ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ANALOG DEVICES CUSTOMIZED MODULES FOR SYSTEM PROVIDERS' MOST CHALLENGING NEEDS

Meeting the trends and challenges in the aerospace and defense industry requires breaking down the barriers between what were previously disparate sets of capabilities in the industry, and integration on unprecedented levels. The Department of Defense (DoD) continues to challenge the market with requirements for ever-bolder innovation at a faster pace, as well as innovation that has a clear path to be used beyond defense purposes in the commercial sphere. To meet these challenges, aerospace and defense system providers need to ensure their systems (1) meet the key performance parameters within, (2) an ever decreasing footprint, and (3) can achieve a price that meets the market demands of today and tomorrow. To achieve that, system providers are increasingly asking partner companies to go beyond semiconductors and deliver entire subsystems for their designs. Analog Devices, Inc., (ADI) has a diverse set of capabilities and system-level expertise to ensure it can support the system providers with such customized modules and partner with them from concept to creation as a one-stop shop.

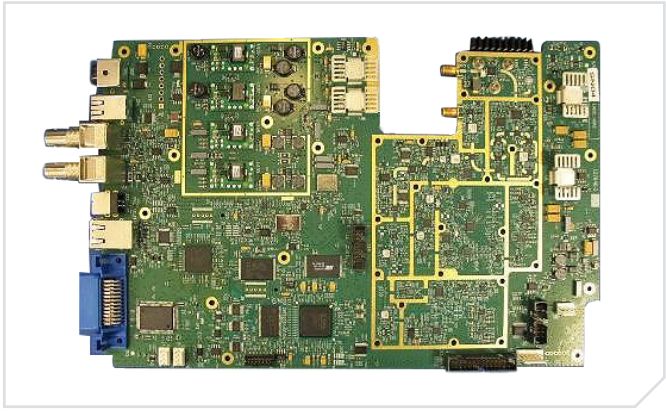
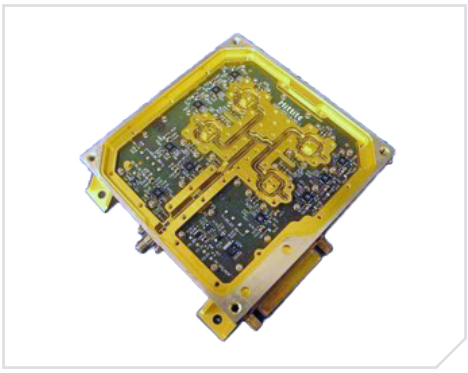


Figure 1. Highly integrated 20 GHz signal generator with voltage regulation and control on a single PWA.

Going Beyond Semiconductors

With over 20,000 products on the market today, Analog Devices is well known for being the industry's most prolific provider of digital, analog, RF, microwave, and millimeter wave semiconductor components. The acquisition of Linear Technologies and the addition of 7500 more power management, data conversion, and interface semiconductor ICs will give ADI the broadest portfolio of semiconductor intellectual property available today.

Analog Devices is also gaining recognition for its ability to go beyond semiconductor intellectual property to leverage its portfolio into highly integrated modules, products, and subsystems.



Parameter	Typical
Input Frequency Range (GHz)	1 to 2
Output Frequency Range (GHz)	29 to 31
Gain Flatness –1 GHz (dB)	3
Input Power (dBm)	–30 to +5
Output Linear Powerr (PSK) (dBm)	+37
Phase Noise –100 KHz (dBc/Hz)	–66
Spurious (dBc)	–60

Figure 2. ADI Ka-band upconverter with integrated HPA and waveguide interface.

ADI's Integrated Solutions business was acquired as part of the Hittite Microwave Corporation acquisition in the summer of 2014. Hittite had been developing custom microwave assemblies since shortly after the company's inception in 1985. Integrating homogenous IP on chip and heterogeneous IP in multichip modules was a natural evolution from customer requests for greater functionality in smaller form factors without compromising performance. The highest levels of integration and performance demand were first led by military applications. The company leveraged its own semiconductor technologies, as well as third-party components into a wide variety of high reliability products ranging from ultralow phase noise frequency synthesizers to kilowatt level high power amplifier solutions for military and space applications. Many of these products contain components that are specifically tailored to meet a customer's performance, size, and cost requirements.

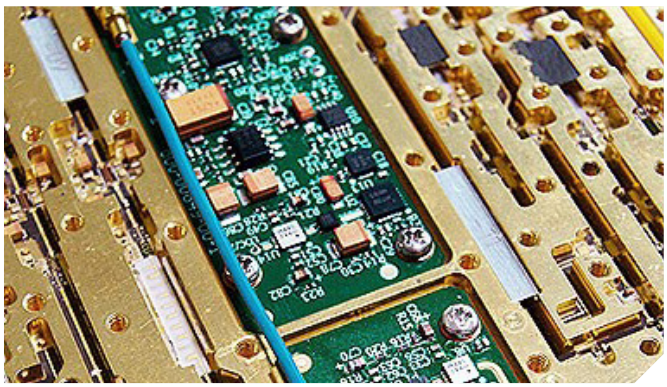
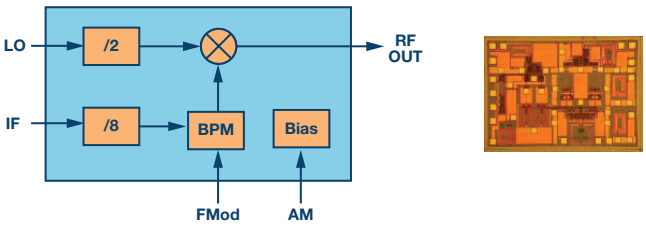


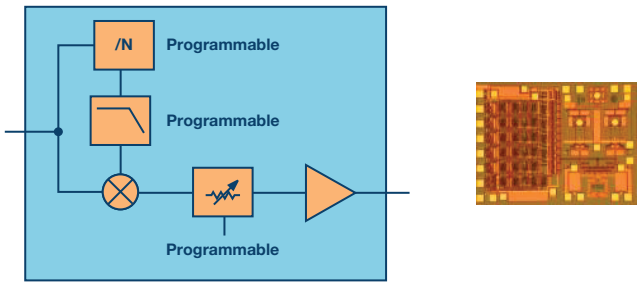
Figure 3. Multichannel, multiband millimeter wave frequency converter with integrated LO generators.

A Legacy of Innovating with Impact

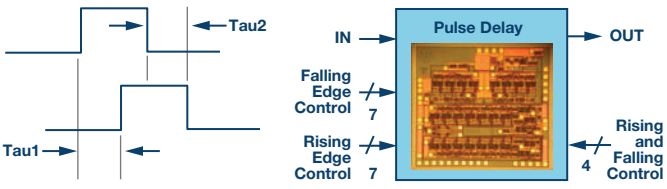
ADI innovates at many levels. For example, ADI innovation in high performance synthesizer and exciter solutions enables customers to bring a new level of performance to their platforms and, in a few cases, to open new markets. Figure 4 shows four of the many hundreds of custom MMIC die that have been developed to solve specific system-level problems. These four MMICs were developed to allow for a smaller, ruggedized exciter solution. This synthesizer module was designed for a mid-volume market where the correct balance of cost and performance needed to be achieved.



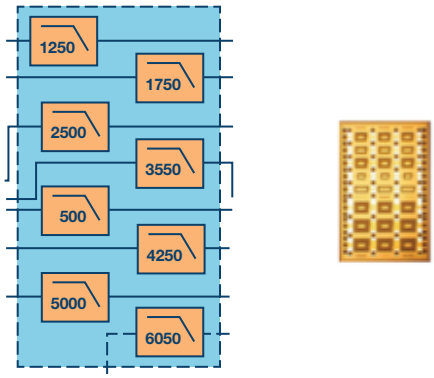
(a) AM and PM Modulator Chip Provides Doppler Compensation



(b) Programmable Single Sideband Frequency Converter Enabling Direct Synthesis



(c) Pulse Generator MMIC Provides Programmable Timing



(d) MMIC with 8 Low-Pass Filters Enables Size Reduction

Figure 4. Examples of custom MMIC innovations to solve synthesizer problems.

These devices allowed a reduction in volume and in price of more than 50% and a reduction in weight of nearly 70%. This in turn allowed the customer to add additional functionality to their system and secure a multidecade production contract from the government.

Another example of ADI innovation is the development of an application specific dielectric resonator oscillator (DRO) that is assembled into a shock- and vibration-damped configuration to allow state-of-the-art performance in extreme environments.

Figure 5 shows ultralow phase noise performance over an extended temperature range while maintaining outstanding performance in the field. As a result, the customer was able to enhance the dynamic range of their system and extend its mission capabilities.

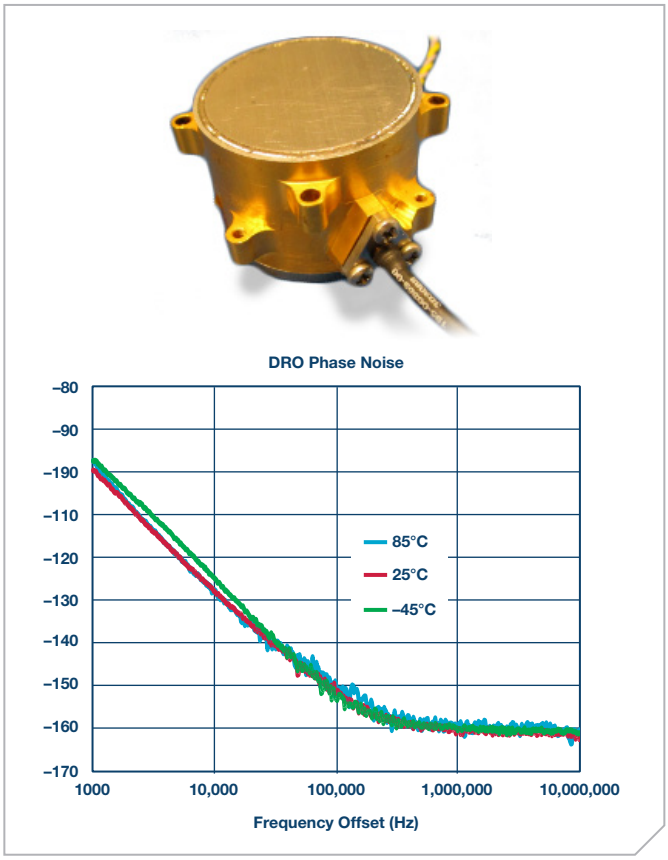


Figure 5. X-band DRO phase noise over temperature with shock and vibration isolation.

The work of ADI Integrated Solutions extends into a variety of tuner and frequency converter applications covering frequencies well into millimeter wave range. In addition, signal conditioning, amplification, and customized test equipment assemblies have been developed for demanding military applications.

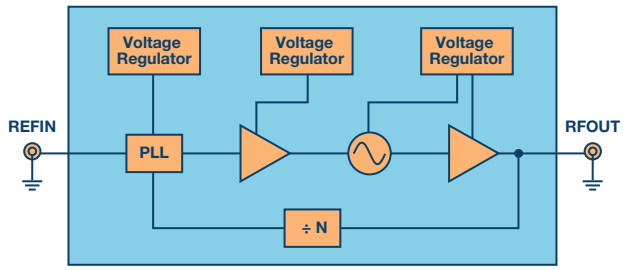


Figure 6. ADI HMC-C070 5.5 GHz to 10.5 GHz microsynthesizer product.

ADI Integrated Solutions is also developing custom and standard gallium nitride (GaN)-based, fully integrated high power amplifier (HPA) solutions. ADI continues to advance new GaN devices for broad market consumption and work on integrated solutions to develop more targeted devices aimed at meeting specific customer needs. ADI's HMC8113 is pictured in Figure 7. This rack-mount HPA was developed with ADI devices and incorporates an array of fault monitors, power supply sequencing algorithms, and load protections to protect the unit when deployed in the field. This unit is capable of delivering over 500 W CW from 2 GHz to 6 GHz. The HMC8114 is another HPA capable of delivering over 90 W from 6 GHz to 18 GHz. Both of these power amplifiers benefitted from custom MMIC designs, as well as leveraged innovative digital and control solutions, mechanical and thermal solutions, and low loss microwave power combining techniques.

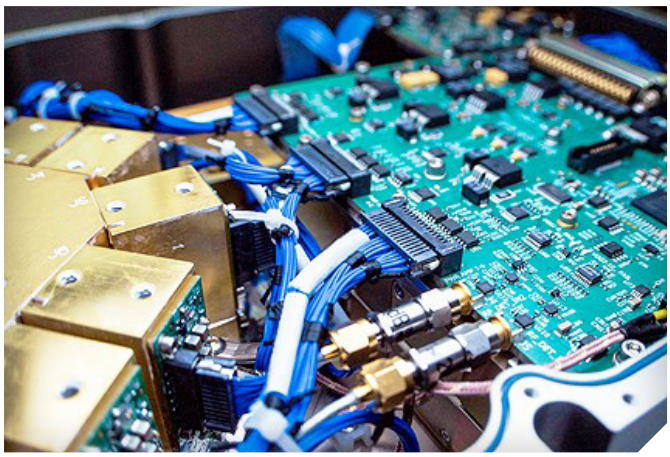


Figure 7. ADI HMC8113 500 W 2 GHz to 6 GHz and HMC8114 90 W 6 GHz to 18 GHz GaN high power amplifier products.

Most recently, ADI has begun talks with customers interested in integrating advanced transceiver technologies into chip-scale integrated solutions. ADI expertise in this area can enable customers to drive down form factors and move digitization to, or much closer to, their antennas. Integrating the AD9371 at the chip level allows for advancements that are Ahead of What's Possible™ today. On its own, this device is a highly integrated, wideband RF transceiver offering dual-channel transmitters and receivers, integrated synthesizers, and digital signal processing functions. When integrated with the correct RF, digital, and power supply die, this device can enable new frontiers in communications, EW, and radar applications.

Success Through Partnering with Customers

The most successful development efforts always come from an open dialogue with customers. Understanding the key performance parameters (KPPs) is the mandatory first step. This can often make or break any design effort. Designers often try to simultaneously optimize performance in many opposing dimensions, so trade-offs generally need to be considered throughout most state-of-the-art designs. Understanding which parameters are critical differentiators for customers allows design teams to start and stay on the correct path throughout product development.

ADI leverages the Integrated Product Team model to optimize cooperative engagements.

To ensure clear communications and reduce program risks throughout the development activities, ADI prefers to leverage an integrated product team (IPT) approach on new module designs. Often seemingly small decisions can have a great impact, either positively or negatively, on a development program. With the IPT model, stakeholders from multiple design and business areas remain engaged to ensure decisions are consistent with all goals, risks are continually mitigated, and program needs are met efficiently. For instance, the decision to produce an extra control/interface board has little cost impact, but it may allow the customer team to retire certain system-level risks months before initial hardware is ready for integration.

This is also true of providing drawings, solids models, or even empty housings: a small incremental cost that can mitigate or eliminate risks. Working closely with a customer also allows ADI to bring design alternatives into the discussion.

Extending Customer Design Capabilities

ADI design and applications teams are setup to work as an extension of a customer's design resources. Module designers are able to work seamlessly with a customer's system designers by leveraging a wide range of common tools and calculators to model electrical performance and physical attributes. These module level models can be imported into system-level models to reduce integration risks and help ensure the end product interfaces seamlessly at the next higher level of assembly. This often contributes to first pass success.

ADI has facilities and personnel cleared to perform classified DoD work up to the top secret level.

Predictive analyses are used to optimize signal chains and, when needed, to define new monolithic microwave integrated circuit (MMIC) performance requirements. In most cases, module and system designers construct their signal chain solutions from commercially available

components. Analog Devices can rely on a vast array of components and their underlying intellectual property (IP). ADI can leverage this IP at many levels. ADI has thousands of die that are available in a variety of packages, but are not available in die form for a variety of reasons. ADI's Integrated Solutions Group has access to these die, so it can help reduce size and performance, depending on the packaging technologies employed.

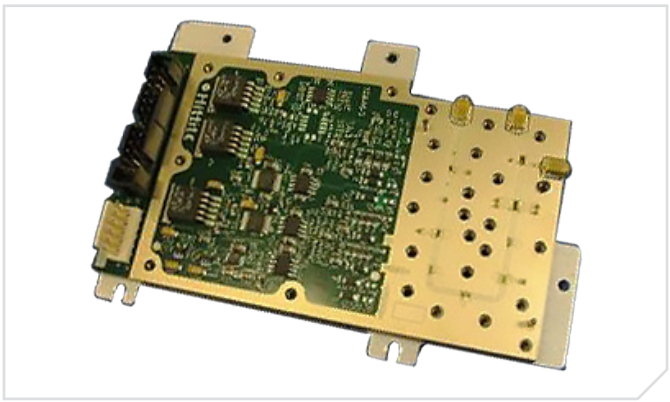


Figure 8. 70 GHz signal generator PWA.

Analog Devices can also screen, modify, or create MMICs to meet the demanding needs of state-of-the-art modules. While commercially available components are often sufficient for a signal chain, efficiencies are possible with slightly modified performance. Because Analog Devices owns the underlying IP, it is possible to screen a die or modify component performance to achieve these efficiencies. As a result, system designers can enjoy the competitive advantage of higher efficiency performance, added capabilities, or both.

EM simulation tools are used to model transitions and cavities to minimize insertion losses and mismatches. The simulation also ensures cavities do not promote electromagnetic modes. These analyses are important as components are incorporated into module designs.

Mechanical designers regularly leverage ADI's solids models and CAD drawings to validate system parameters and ensure proper fit. Thermal models are ported into system models to validate conduction and convection cooling scenarios needed to maintain appropriate junction temperatures under extreme operating conditions. These interactions are critical to system reliability and MTBF performance.

ADI has always placed the highest emphasis on delivering products that meet the highest levels of reliability. We achieve this by incorporating quality and reliability checks not only in all realms of product and process design, but in the manufacturing process as well. ADI maintains several state-of-the-art ISO9001 and AS9100 manufacturing facilities that meet the demands for highly integrated, cost-effective chip and wire and surface-mount assemblies. Our manufacturing and screening standards conform to MIL-PRF-38534/5 and MIL-STD-883. We maintain Class 100,000 clean rooms used for assembly and testing and several Class 100 work areas devoted to testing and inspection of space level products. ADI also has facilities and personnel cleared to perform classified work for the Department of Defense up to the top secret level.

In conclusion, having an understanding of customers' systems allows ADI to pursue solutions that are precisely tailored for their applications. Analog Devices is continually pushing technology frontiers, which allow customers to stay ahead of what's possible. ADI's breadth of component and integration expertise enables development of custom modules for the most innovative design requirements. The ability to tailor MMICs allows ADI to optimize signal chains rather than having to use the closest devices available. Integrating on-chip, in-package, and at the LRU level make Analog Devices highly qualified to simultaneously meet the most challenging performance, SWaP, and business requirements. Owing to the intellectual property of the critical components within ADI's modules ensures unprecedented obsolescence management and product lifecycle support for our customers.

Microwave Simulation Tools	*Linear Simulation*	Microwave Office
		ADS
	2.5D Simulation	AXIEM
		Momemtum
		Sonnet
	3D Simulation	HFSS
		CST
	Filter Synthesis	Genesys
		Ansys
System Analysis Tools	*Cascade Analysis*	Virtual System Simulator
		Genesys Spectrasys
		Custom in-house
	Statistical Analysis	Virtual System Simulator
Digital/ Firmware Tools	*FPGA Tools*	Xilinx® ISE Design Suite
		Xilinx Vivado
		Modelism
	Signal Integrity	Hyperlynx
Analog Design Tools	*PSPICE*	Microcap
		LTSPICE
		ADISimPE
		PSPICE
	HSPICE	Cadence
Reliability Prediction Tool	*MBTF/FITS Prediction*	PTC Windchill
Mechanical Design Tools	*3D Solid Modeling*	Inventor
		SpaceClaim
	2D Modeling	AutoCAD
Physical Analysis Tools	*Structural FEA*	Ansys Mechanical Enterprise
	Thermal FEA Linear and Dynamic	TAS—Gate Level
		Ansys—Gate to System
	Thermal CFD	Qfin
Layout Tools	*Routing*	PADS Layout 9.5
		Cadence/Allegro
	Schematics	DXDesigner

Figure 9. Example design tools employed.

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