving new communications standards (higher frequencies, wider bandwidths, Wi-Fi, and cellular networks). Emerging markets and ubiquitous data collection require lower cost of tests. If there are tens of billions of units out there all communicating, things cannot be tested the way they have been up until now. There has to be a real increase in performance with a resulting decrease in cost.

These innovative solutions are requiring higher frequencies and wider bandwidth testing. How do we test a device that has multiple radios on board that's shipping in very large volumes where we have to do multiple types of tests on it? Test times have to be reduced, and we need to be able to ensure that when a test is done, it doesn't have to be repeated—the test is highly accurate and repeatable. This also drives the need for reconfigurable hardware platforms. The same platform must be used as a general foundation for testing all of these radio standards and devices.

RF and microwave solutions ADI has and will have in the future provide wideband RF and microwave performance all the way from the antenna (sensor) to the processor or the cloud, perhaps. This will drive scalable performance and power for all the different types of testing, to support different classes of instruments. ADI also has achieved higher integration using smaller solutions with higher performance. Being able to have the same equipment test multiple standards will result in smaller equipment.

Signal Chain Equipment Examples

Some of the high speed and RF electronic test and measurement products ADI offers includes oscilloscopes, RF power meters, vector signal analyzers (VSAs), network analyzers, signal and spectrum analyzers, signal generators, scanners/receivers, RF sources, EMI test receivers, broadband amplifiers, electromagnetic susceptibility (EMS) test systems, cable and antenna analyzers, and simulators for Bluetooth, WLANs, and cellular.

Vector Signal Analyzer

A vector signal analyzer is an instrument that measures the magnitude and phase of the measured signal at a single frequency within the range of the instrument. That can be delivered in various forms graphically and across various connections to measure things like code domain power, error vector magnitude, and spectral flatness. There are a variety of measurements that can be obtained from this basic instrument. ADI's strengths are in ADC drivers and ADCs, direct digital synthesis, and clock generation chips. ADI's PLLs and VCOs dominate RF instrumentation, and ADI switches are everywhere.

The vector signal analyzer, previously known as a spectrum analyzer, measures and displays amplitude vs. frequency (frequency domain), but it can often have time domain information. It's becoming very versatile in terms of what it can display. Its input frequency range can be from 9 kHz to 6 GHz and beyond. The next higher bandwidths are typically 13 GHz and 26.5 GHz, and up to 77 GHz. So upconversion and downconversion can be tested using lower frequency components and systems.

Prior to the acquisition, ADI had only about 20% of the RF signal chain. Now, the company has added a variety of functions such as passive mixers, RF switches, narrow-band and wideband VCOs, and tunable filters. Nearly every RF component has been improved in some way. [See the Vector Signal Analyzer Signal Chain.](#)

Synthesizer

A synthesizer is an instrument to generate reference or comparison signals to test various types of equipment. ADI's portfolio of high speed and RF components includes passive mixers, VCOs, tunable filters, switches, and so on. It's about creating signals of all kinds, and this type of block can be a standalone type of equipment or a block within another type of equipment such as a signal analyzer or a network analyzer. The synthesizer is the next block as the frequency generator or modulation component. [See the Synthesizer Signal Chain.](#)

Oscilloscope

The last block is the oscilloscope, which is one of the most useful types of electronic test and measurement equipment. It provides analysis and display of a signal such as amplitude, frequency, rise time, time interval, and distortion. ADI components at play here include ADCs to get to bits that can then be processed for display or analysis. Things like digital signal processing, filters, voltage gain amplifiers (VGAs), and PLLs/VCOs are necessary to drive the timing for the oscilloscope that would be set on the front panel. [See the Oscilloscope Signal Chain.](#)

RF and Microwave Control Products

RF switches and attenuators is an important class of components used in every piece of RF equipment. Through the acquisition, ADI has a very wide portfolio of these components for simple switching purposes, and also for digital attenuation for digitally controlling attenuation. This includes switches for controlling input and output, for transmit and receive, and switches for selecting various filters.

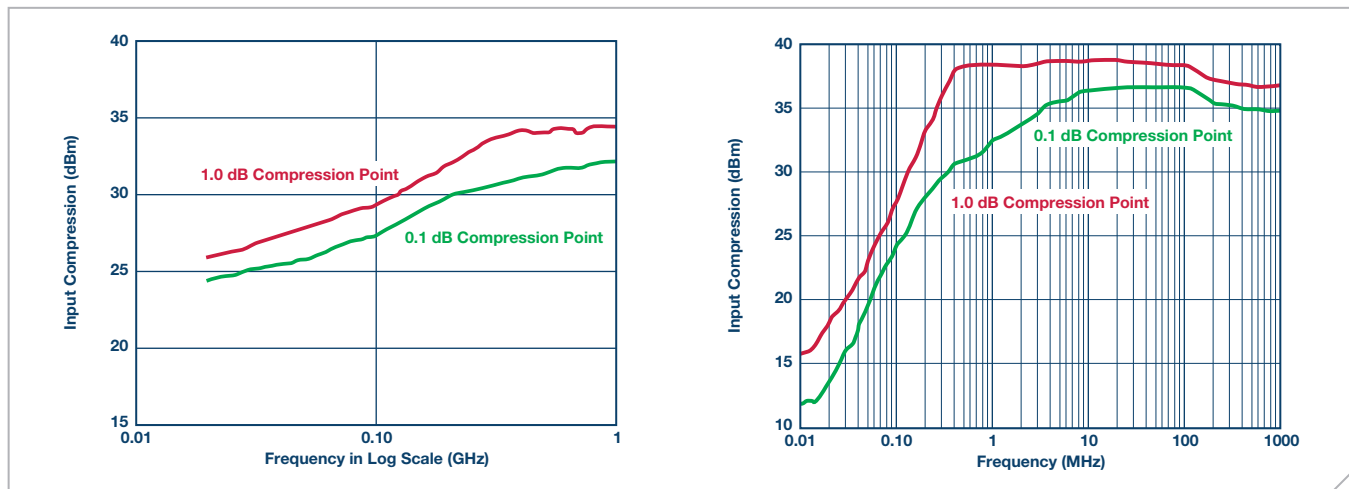


Figure 2. Comparison of a typical GaAs switch on the left vs. a silicon switch.

Figure 2 shows an example of Gallium Arsenide (GaAs) vs. silicon switches. On the left is a GaAs switch; on the right is a silicon switch. The important difference is that the silicon switch goes all the way down to 9 KHz, which is of vital importance to test and measurement applications that require the amp to go down to dc or very low frequency to be able to capture baseband type signals and antialiasing.

But it's not just about the RF. There is a wide variety of converters:

- ▶ AD9625 12-bit, 2.6 GSPS/2.5 GSPS/2.0 GSPS, analog-to-digital converter
- ▶ AD9691 14-bit, 1.25 GSPS JESD204B, dual analog-to-digital converter
- ▶ AD9684 14-bit, 500 MSPS LVDS, dual analog-to-digital converter
- ▶ AD9690 14-bit, 500 MSPS/1 GSPS JESD204B, analog-to-digital converter
- ▶ AD9152 dual, 16-bit, 2.25 GSPS, TxDAC+® digital-to-analog converter
- ▶ AD9154 quad, 16-bit, 2.4 GSPS, TxDAC+ digital-to-analog converter

Good RF Needs Good Power

ADI now has the world's lowest noise LDOs. The low noise, high PSRR power supply rejection ratio LDOs are necessary for good frequency generation. ADCs are used for measuring the signal, but RF DACs also are used for generating and synthesizing RF and high frequency signals; Figure 3 shows the various components that might be used. On the left-hand side are the ADCs powering the various rails using very clean power, using switching supplies to generate different types of rails, and on the right-hand side, a typical application using an RF DAC, again using the negative LDOs for the lowest noise and therefore the highest accuracy and the most stable outputs for the DAC for RF.

Author/Presenter

Mel Conway is the product manager for instrumentation, high speed and RF, and precision at Analog Devices. Mel has been with Analog Devices for 15 years, and his experience includes mixed-signal and digital design, software engineering, applications engineering, and marketing. He has designed products for the industrial, instrumentation, energy, and consumer segments.

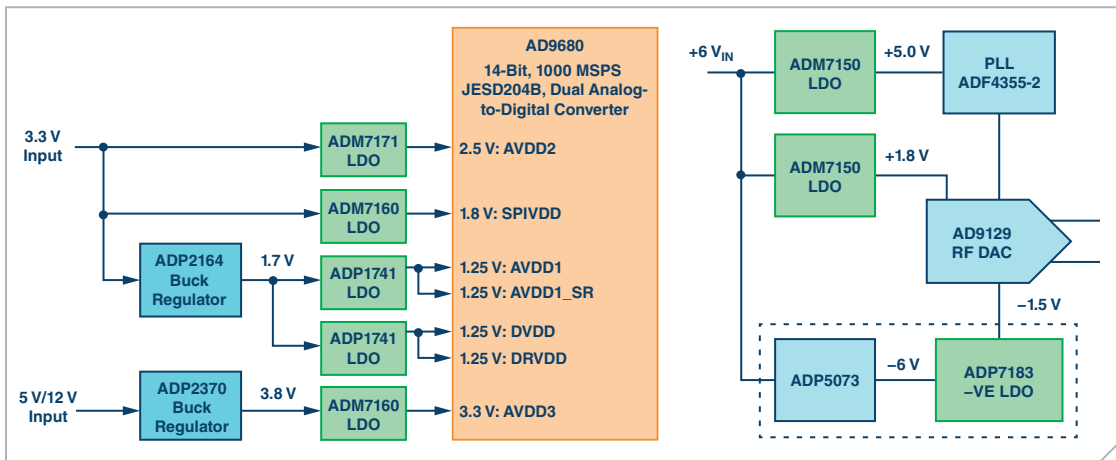


Figure 3. Clean power for converters results in clean signals. On the left-hand side are the ADCs powering the various rails using very clean power.

More than Silicon

ADI is more than just silicon. The company is proud to be able to help engineers and designers in the development of RF systems, including free design tools; rapid prototyping platforms based on FPGAs from partners; Circuits from the Lab® reference designs that comprise layouts and designs; and EngineerZone® technical forums.

An analog Design tool called ADIsimRF™ is an RF signal chain calculator that can calculate cascaded gain, noise figure, IP3, and more. Up to 20 different stages can be inserted, removed, or temporarily muted as required.

Conclusion

This paper has discussed the broad spectrum that ADI now covers—up to 100% of very high performance and complex types of equipment. One very important point is that ADI has components to fit nearly all of the function gaps on a signal chain. ADI is now #1 in RF semiconductors, can now capture up to 100% of RF signal chains, covers the complete frequency range from 0 Hz to 110 GHz, has more than 1000 RF and microwave parts, and maintains leadership as #1 in converters and linear.

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