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June 2011

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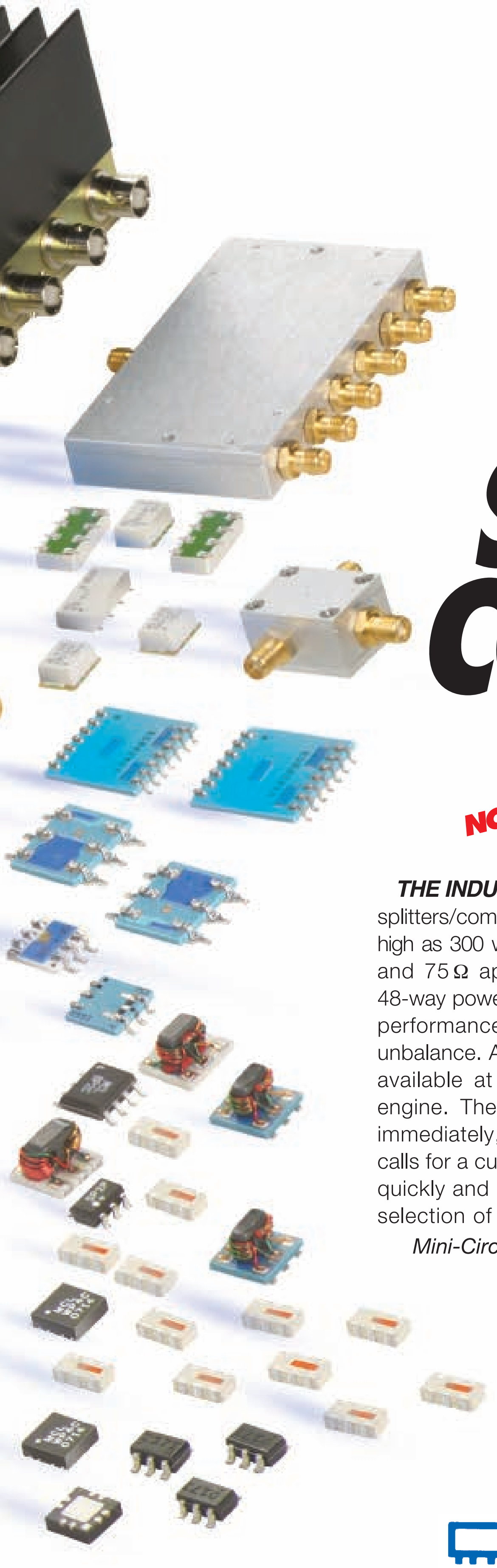

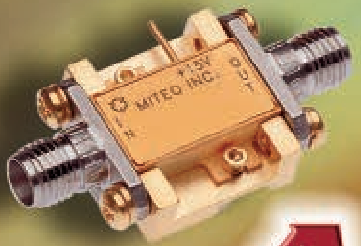

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OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
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AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

Note: Noise figure increases below 500 MHz.

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JUNE 2011 VOL. 54 • NO. 6

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Presented by Besser Associates
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RF and Power Electronics Opportunities for GaN Market Growth

This webcast examines how defense markets will command a significant proportion of the early market for GaN devices with development focused on next generation radar, electronic warfare and communications systems.

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Executive Interview

NXP's **John Croteau**, Senior Vice President and General Manager, Business Line High Performance RF, discusses the RF semiconductor market, the advantages of various semiconductor technologies and his company's product roadmap.

Online Technical Papers

Choosing the Right RF Switches for Smart Mobile Device Applications
White Paper, Skyworks Solutions

Application and Use of the 350AH1 Low Frequency Amplifier
Jason Smith and Pat Malloy, AR Worldwide

Emerging 4G Communications Systems Making Digital Pre-distortion Fast and Practical for all Engineers
White Paper, Agilent Technologies

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YSF-122+	800-1200	20.4	0.2	20.5	21.3	3.4	36	2.69
YSF-2151+	900-2150	20.0	0.4	20.0	21.0	3.1	35	2.95
YSF-162+	1200-1600	20.1	0.2	20.0	21.0	3.2	35	2.69
YSF-232+	1700-2300	20.0	0.2	20.0	21.0	2.8	35	2.69
YSF-272+	2300-2700	19.0	0.7	20.0	21.0	2.5	35	2.59
YSF-382+	3300-3800	14.5	0.9	20.0	21.0	2.5	36	2.59
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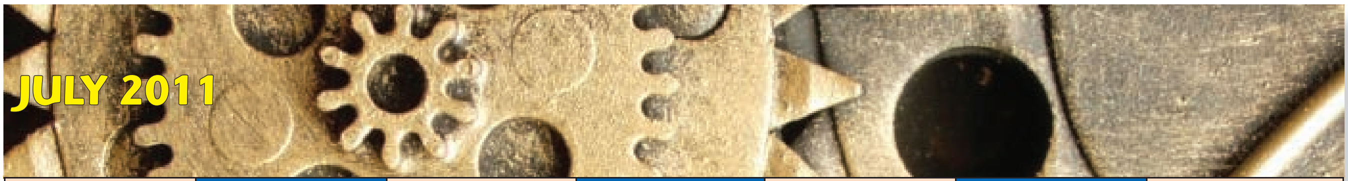

JULY 2011

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
26	27	28	29	30	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

July 3–8: **AP-S/USNC/URSI 2011** Spokane, WA

July 4–6: **HPSR 2011** Cartagena, Spain

July 4–7: **IPFA 2011** Incheon, Korea (South)

July 12–15: **PS 2011 International Conference on Photonics in Switching** Osaka, Japan

July 14: CST **Studio Suite Training for EMC Signal Integrity** Penang, Malaysia

July 17–18: **PACCS 2011** Wuhan, China

July 19–20: **ASQED 2011 Asia Symposium Quality Electronic Design** Kuala Lumpur, Malaysia

July 19: **MWJ Besser Webinar: LTE Overview** Sponsored by Anritsu

July 20: **Innovations in VSA Webcast** Agilent Technologies

July 26–30: **CSQRWC 2011** Heilongjiang, China

July 27: **Innovations in LTE Webcast** Agilent Technologies

July 24–31: **ISaCoNaS 2011** Castellaneta Marina, Italy

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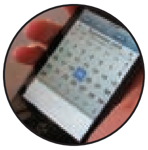

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MEDAV Seminar
Radio Monitoring, Strategic and Tactical Reconnaissance Systems, Automated Processing and Information Fusing
June 27–July 1, 2011 • Berlin, Gemany
www.medav.de

Joint Navigation Conference
June 28–30, 2011 • Colorado Springs, CO
www.jointnavigation.org

JULY

AP-S/USNC/URSI 2011
IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting
July 3–8, 2011 • Spokane, WA
www.apsursi2011.org

ASQED 2011
Asia Symposium Quality Electronic Design
July 19–20, 2011 • Kuala Lumpur, Malaysia
www.asqed.com

AUGUST

NIWeek 2011
August 2–4, 2011 • Austin, TX
www.niweek.com

EMC 2011
IEEE International Symposium on Electromagnetic Compatibility
August 14–19, 2011 • Long Beach, CA
www.emc2011.org

AUVSI Unmanned Systems N. America 2011
August 16–19, 2011 • Washington DC
http://symposium.auvsi.org/auvsi11/public/enter.aspx

SEPTEMBER

11th Mediterranean Microwave Symposium
September 8–10, 2011 • Hammamet, Tunisia
www.mms2011.com

ION GNSS 2011
September 20–23, 2011 • Portland, OR
www.ion.org

OCTOBER

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October 9–14, 2011 • Manchester, UK
www.eumweek.com

7th Annual COMSOL Conference
October 13–15, 2011 • Boston, MA
www.comsol.com/conference2011/usa/

MUD 2011
Microwave Update
October 13–16, 2011 • Enfield, CT
www.microwaveupdate.org

AMTA 2011
33rd Annual Symposium of the Antenna Measurement Techniques Association
October 16–21, 2011 • Englewood, CO
www.amta2011.org

MWP 2011
IEEE International Topical Meeting on Microwave Photonics
October 18–21, 2011 • Singapore
www.mwp2011.org

4G World
October 24–27, 2011 • Chicago, IL
www.4gworld.com

RADAR 2011
International Conference on Radar
October 24–27, 2011 • Chengdu, China
www.radar2011.org

NOVEMBER

COMCAS 2011
International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems
November 7–9, 2011 • Tel Aviv, Israel
www.comcas.org

MILCOM 2011
November 7–10, 2011 • Baltimore, MD
www.milcom.org

AOC 2011
48th Annual AoC International Symposium and Convention
November 13–16, 2011 • Washington, DC
www.crows.org

DECEMBER

APMC 2011
Asia Pacific Microwave Conference
December 5–8, 2011 • Melbourne, Australia
www.apmc2011.com

COVER FEATURE

SUCH GREAT HEIGHTS

In 2003, an alternative rock band called The Postal Service filmed a music video at Skyworks' Newbury Park, CA facility. The video for the song "Such Great Heights" features images of a male and female worker in their clean room garb interspersed with close-ups of wafer processing equipment operating with speed and precision (see ***Figure 1***). As the two workers carefully hand over a wafer, the video unfolds through a sequence of shots: machines assembling wafers, a bank of RFICs making its way into a satellite that circles the Earth. The video then zooms down to a building complex in Salt Lake City, UT that resembles an integrated chip from above. A match cut is made to a monitor in the factory displaying an identical integrated circuit as the video cuts back to the two workers handing over the wafer.

▲ *Fig. 1 Images from "Such Great Heights" video.*

Budding love story or portrayal of workers isolated in their clean room suits focusing on their duties, the video depicts awe-inspiring technology and manufacturing capability. And in 2003, this high volume manufacturing was necessary to support one of the commercial wireless industry's major growth spurts. It was one year after Alpha Industries and Conexant's Wireless Division merged to form Skyworks Solutions, a new company that could leverage its broad technology portfolio and diversified customer base into a daunting competitive advantage in an arena that would become increasingly exclusive and lucrative.

In the cellular handset market, 400 million units were sold in 2001, a 500 percent increase over the levels five years earlier. During this time, enhanced wireless bandwidth (2.5G and 3G) and intensely competitive pricing resulted in a substantial increase in new cellular subscribers. Meanwhile, handset OEMs and contract manufacturers, driven by accelerated time to market and pressure to lower costs, were looking to simplify architectures with a more complete semiconductor solution, especially in the RF section. Following the lead of Intel's Gordon Moore, Skyworks' executives

DAVID VYE
Editor, Microwave Journal

foresaw how exponential growth for mobile devices would transform the commercial RF chip market forever, they joined forces to create an entity with the capacity to drive economies of scale in manufacturing and technological development.

At the time of the merger, Skyworks had its eye on capturing a "disproportionate share of a $10 B total addressable market," which included the RF, mixed-signal and digital content of the wireless semiconductor market. Skyworks' strategy called for leveraging its market position in switches, power amplifier modules and single-chip direct conversion transceivers to be at the forefront of integrating the RF section into a single package. *(Note: As transceivers became integrated into the baseband IC by manufacturers such as TI, Qualcomm, NXP, Freescale and MediaTek, RF manufacturers such as Skyworks and RFMD lost the support of many mobile phone platforms for their transceivers and subsequently exited that business, at least for multi-mode phones).*

The newly combined company had approximately 750 engineers worldwide (according to its annual report), state-of-the-art GaAs HBT and PHEMT fabrication facilities and access to key analog, RF CMOS, SiGe processing, along with a formidable assembly and test operations for high volume production of its multichip modules. By the time Skyworks filed its first annual report, it had streamlined the overall organization, shortened the manufacturing cycle, improved capacity utilization and achieved combined company revenue of $543 M (compared to the previous year's $458 M). Nearly 10 years later, the RF chip market continues to grow and Skyworks, now with over 4,000 employees worldwide, posted earnings of $1.072 B in fiscal 2010, a year-over-year increase of 34 percent.

The company is targeting three key growth areas: mobile Internet, linear components and vertical markets. Growth in its mobile Internet sector is driven by increasing RF content per device (Smartphones), leveraging a diversified customer base, and the company's sizable market share, reported by Skyworks to be more than 40 percent (based on units). The analog or linear components business unit targets broad market diversity including: infrastructure, broadband, industrial medical and military verticals. The company's portfolio of linear RF components includes PLLs, timing and delay modules, network control functions, LNAs, discrete diodes, switches, attenuators and VCOs. The vertical markets sector addresses applications ranging from wireless local area networks (WLAN), automated metering infrastructure (AMI), automated meter reading (AMR), professional mobile radio (PMR) and other ISM band applications.

Efficient operation on this scale requires sophisticated organizational systems, well-defined processes and infrastructure. According to David Stasey, V.P. of the Analog Components business unit, "Our business unit structure is an important part of our overall strategy. The marketing groups are part of the business units. Product marketing managers have ownership of the products to avoid conflicting interests between individuals within the business unit. We have designers and applications engineers all working within that product marketing group. Then there are some common pools shared between the groups. For instance, all our techs are cross-trained. So in the lab all techs are organized under one leadership pool. They are assigned out to projects as needed along with other common functions such as layout support, product engineering, and test engineering."

Stasey also says the product marketing, design and application piece of the operation is very homogenous and responsive to the customers needs. "If there is a customer issue, then customer quality will get involved. Customer quality along with management will assign responsibility for taking corrective action. The applications group and designers will work together to resolve the issue. That way we have problem solvers from two perspectives working on it and everyone is aligned to achieve the same end result."

When deciding which products to develop, Skyworks operates by a well-defined set of procedures that could have easily been conceived by engineers. According to Technical Director David Whitefield, the company solicits a lot of new product ideas from within the individual product groups and the entire Skyworks community. As a result, the company regularly conducts a fairly rigorous prioritization process that involves both bottom-up and top-down forecasts to determine the best resource allocation, which results in investments that are a function of customer demand and the overall market opportunity. "We don't throw away ideas that might take a little more time, but we do look for a fit within our current state of technology and capabilities. Other ideas might get delayed until the technology or sales channel evolves. Or, sometimes a new technology is required, and that is where I might come in."

Some engineers are notorious for just wanting to focus on technology with little interest in the business or marketing side of their company. Stasey and Whitefield do not encounter much of that with the team at Skyworks. As Whitefield states, "We are a very pragmatic company – cost, size and performance are big things for us and our designers get that. On the technology side, there's a lot of interaction between disciplines." Designers and process engineers as well as the modeling group work on problems together. So while the designers have a pretty deep reach into the tools and the process technology, they are also engaged directly with customers.

How designers, application engineers and customers interact is a little different depending on product line, according to Applications Engineering Manager Rick Cory. This is due to the demands of the market niches they address. According to Cory, "As a company, we have to develop products that the market wants and that work better than other products on the market. We also have to work with the customer to make sure they understand how best to use these products. So, you can't have someone who is solely an applications engineer or solely a design engineer, because everyone has to look beyond just getting their job done."

Cory believes the differentiations between the role of the designer and the applications engineer are not minor, "but many of their functions overlap quite a bit." Designers have to be very sensitive to what the market wants so Skyworks designers talk directly to customers. Designers also have a different perspective on the products because they have designed them and they know them inside and

out. "We want designers designing, but they will be less effective if they don't have customer input."

A company's way of operating evolves from its past experiences with success and failure, guided by its culture. History and people define a company. A powerful business case might exist for merging companies, but success depends on the compatibility of their cultures. Stasey describes the culture at Skyworks as very open and communicative. In fact, every employee, including the executive staff, works from cubicles, fostering this spirit and a very flat organization.

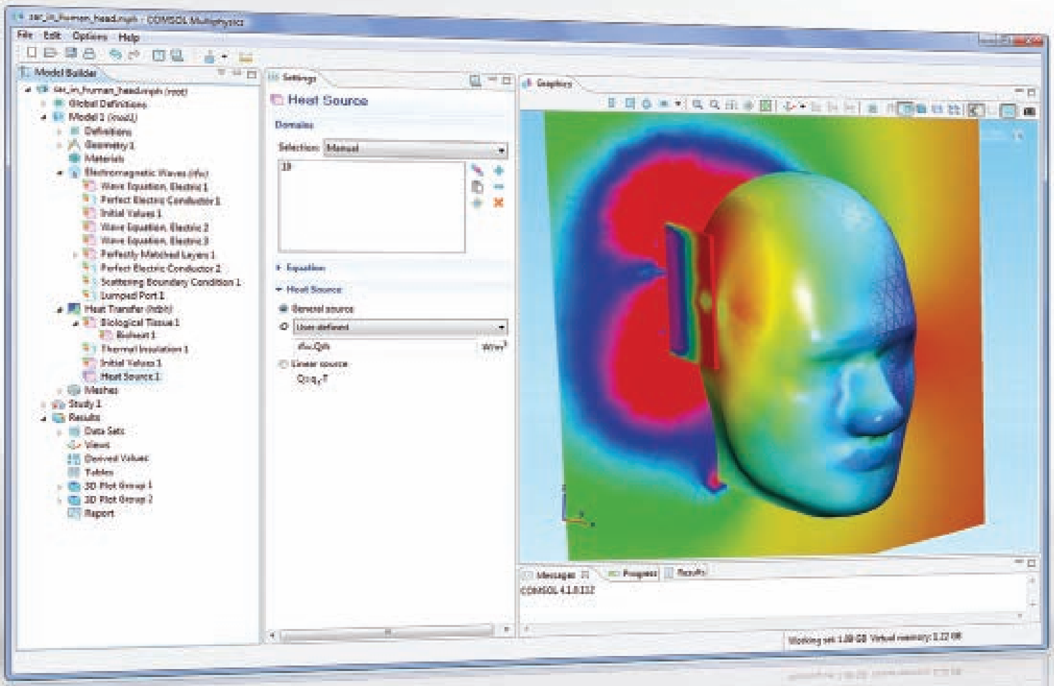
At the time of the merger, there were admittedly different perspectives and approaches for handling things at each company, but Skyworks has successfully blended cultures and all groups now work well together, taking the best approaches from each. Marketing Director Thomas Richter, who worked for Conexant at the time of the merger, concurs. "It did not take too long to merge cultures. The Conexant employees saw how Alpha employees were successful in doing some things differently. So we would adapt various methods. After a short while I don't think there was much difference among the various locations. Today our design centers are characterized by their core competencies rather than anything else."

Whitefield conceded that pre-merger, Alpha's systems and processes were not as robust as Conexant's so it was a nice marriage. "As we've been getting bigger, many of those systems have been critical to our ability to do what we do. If you look at us today, we are the largest company in [RF] power amplifiers globally. We're in just about half of all the mobile handsets made. We 100 percent RF test the chips, which is 4 million parts a day. All this indicates that we've got pretty good systems in place."

The RF/microwave industry is composed of hundreds of small-to-medium-sized businesses. Very few of them have grown to the size of Skyworks with annual revenue above nine figures. Even fewer have done so without shifting their focus from RF components toward system integration or evolving into a large defense contractor. Ironically, Skyworks' roots go back to a small, defense-oriented business with a colorful past and management that guided the company through an unprecedented transformation.

The openness described by Stasey began with the founders of Alpha Industries and has been perpetuated through successive leadership. According to a 2001 interview with then VP and CFO Paul Vincent, Alpha has always been set up in a nonhierarchical way, encouraging strong communications between people at all levels in the company. This goes back to George Kariotis, who used to exclaim that "there will be no neckties in this company," even though the business culture at the time still wore suits and ties in the office (***Figure 2*** shows typical engineers from the early 1960s).

In 1962, George Kariotis and his brother Andrew set up shop in an old textile mill outside of Boston, building waveguide assemblies. As children of immigrants, they acknowledged their ancestry by naming the company after the first letter in the Greek alphabet – Alpha Microwave. Within a year, the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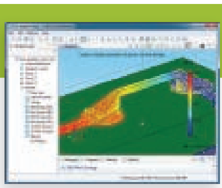

company made its foray into the realm of microwave semiconductors when it began to make and sell point-contact diodes, the oldest of microwave semiconductor devices.

Point-contact diodes, developed during World War II, were used for detectors and mixers in superheterodyne radar receivers. Sylvania Electric Products was the first to market a commercial point contact diode (the 1N34 in 1946). Theoretical work done in the late 1930s and early 1950s predicted that diodes could also be used for amplifiers and oscillators as well. In support of electronic warfare systems, solid-state research on diodes and transistors took place at a fevered pitch. By the early 1960s, researchers from Bell Labs and the US Army Signal R&D lab were investigating various silicon and GaAs diode technologies for their suitability in applications such as broadband amplifiers, harmonic generators, mixers, switching and limiters. Leading companies manufacturing microwave diodes included Bomac, Western Electric, Raytheon, Microwave Associates and Sylvania Electric Products, a subsidiary of General Telephone & Electronics (GTE) Semiconductor Division.

▲ *Fig. 2 Typical business attire for engineers in the 1960s.*

If the Cuban missile crisis represents the peak of the Cold War, the early 1960s were certainly a boom time for defense companies such as Alpha, which experienced rapid growth. Reflecting its expanding product lines, the company changed its name to Alpha Industries and formed the Microwave Components Division and Semiconductor Division in 1965 and began trading publicly in 1967.

Alpha pulled off a major coup in 1970 by acquiring the Microwave Device Department of Sylvania Electric Products (GTE) and its extensive product line of diodes, with an annual volume of approximately \$4 M, reportedly for \$10,000 cash down, a seven-year note and stock (see **Figure 3**). The acquisition greatly expanded Alpha's customer base and Sylvania's large existing diode inventory helped pay off the

▲ *Fig. 3 Alpha ran this advertisement in* Microwave Journal® *to highlight the Sylvania Microwave Corp. acquisition in 1971.*


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ECAD INTERFACE
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• Links to popular EDA layout for package and board simulations
• Add HFSS accuracy to circuit and system simulations
MULTIPHYSICS
• Direct links to ANSYS Mechanical
• Thermal
• Stress
• Vibration
• Coupled EM-Mechanical analysis

loan in half the time. According to its ads at the time, Alpha now possessed "the broadest selection of microwave diode types and packages in the industry, from UHF to Ka-band." The sale also gave Alpha a new home, the current Skyworks' headquarters at *Sylvan* Road in Woburn, MA.

Alpha's strategic acquisition transformed the company overnight into a major supplier in the diode business and player in the defense market. The move also put them in direct competition with two local giants in the microwave semiconductor industry, Raytheon and Microwave Associates (name changed to M/A-COM in 1978) — a regional rivalry that would exist between these companies for decades as the companies battled each other for market share and even engineering resources.

From 1977 to 1984, the company grew from $10 M in sales to $60 M, accompanied by a corresponding growth in earnings. Two-thirds of Alpha's business was military. Company growth led to the acquisition of MD-based ceramic filter manufacturer Trans-Tech in 1981. Further expansion of its millimeter-wave-diode product line came when it acquired Gunn diode manufacturer Central Microwave Co. (CMC) of Missouri. Just prior, George Kariotis left Alpha Industries to pursue his passion for politics, serving as MA Governor Ed King's Secretary of Economic Affairs in 1979 (Kariotis ran as the Republican candidate for Governor in 1986, but lost to Mike Dukakis).

And then the company hit a rough patch. The year-after-year high growth and growing complexity of product design led to production difficulties in its microwave component division responsible for making GaAs FET multi-function hybrids. As a result, the company had to stop taking orders at that plant. Meanwhile, a new plant in Methuen, MA, which was built to help expand production capacity, sat mostly idle. Alpha's rapid growth faltered. Alpha removed the divisional management and brought in the company's newly appointed President M.J. "Woody" Reid to run the division. *(Reid joined the company in 1969 as an engineering group leader and became Division Manager of the Solid-state Division in 1971).*

To add to Alpha's difficulties, the company was indicted by grand jury on suspicion of bribery in 1984 for purchasing a marketing study that turned out to be a report previously delivered to the Navy. This led to a four-month suspension from receiving military contracts, costing the company $10 M worth of business. Eventually, Alpha settled with the Pentagon, and the Air Force dropped Alpha's suspension. At the time, George Kariotis acknowledged his company's poor judgment in buying the report, but denied that the payment was a bribe.

But the impact was felt, nonetheless. Alpha estimated that it began losing business at the rate of $2.5 M a month. The company stock dropped from a high of $19 a share to $9.50. Profits for the quarter that ended March 31, 1985 collapsed to nearly zero. In the next quarter, Alpha lost money for the first time since 1974 and continued to operate at a loss for two more consecutive quarters. The productivity problems forced the company to cancel orders, reducing the division's backlog from $18 M in June of 1985 to about $12 M by the New Year. Investment in the Methuen plant and a new GaAs fab in Woburn had drained a much-needed $20 M out of the company's cash reserves. With Alpha's strategy for growth centered on the Microwave Component division, the setback was especially hard on the entire company. With morale at an all-time low, "Our dear competitors did a number on us and sucked a lot of good people out of that division," stated Kariotis in an interview at the time.

Still, the company held a strong position in the profitable off-the-shelf diode niche market and the general microwave market was growing at about 20 percent. Alpha dug in and re-tooled, starting with substantial cutbacks to its expenses and plans to launch any new ventures. And the future held promise. According to Vincent, the $ 20 M investment in the Woburn GaAs fab allowed the company to participate in the DARPA MIMIC program in the late 1980s. In 1987, the company entered a joint venture with Martin Marietta to share R&D expenses in developing millimeter-wave MMICs. As partners in the MIMIC program, Alpha focused on millimeter-wave technology, MIMIC partner ITT was responsible for microwave technology and Martin Marietta was the integrator. The GaAs fab investment, strategic partnerships and MIMIC program helped Alpha crawl its way out of the abyss. As a defense contractor, Alpha built specialized GaAs semiconductors for satellites, missile and radar systems. Although it was a defense program, MIMIC was instrumental in helping this microwave company move into high volume commercial applications, such as LNAs, GPS and base station components and switches for handsets. With a shrinking US military budget in the early to mid 1990s, company executives decided to push Alpha's technology toward commercial applications, namely cellular telephones. But there were still plenty of obstacles to navigate.

In 1992, M/A-COM and Alpha were both trying to become more efficient and move into the nondefense electronics arena. They often called on the same large military and commercial customers. M/A-COM, under the leadership of President and CEO Thomas Vanderslice, had been downsizing – selling seven companies acquired during the booming military buildup of the 1980s. Cuts in military spending resulted in fewer potential dollars for either company, although each had made strides to be less reliant on government contracts while attracting a greater portion of nonmilitary business.

Driven by the same market dynamics and sensing a weakened competitor, M/A-COM's Vanderslice attempted a hostile takeover of Alpha in April of 1992, offering to acquire the company's stock for $4 a share, a total of $32 M. In a letter to Alpha's President and CEO M.J. Reid, Vanderslice commented that Alpha's short-term earnings and "relatively small size of Alpha's operations, the capital and indirect cost requirements it now faces, and the consolidation which is taking place in the industry, make our combination compelling." Alpha immediately rejected the offer. Three weeks later, Vanderslice went public to try and gain the support of Alpha shareholders.

"Alpha is a fine company, but they don't have the dollars to put in research and development – and they are a market niche-oriented company that would do better with us," declared Thomas Vanderslice, President and CEO of M/A-COM in 1992.

In an interview with the *Boston Globe,* Vanderslice said he thought a merger with Alpha "could be a marriage made in heaven." Kariotis disagreed, saying that for Alpha customers and employees, the M/A-COM offer "is more like a marriage made in hell" and insisted that Alpha had a new strategy it wanted to implement and therefore wanted to remain independent. Controlling 22 percent of Alpha's shares, Harvey Kaylie, President of Mini-Circuits, was the company's largest shareholder and an Alpha Director at the time. Kaylie assured the board that "he would stay with Alpha and if put to a vote he would not sell his shares." Kariotis also retained the services of Wall Street investment bank Goldman Sachs to help fight the takeover threat. With the legal and financial guidance of Goldman Sachs, backing of the company's largest shareholder and belief in the company's future direction among board members, Alpha was able to fight off M/A-COM's take-over attempt.

Despite the exodus of technical talent experienced by Alpha in the mid 1980s and the hostile takeover attempt in the early 1990s, the company was still able to recruit some key technical personnel and managers. Daniel Gallagher joined the company in 1989 as Director of Device Operations of Alpha's Devices Group and became Vice President the following year. Gallagher had spent more than 21 years at M/A-COM, eventually serving as Vice President and General Manager of the company's Advanced Semiconductor Division in Lowell, MA. Tom Leonard joined Alpha Industries in 1992 as a Division General Manager at the Methuen facility and served as its Vice President after 1994. Leonard had also held a variety of executive and senior level management and marketing positions at M/A-COM, Varian Associates Inc. and Sylvania. Leonard served as President of Alpha Industries, from 1996 to 1999 and served as Chairman of the Board from April 2000 to June 2002. In addition, Skyworks' current CEO, Dave Aldrich joined the company in 1995 as Vice President, CFO and Treasurer. From 1989 to 1995, he had held senior management positions at M/A-COM.

Together, these managers led the company through a dramatic transformation from defense contractor to commercial vendor. They quickly recognized that by trying to serve these markets simultaneously, they ended up serving both poorly. And so the decision was made to pursue just the commercial market. In 1994, the company transferred certain product lines from the Methuen facility to the company's headquarters in Woburn, closing that facility the following year. Leonard's office also moved to Woburn as he became Vice President. One of his first actions was to implement company-wide training in the Total Quality Management (TQM) process, instilling tighter manufacturing controls. By the end of the 1990s, Alpha was primarily a commercial supplier; it transformed its culture, systems, and approach to designing products and supporting customers in the process.

Today, Skyworks is a direct descendant of this 1990 transformation. Through the 1980s and 1990s engineers frequently bounced from M/A-COM to Raytheon to Alpha Industries and back again. Today Skyworks

and its competitors are much better at retaining talent. The landscape has changed because a number of these organizations are no longer the same as they used to be. Today all those companies are more highly specialized and focused on specific markets than they were. A defense contractor such as Raytheon is much more focused on systems than on microwaves. As a result, they are not pumping out the quantity of engineers with RF component experience that they used to.

Cory joined Skyworks right after it became Skyworks. Before that he "had done the merry-go-round," including an interlude with the Analog IC group at Analog Devices, but it was not the same focus as Skyworks. Cory suspects that company specialization has made it harder for people to bounce between companies and hit the ground running. "So that makes us (the engineer) a little less portable, but on the other hand, the big advantage is that we can specialize and offer a lot more to our current employers."

Whitefield had a different opinion on the labor market. He has been with Skyworks for 18 years and "didn't get drawn into the exchange program. We currently have design centers, which we didn't have years ago when engineers moved between the larger companies. Some companies could certainly see attrition, but fortunately we don't see much."

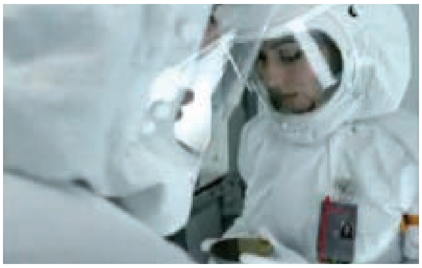
Skyworks is expanding. Today it has more than 90 open positions across the globe. It is a challenge to fill technical positions, but it continues to work with universities and expand its design centers, opening one in Greensboro, NC and one in Ottawa, Canada. The company is mostly hiring engineers with their master's degrees and PhDs right out of school for application engineering. Engineering today, especially in RF, is so application intensive. The two most recent application engineering hires are both Mandarin speaking, one with his master's and the other has his PhD. When the company hires these recent grads, Cory likes to congratulate them and tell them that "they are now ready to begin their real education. The advanced degree only proves they have the aptitude to learn this stuff. We like to assign them to senior people to teach them the practical side of engineering."

According to Stasey and Whitefield, back in the 1980s, there were a bunch of analog guys and digital was sort of the new appealing place to be. And then in the 1990s, everybody was digital and you couldn't get any analog guys. Because of the proliferation of wireless, Skyworks is seeing more multi-disciplined engineers coming out of university now, graduates are not labeled as either analog RF or digital as much as they used to be.

"Certainly they will come out of school with a tendency toward a certain discipline, but today you've got to know a little bit about all of those things," said Cory. "Today they are getting much more of a mix. Just recently we were hiring for a couple of positions and we had a candidate with a good silicon background, but his work didn't really pertain as much to RF as we would have liked. He reminded us that he was working with processors operating at 5 GHz; everything is RF now."

Skyworks has a number of programs in place to coordinate engineering efforts and orient new hires. New employees at a design center will work from the Woburn (HQ) facility for a week at a time to get a feel for the environment. Groups will frequently visit remote sites for working meetings and design reviews, on top of being connected via phone and Internet.

Technical reviews occur quarterly by phone, in addition to a company sponsored technical conference. For the technical reviews, a couple dozen people across the company will travel to these reviews and there is a dial-in for the rest of the company to listen in. In these reviews, they walk through the latest technology updates on all aspects of business, such as packaging, PHEMT, Silicon, HBT, and all aspects of development. So for instance, they might talk about some new modeling technique now available and how



▲ *Fig. 4 Closing shot from "Such Great Heights" video.*

to get to it. It's an all-day event and they typically have about 200 people participating.

bit.ly/j6FXOT.qrcode

View video here.

Whitefield is head of the steering committee for the company's internal technical conference. "We solicit papers in different categories, review them and have people present them, just as they would at any other external technical conference. But the beautiful thing is that we don't have to filter what we say because it is all Skyworks employees. So we can present proprietary and confidential information. It's great because you don't get the superficial, boiled down version. You get the real version. It is also about team building, because you get to talk directly to the author."

Past Technical Conference Session Topics Have Included:

- Process Technology and Reliability
- Manufacturing and Test
- Packaging Technology
- Circuits and Systems
- Design Automation/Device Modeling
- New Materials and Material Interactions

Stasey and the company also take pride in the Skyworks leadership development program. It's a multidisciplined curriculum for potential leaders. In short, Skyworks believes in openness, professional development and operating within well-defined processes as the key ingredients to its success (see ***Figure 4***). Is there any other way to achieve such great heights? ■

In May, Skyworks announced that it was acquiring SiGe Semiconductor for $210 M. Read more in this month's Around the Circuit column (see page 62).

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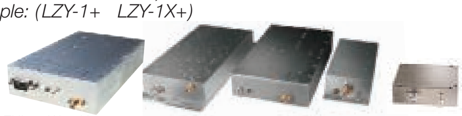
With Heat Sink/Fan										
LZY-1+	20-512	43	+45.7	+47.0	8.6	+54	26	7.3	1995	1895
LZY-2+	500-1000	46	+45.0	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41.0	+42.0	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920
NEW										
ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220
ZVE-3W-83+	2000-8000	36	+33.0	+35.0	5.8	+42	15	1.5	1295	1220
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920

• ***Protected under U.S. Patent 7,348,854***

For models without heat sink, add ***X suffix*** *to model No.*
Example: (LZY-1+   LZY-1X+)



ZHL-16W-43X
ZHL-30W-262X

ZHL-5W-2GX

LZY-1X+
LZY-2X+
ZHL-10W-2GX
ZHL-50W-52X
ZHL-100W-52X
ZHL-100W-GAN+

ZHL-20W-13X

ZVE-3W-83+
ZVE-3W-183+

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IF/RF MICROWAVE COMPONENTS

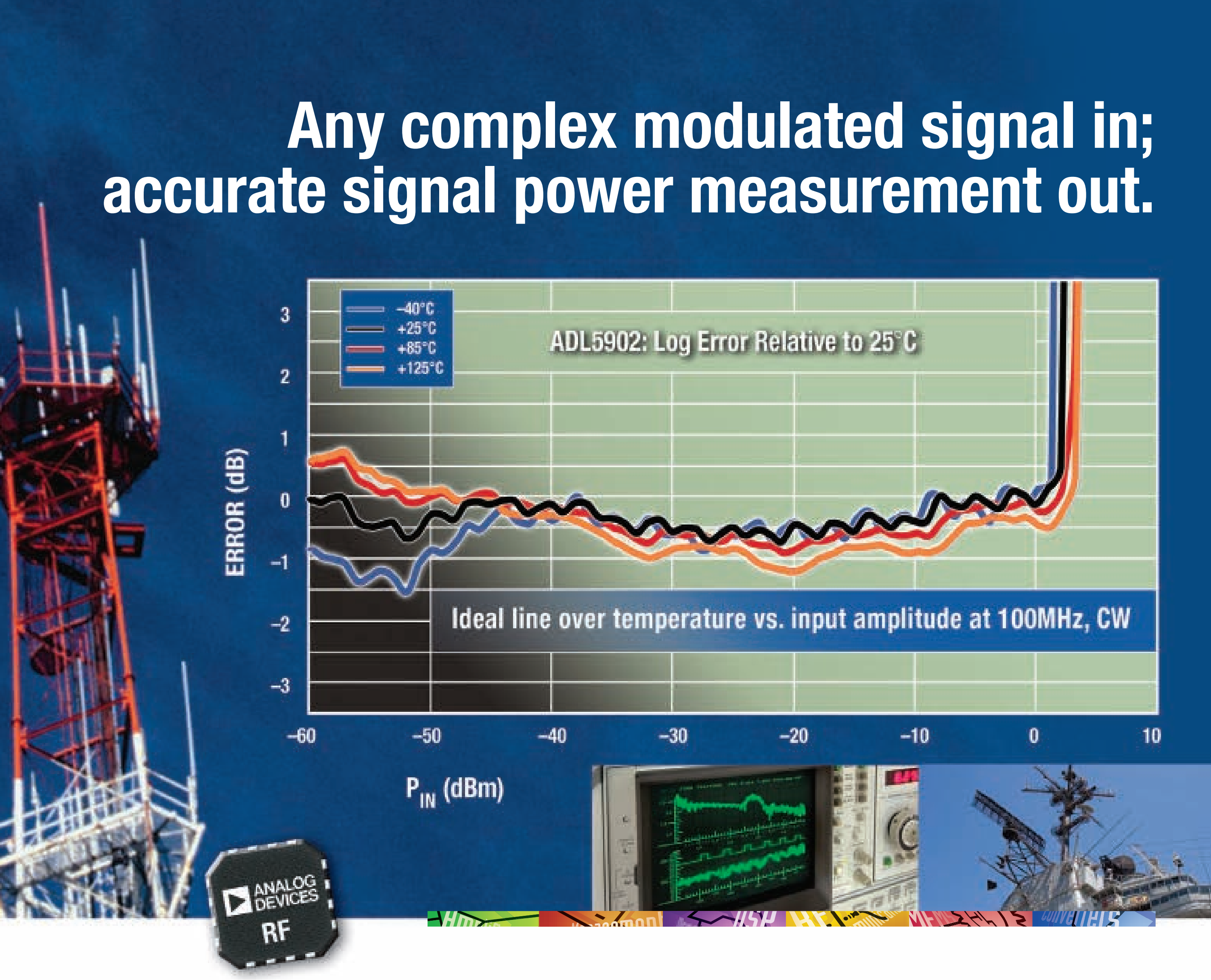
416 rev V

TARGETING PIM TESTING

As the electromagnetic spectrum becomes increasingly crowded, regulatory agencies focus on enforcing existing regulations and establishing new ones to ensure that communications and radio location systems remain operational. In this environment, it is of paramount importance to monitor spurious emissions of systems at the design, type approval testing and production stages. K&L Microwave and sister company Dow-Key Microwave have developed a series of products to make such testing more accurate and efficient. Bandpass/bandstop (BP/BS) and lowpass/highpass (LP/HP) diplexers meeting rigid Passive Intermodulation (PIM) specifications are the essential building blocks of innovative testing system architectures. By integrating these filters with Dow-Key's switch matrices, an OEM can construct a single automated test system capable of covering a variety of frequency bands. Test systems of this kind can be further expanded to accommodate injection of interfering signals, monitoring ports and other customer requirements.

Traditionally, diplexers are used to separate two frequency bands. K&L Microwave has designed a series of high Q cavity BP/BS diplexers to perform this function. The diplexer design features one bandpass and one bandstop filter sharing a common port. The two filters are at the same center frequency and have the same, or very similar, bandwidths in order to perform two important functions during testing. First, this arrangement provides a broadband match at the common port, maximizing performance of the device under test (DUT). Second, the two filters separate the fundamental carrier from any spurious emissions that may be created by the DUT. The DUT is connected to the common port of the diplexer, and the bandpass port can be terminated or used to test the output at the DUT's fundamental frequency. The bandstop port is connected to a spectrum analyzer to measure the spurious emissions generated by the DUT. High Q cavity bandstop filters, by their nature, are re-entrant at approximately twice center fre-

K&L MICROWAVE
Salisbury, MD


Any complex modulated signal in;
accurate signal power measurement out.
−40°C
+25°C
+85°C
+125°C
ADL5902: Log Error Relative to 25°C
ERROR (dB)
3
2
1
0
−1
−2
−3
Ideal line over temperature vs. input amplitude at 100MHz, CW
−60
−50
−40
−30
−20
−10
0
10
P IN (dBm)
ANALOG DEVICES
RF

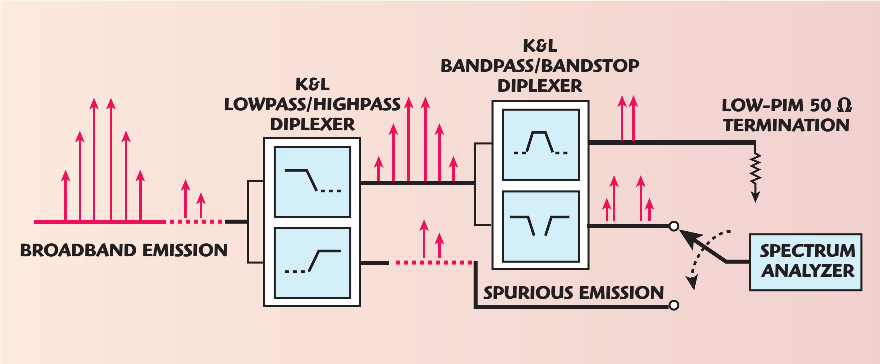


Fig. 1 *Broadband PIM monitoring.*

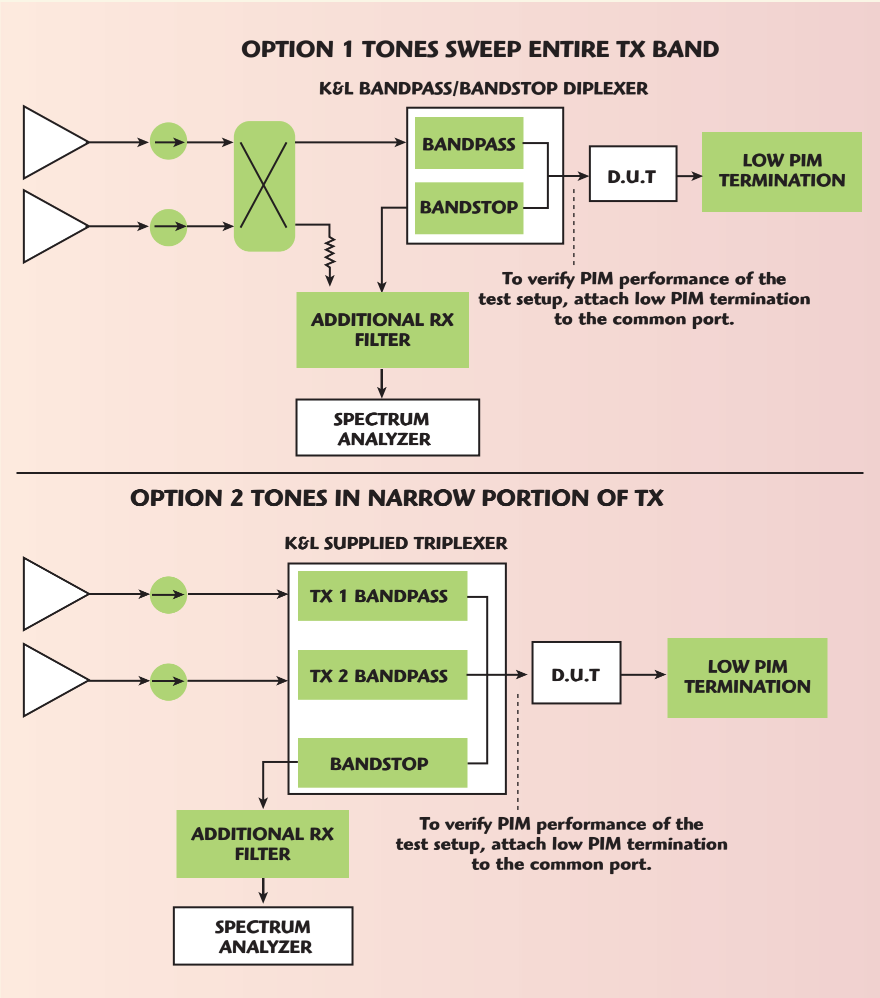


Fig. 2 *Reflection mode system configurations.*

quency; therefore, the BP/BS diplexer cannot be used to test spurious emissions beyond that point. To measure those frequencies, an LP/HP diplexer is needed.

K&L Microwave has designed LP/HP diplexers with crossovers useful for the major cellular bands. By connecting the DUT to the common port, as with the BP/BS diplexer, the far out-of-band emissions can be measured at the highpass port. These diplexers contain highpass filters that extend as far as 13 GHz to cover all of the known regulations regarding cellular spurious emissions. To simplify measurements, the LP/HP diplexer can be cascaded with a BP/BS diplexer. In this case, the lowpass port of the LP/HP diplexer is attached to the common port of the BP/BS diplexer, as shown in ***Figure 1***.

When cascading the two diplexers together for testing, the customer will select an LP/HP diplexer with a crossover slightly below two times the center frequency of the BP/BS diplexer. Once assembled, the DUT is attached to the open common port, the bandpass port can be terminated, and spurious measurements are made at the bandstop and highpass ports, as in Figure 1. In this way, the spurious emissions of a device can be accurately determined. Of course, it is critically important that the filters used for the testing do not cause false readings. In cases where multiple high power carriers are transmitted by the DUT, one has to consider PIM that may be generated by the filters.

In order to provide the most cost-effective solution while maximizing performance, K&L Microwave offers BP/BS and LP/HP diplexers for bands of interest in three variations. Each of the variations has a guaranteed level of PIM performance allowing the customer to select filters best suited to existing needs. The base part number and lowest-cost option has guaranteed PIM of -100 dBc when subjected to two input tones of +43 dBm. For situations where somewhat better PIM performance is needed, a "-1" is added to the end of the part number, denoting PIM of -130 dBc at the input powers noted above. For the most stringent testing requirements, "-2" versions are guaranteed to meet -156 dBc PIM at the same input powers. For example, the three variations of a GSM900 BP/BS are WSD-00491, WSD-00491-1 and WSD-00491-2.

In addition to testing OEM transmitters as noted above, these diplexers can be used to test stand-alone passive devices for their PIM performance. In stand-alone cases, there are two basic configuration options that allow utilization of existing lab equipment to verify the PIM performance of parts. Measurement can be made using Reflection Mode or Through Mode; see ***Figures 2*** and ***3***. With the system configured as shown, the PIM performance of a passive DUT can be measured at any frequency supported by the available equipment. This approach makes it unnecessary to purchase expensive equipment that can only measure PIM performance in one frequency band.

Ultimately, taking advantage of the Switch Matrix expertise of Dow-Key Microwave, these filters can be integrated into a system that allows testing of multiple functionalities over multiple

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SPECIFICATIONS

Part Number	*Architecture*	*Freq (GHz)*	*Gain (dB)*	*Avg P_{OUT} (dBm)*	*EVM %*	*V_{CC} (V)*	*Current at P_{OUT} (mA)*	*Package Style*	*RoHS Comp Pb Free*
RF5365/75	2.4 GHz FEM, PA, SP3T SW, and P_{DET}	2.4 to 2.5	27	18	3.0	3.0 to 4.8	170	QFN 2.5 x 2.5	Y
RF5385/95	2.4 GHz FEM, PA, SP3T SW, and P_{DET}	2.4 to 2.5	27	20	3.0	3.0 to 4.8	190	QFN 2.5 x 2.5	Y

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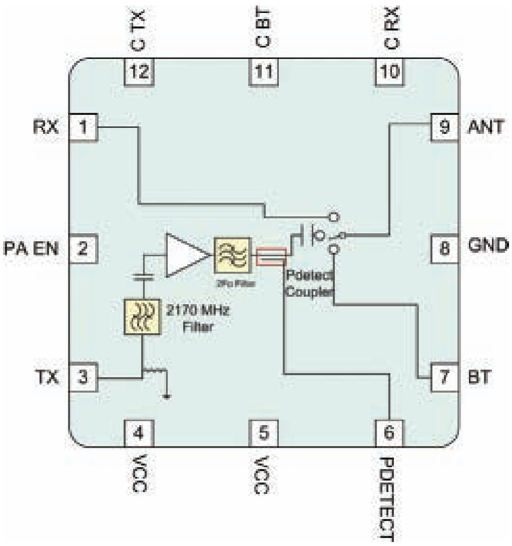
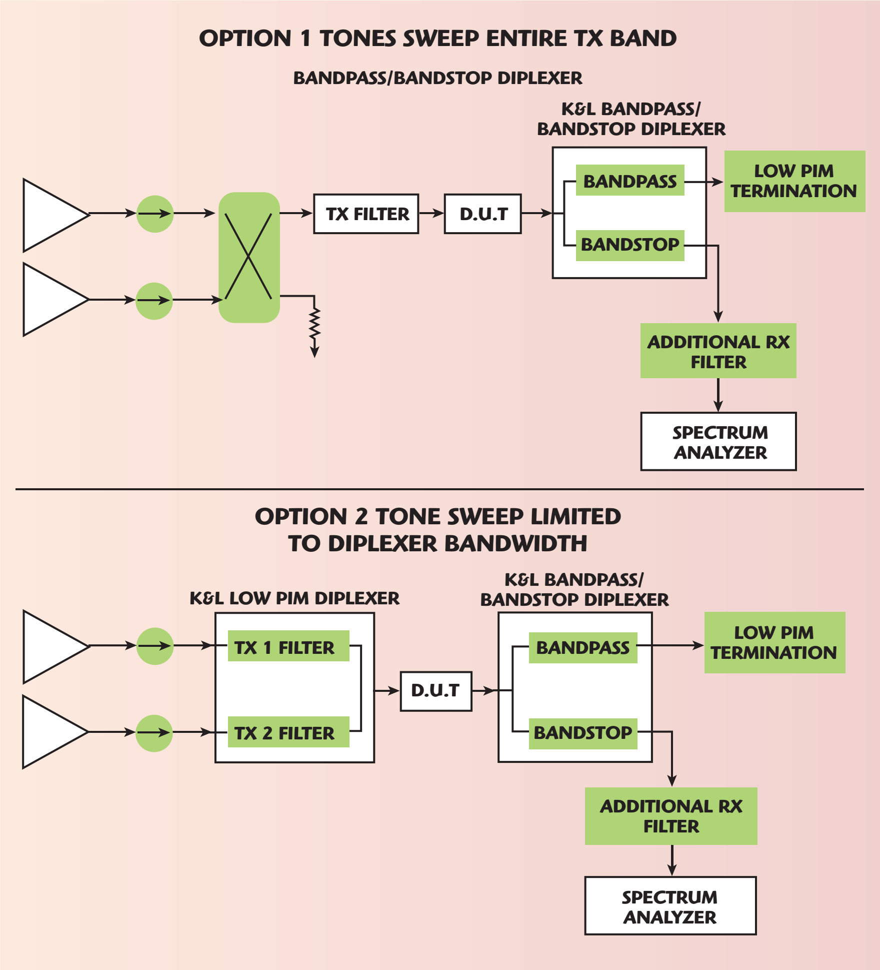


RF5365/RF5375 (mirror image)
- **PA, LPF, SP3T**
- **18 dBm at 3.0%**
- **2.5 x 2.5 x 0.5 mm**

RF5385/RF5395 (mirror image)
- **High Power PA, SP3T**
- **20 dBm at 3.0%**
- **2.5 x 2.5 x 0.5 mm**



▲ *Fig. 3 Through mode system configurations.*

frequency bands. PIM testing can be performed using broadband amplifiers, combiners, and spectrum analyzers. In applications where PIM performance is not as stringent, such as the testing of cellular chipsets, spurious out-of-band measurements can be made and coupler ports can be supplied to allow the injection of interfering signals for performance testing under simulated adverse environments. These custom test solutions can be designed to meet the exact requirements of a type approval test lab or for performance testing of production hardware. ***Figure 4*** shows typical layouts for both PIM and small signal testing applications. Ease of calibration is an additional advantage inherent to test systems realized in this way.

This product feature provides an overview of a scheme for assembling affordable and flexible broadband emission monitoring test systems from high-performance building blocks. Dow-Key Microwave and K&L Microwave supply cost-effective test solutions tailored to customers' specific needs.

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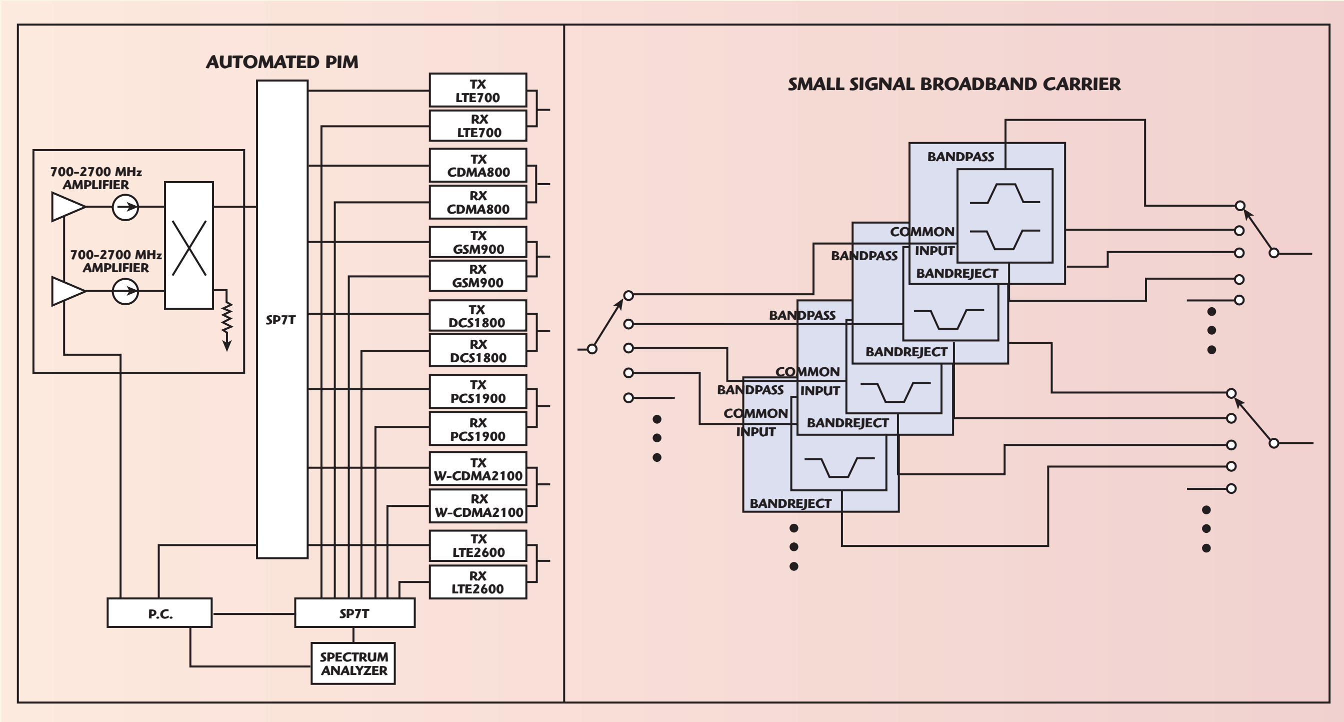

▲ *Fig. 4 Broadband emission test systems.*


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IMPACT OF MATERIALS ON MICROWAVE CABLE PERFORMANCE

Cables are often the last component considered during system designs. In many situations, cables are the system's lifeline. For example, if the cable system used for data transmission in a spacecraft fails, the communication between the craft and the ground station could be lost. Cable reliability is based on both durability and signal integrity and the materials used to engineer the assemblies have a direct impact on their life in any environment.

The environments in which microwave cable assemblies are being used are becoming more challenging with exposure to such conditions as extreme temperatures, chemicals, abrasion and flexing. Additional challenges include the need for smaller, lighter packaging for cable systems that last longer and cost less. To ensure signal integrity and product reliability, it is essential to identify the electrical, mechanical, environmental and application-specific constraints that can affect the cable's overall performance. These variables have a direct impact on the materials used for cable dielectric and jacketing as well as the construction of the cable. Also, testing and data analysis are key to ensuring that the cable will, in fact, perform reliably in a specific environment.

IDENTIFYING CONSTRAINTS

Environmental influences are having more of an impact on RF/microwave cable assemblies. Electrical performance is probably the first and foremost consideration and many factors can potentially compromise signal integrity, such as internal and external electromagnetic interference (EMI), voltage standing wave ratio (VSWR) and insertion loss. Electrical performance is typically very reliable when no other environmental factors are involved. However, when mechanical, environmental, or application-specific stress is added, maintaining reliable electrical performance can be more challenging.

Mechanical stress occurs when cables are exposed to various types of movement. Flexing creates kinetic energy in the cable, which can cause severe damage if not properly managed. One of the biggest causes of mechanical stress on cables is when the cable is part of equipment handled by a person. An operator can kink, pinch or crush a cable by stepping on it or rolling over it. Therefore, crush and tensile strength is essential in mitigating mechanical stress. Also, cables used with portable equipment can come into contact with sharp surfaces that cut cables or expose them to abrasion. When the complexities of compensating for vibration or gravity are added, mechanical stress can significantly compromise stability and cause premature failure of a cable.

Environmental stress results from the physical area in which the cables are used. Extreme temperatures and pressures affect cable materials. Low temperatures make them brittle and high temperatures cause them to become very soft. Vacuum leaches oils and additives out of a cable, contaminating a clean room manufacturing process, while hydrostatic pressure causes gas or liquids to permeate cable jackets. Radiation can damage both dielectric and jacket materials, depending on the type and dosage level. Friction resulting from cable movement can compromise cable jackets by causing particulation, while contaminants such as mud, chemicals or metal chips can damage the cable

PAUL PINO
W. L. Gore & Associates, Inc., Landenberg, PA

jacket. Environmental stress can significantly compromise dielectric and jacketing materials, so these issues must be taken into account when designing a cable assembly.

Application-specific stress results from constraints that are unique to the application in which the cable will be used. In aerospace applications, cables need to be the lightest and smallest possible size in order to minimize mass during take-off. If the cables are used by technicians or other personnel, safety issues such as flammability, voltage and halogen use are factors.

One of the added complexities of designing cable assemblies is that electrical, mechanical and environmental performance is interwoven. Each has a direct impact on the other, so the design must be thoroughly tested for the specific application.

TABLE I

PROPERTIES OF SILICONE

	Advantages	Disadvantages
Electrical		Dielectric constant
Mechanical	Flexible at low temperatures	Low cut-through resistance High coefficient of friction High specific gravity
Environmental	Radiation resistance to 10^8 RADs	Outgasses silicone oil Low resistance to oil Tacky texture
Application-specific	Low-profile packaging	Weight Thick insulation needed, leading to large outer diameter

TABLE II

PROPERTIES OF POLYURETHANE

	Advantages	Disadvantages
Electrical	Overall electrical performance	Dielectric withstanding voltage
Mechanical	Cut-through resistance Abrasion resistance Flexibility Flame treatment does not reduce flexibility	Tacky in high-flexibility grades
Environmental	Solvent resistance UV resistance Radiation resistance Fungus resistance Halogen-free	Temperature resistance Contaminant resistance
Application-specific	Primarily used for jacketing	

TABLE III

PROPERTIES OF POLYETHYLENE

	Advantages	Disadvantages
Electrical	Dielectric constant	
Mechanical	Abrasion resistance Wide range of grades	Stiff in abrasion-resistant grades
Environmental	Chemical resistance Coefficient of friction Radiation resistance	Temperature resistance Adhesion Flame retardance
Application-specific	Used for conductors and jacketing	Flexibility

CHOOSING THE RIGHT MATERIALS

Ensuring high quality signal stability means evaluating the dielectric and jacket materials for attributes that account for the harsh elements of the application. The dielectric materials used in signaling cables affect the signal integrity as well as the robustness of the cable. The material used in an outer jacket affects maximum voltage and resistance to abrasion. Jacket materials must survive most of the external factors (such as temperature, friction, liquids and gases) to protect the conductors inside the cable. The list of possible materials used in cable dielectric and jacketing is very long and many of these have been developed for specific applications. Because each material has unique properties, some are more appropriate than others for use in microwave cables engineered for challenging environments.

Silicone

Silicone (see ***Table 1***) is primarily used as a cable jacket and is very flexible, even at low temperatures. However, it can be cut easily and its sticky surface results in a high coefficient of friction, so it is not good for clean room environments. Silicone's tensile strength and tear resistance is low, requiring it to be thicker as compared to other jacket materials. Some surface treatments are available to reduce the coefficient of friction, but these tend to wear off over time. Silicone has very good radiation resistance, but the grades of silicone used for cable jackets are known to outgas silicone oil in vacuum applications, such as a thermal vacuum chamber. If weight is an issue, silicone is not the optimal choice. If flexibility is important and weight is not a factor, silicone is a good choice. However, it is more labor-intensive to gain access to the conductors, which results in higher costs for termination.

Polyurethane

Polyurethane (see ***Table 2***) is a good jacket material, but it is not used as a dielectric material because its dielectric withstanding voltage is low when compared to other materials. Halogen-free grades are available. Mechanically, polyurethane is flexible and is very resistant to cut-through and abrasion. Treatment for flame resistance does not reduce its flexibility. However, the more flexible grades tend to be sticky or tacky, which results in a higher coefficient of friction. Environmentally, polyurethane is resistant to solvents, UV rays, radiation and fungus. Polyurethane does not have a very broad temperature range; it becomes brittle at approximately -40° and its upper temperature limit is approximately 100°C. Also, polyurethane cannot survive the chemicals used for cleaning.

Polyethylene

Polyethylene (see ***Table 3***) is most appropriate as a dielectric for conductors, because polyethylene jackets tend to be stiff, which affects the flexibility of the cable. Polyethylene has good dielectric constant properties, when used in conjunction with foam. Mechanically, high molecular-weight polyethylene is abrasion-resistant and low-friction, but it is also stiff when compared to other materials. Like polyurethane, polyethylene's temperature range is rather limited and it is difficult to bond chemical boots to polyethylene cable jackets. Overall, the mechanical properties of polyethylene are reduced by flame-retardant treatments.

Fluoropolymers

Fluoropolymers such as fluorinated ethylene propylene (FEP), perfluoroalkoxy (PFA) and polytetrafluoroethylene (PTFE) are excellent jacket materials (see ***Table 4***), particularly in applications in which the cost of system failure is high. The dielectric withstanding voltage of fluoropolymers is among the highest of any dielectric material. Fluoropolymers can withstand extreme temperatures, but each material has its own range: FEP can handle temperatures ranging from -250° to 150°C, while PFA ranges from -250° to 200°C. PTFE is suitable for temperatures from cryogenic to 260°C, without losing flexibility. Fluoropolymers can also withstand exposure to chemicals, acids and aggressive solvents and they are naturally non-flammable. PTFE and its co-polymers also have the benefit of low outgassing, which is critical for ultra-high vacuum (UHV) environments. Most fluoropolymers are flexible, but, like temperature resistance, flexibility varies depending on the specific material. PFA is the stiffest followed by FEP and PTFE and engineered PTFE is the most flexible. Anything that is added to a cable's dielectric, jacket, conductors or shield wires, will outgas in a vacuum. When materials outgas, particulate matter condenses on cooler surfaces, which are typically the work surfaces in the application area. In a satellite, optics can become fogged by silicone oil or other processing lubricants that outgas from a cable. PTFE is chemically inert and does not contain any process additives, oils, lubricants or plasticizers, making it the best material for vacuum environments.

TABLE IV

PROPERTIES OF FLUOROPOLYMERS

	Advantages	Disadvantages
Electrical	Dielectric constant	
Mechanical	Flexibility Tensile strength	Abrasion and cut-through resistance
Environmental	Liquid and gas resistance Temperature resistance UV resistance No outgassing Coefficient of friction	Radiation resistance
Application-specific	Used as dielectric jacketing Flame resistance Performance standards	Additional processing required

Engineered Fluoropolymers

One of the few negatives of fluoropolymers is they are not very resistant to abrasion and cut-through. Certain fluoropolymers can be engineered to enhance their physical, chemical and electromagnetic attributes, which improves a cable's ability to withstand the specific challenges of a microwave application. Ethylene tetrafluoroethylene (ETFE) can be irradiated to improve its mechanical properties and chemical resistance, however, irradiation increases stiffness, so there is a significant decrease in flexibility. PTFE is naturally thermal-resistant and chemically inert, so its temperature and chemical properties are not altered when engineered to enhance electrical or mechanical attributes.

TABLE V

ENHANCED PROPERTIES OF ENGINEERED FLUOROPOLYMERS

	Properties
Electrical	Dielectric constant
Mechanical	Flexibility Tensile strength
Environmental	Temperature and UV resistance Chemical resistance Coefficient of friction Outgassing
Application-specific	Liquid and gas resistance Weight and size

Specialized technologies have been developed to engineer PTFE so that it can withstand a wide variety of environmental and mechanical challenges (see ***Table 5***). The dielectric materials used to insulate conductors can significantly affect insertion loss, cable size and flexibility. The lower the dielectric loss, the less insertion loss the cable exhibits. Typical fluoropolymers have a dielectric constant of 2.1. To reduce cable size, PTFE can be engineered to have a dielectric constant of 1.3. For a given impedance (Z0), keeping the outer conductor diameter constant, the inner conductor diameter will be increased, and the conductor loss will decrease. At the same time, its dielectric withstanding voltage can be increased by a factor of 2.5 while achieving a very low loss tangent of 0.00015 at 10 GHz, compared to PTFE's standard construction. With these attributes, a conductor insulated with a 1/2000th inch (50 µm) layer of engineered PTFE can be rated for use at 1000 V. Another version of engineered PTFE can be made semiconductive and be used to increase the effectiveness of a cable's shield. For issues of abrasion or cut-through resistance, PTFE has been engineered to attain a tensile strength that is 50 times greater than standard PTFE and to withstand temperatures from cryogenic to 300°C.

VERIFYING THE DESIGN

Some industries have defined safety, environmental and performance-related standards for cables, but many rugged applications that use microwave cables require going beyond the standards. In these kinds of situations, the manufacturer may need to develop additional tests that evaluate the cable's electrical performance, while simulating mechanical and environmental stress similar to that in the application. It is essential to monitor electrical performance and signal integrity throughout all of the testing.

The specific type of testing that is needed depends on the environmental constraints of the application.

Phased-array applications require close phase tracking of multiple assemblies of the same type and length to minimize residual systemic error. These errors eventually affect system range, clutter and jamming resistance and overall accuracy. Problems with phase tracking most often occur either because of poor materials and process control during cable assembly manufacturing or because assemblies from different manufacturers' components were combined. So phase tracking and stability should be thoroughly tested in the environment in which they will be used.

Mechanical testing verifies electrical performance while the cable is operating in environmental conditions such as crushing, abrasion, potential cut-through, tight bending, continuous flexing, shock and vibration. Using RF/microwave cables generally means that the application requires excellent phase stability, which can be affected with bending and flexing, whether during installation, routine maintenance, or actual use. Random flexing is a frequent issue with a handheld test instrument because the cable assembly is often wrapped around the instrument to carry it. The impact of these movements on system performance must be evaluated during system design. In the lab environment, a technician could roll over the cable with a chair, which means crush strength is also an issue. Random flexing motion is very difficult to model in a test lab, but the worst-case scenario can be modeled using a tic-toc test with repeated bending of 180° or more. Then, a pull test can simulate a cable being used as a tether. During these tests, insertion loss and VSWR should be evaluated.

The cable's electrical performance should also be measured while simulating the environmental conditions in which it will operate — conditions such as temperature, altitude, and pressure extremes, vibration and acceleration, and exposure to liquids or gas or humidity. It is important to monitor impedance during altitude change, mechanical shock and vibration tests. Vibration and shock can cause mechanical and electrical failure due to metal fatigue or cracking of solder joints. Temperature changes have a direct impact on phase length. As the temperature approaches an extreme, the electrical length will change; if it does not change at the same rate as the temperature when returning to normal (a state known as hysteresis), it is very difficult to apply error-correction techniques to the signal. Adding a clamp force during a temperature cycling test allows monitoring of the cable's dielectric withstanding voltage to see how the jacket and conductor change. After the cable is put through substantive mechanical and environmental tests, the manufacturer should again verify that the electrical performance, dielectric, and jacket materials remain stable within the requirements of the application.

For products that will be used in demanding environments, the consequences of cable failure are usually high. Therefore, it is essential to ensure the electrical and mechanical integrity of the cable for the life of the application. To do this means understanding the factors that can compromise cable performance, selecting the right materials to address these factors and verifying the cable's reliability through electrical, mechanical and environmental testing. ■

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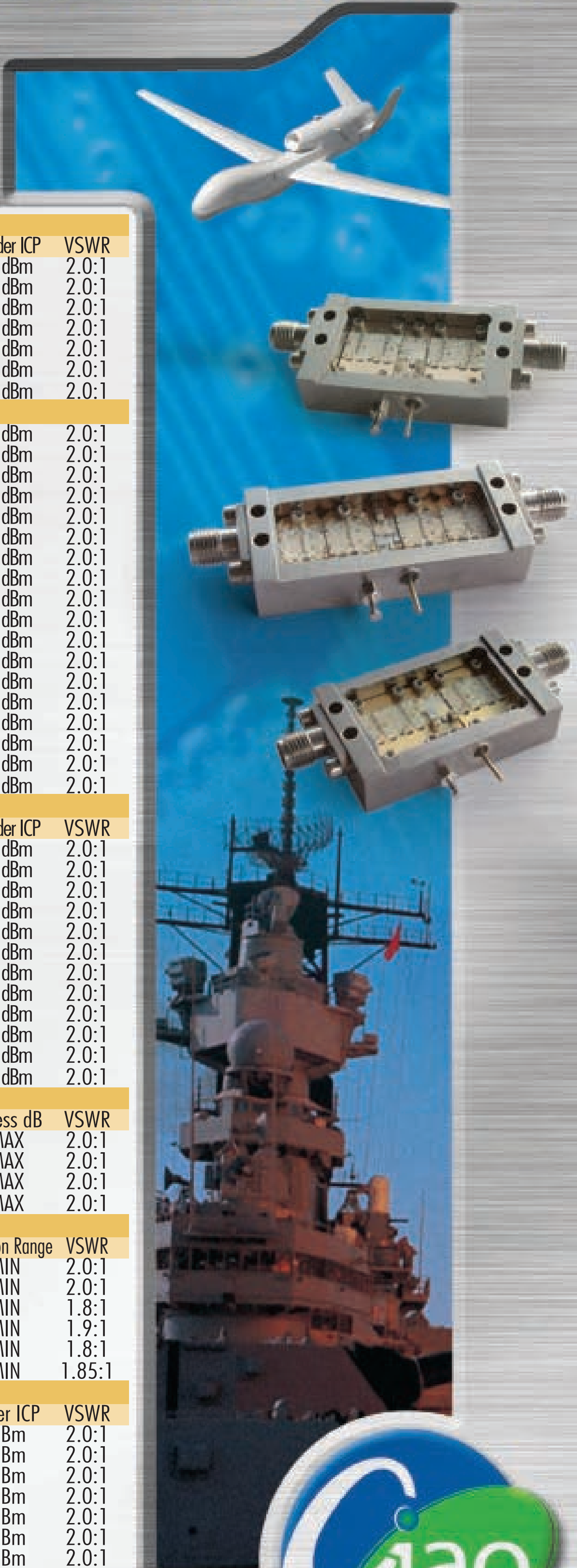

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Electronic Warfare Linked Up with Space Communications

Air, sea and land electronic warfare (ASLEW) is waged within the electromagnetic (EM) spectrum to both attack and defend against enemy personnel and equipment. The Strategy Analytics Advanced Defense Systems (ADS) service report, "Space Communications Systems and Electronic Warfare," predicts that space communications systems will play a strategic role as an electronic warfare force multiplier, as electronic warfare becomes increasingly integrated and net-centric.

Electronic Warfare (EW) uses the electromagnetic spectrum to attack and disable enemy sensors, data links, communications, and directed energy weapons while also denying enemy EW efforts. Unlike physical weapons, such as tanks, aircraft and ships that are specific to air, sea or land domain, EW readily lends itself to multi-domain warfare. This requires increasing use of space communications system assets for effective management.

"Ideally EW needs to be centrally planned and directed, and de-centrally executed with the various investments made by the different branches effectively applied in a coordinated fashion," noted Asif Anwar, ADS Service Director. "To this end, there will be an increase in use of space-based assets to support airborne, naval and ground systems as part of the electromagnetic battlefield management (EMBM) strategy."

"This strategy is already employed by the US military. Other nations also recognize the importance of EW systems," added Eric Higham, ADS Service Director North America. "Space communications assets will be pivotal in supporting the net-centric capabilities required for tighter integration of EW and CIW, cyber/information warfare."

Northrop Grumman Awarded $372 M Contract to Develop EHF Satellite Antenna for B-2 Bomber

A new antenna system now under development by Northrop Grumman Corp. will enable the B-2 Spirit stealth bomber to send and receive battlefield information securely by satellite up to 100 times faster than it can today. The US Air Force recently awarded the company a $372 M contract to begin designing the advanced electronically scanned array (AESA) antenna system as part of Increment 2 of the B-2 extremely high frequency (EHF) satellite communications program. Northrop Grumman is the Air Force's prime contractor for the B-2, the flagship of the nation's long range strike arsenal and one of the world's most survivable aircraft.

"Our work on the EHF antenna system takes full advantage of Northrop Grumman's expertise not only in B-2 advancement, but also in satellite communications," said Dave Mazur, Vice President of Long Range Strike and B-2 Program Manager for Northrop Grumman's Aerospace Systems sector. "This important enhancement will ensure that the B-2 retains its strategic communications capabilities well into the future."

"Our work on the EHF antenna system takes full advantage of Northrop Grumman's expertise not only in B-2 advancement, but also in satellite communications."

Under terms of contract, the company will complete the preliminary design of the AESA antenna system, demonstrate technology readiness and prove its functionality using hardware prototypes. The required engineering design, manufacturing, assembly, integration and test activities will take place at company facilities in Palmdale, El Segundo and Redondo Beach, CA; Dayton, OH, and Tinker Air Force Base, OK. Increment 2 is the largest effort ever undertaken to augment the lethality of the B-2 weapon system.

The three-increment EHF SATCOM program is part of an ongoing effort by the Air Force and Northrop Grumman to keep the B-2 fully mission capable against evolving enemy threats. Increment 1 includes enhancements to the aircraft's processing and communications infrastructure. Increment 2 involves installation of a new communications terminal and the AESA antenna. Increment 3 will integrate the B-2 into the US Department of Defense's Global Information Grid, a worldwide network of information systems, processes and personnel involved in collecting, storing, managing and disseminating information on demand to warfighters, policy makers and military support personnel.

Boeing Phantom Ray Completes First Flight

The Boeing Phantom Ray unmanned airborne system (UAS) successfully completed its first flight April 27 at NASA's Dryden Flight Research Center at Edwards Air Force Base, CA.

The 17-minute flight took place following a series of high speed taxi tests in March that validated ground guidance, navigation and control and verified mission planning, pilot interface and operational procedures. Phantom Ray flew to 7,500 feet and reached a speed of 178 knots.

"The first flight moves us farther into the next phase of unmanned aircraft."

"This day has been two-and-a-half years in the making," said Darryl Davis, President, Boeing Phantom Works. "It's the beginning of providing our customers with a test bed to develop future unmanned systems technology, and a testament to the capabilities resident within Boeing. Just as follow-on tests will expand Phantom Ray's flight envelope, they also will help Boe-

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ing expand its presence in the unmanned systems market."

"The first flight moves us farther into the next phase of unmanned aircraft," said Craig Brown, Phantom Ray Program Manager for Boeing. "Autonomous, fighter-sized unmanned aircraft are real, and the UAS bar has been raised. Now I'm eager to see how high that bar will go."

Phantom Ray is one of several programs in Phantom Works, including Phantom Eye, that is part of a rapid prototyping initiative to design, develop and build advanced aircraft and then demonstrate their capabilities. Boeing's portfolio of UAS solutions also includes the A160T Hummingbird, Integrator, ScanEagle and SolarEagle.

bit.ly/ln91qv.qrcode

Scan to watch first flight video

Harris Corp. Introduces Tactical 3G Cellular Network-in-a-Box for Warfighters

Harris Corp. has introduced KnightHawk™ 3G — a ruggedized, highly mobile tactical base station that enables warfighters on the move to maintain 3G cellular services in locations with limited or no cellular connectivity. Jointly developed by Harris and Battlefield Telecommunications Systems (BTS™), KnightHawk 3G is a customizable cellular Network-in-a-Box (NIB) compatible with commercial off-the-shelf (COTS) equipment, including smartphones and tablets. Each KnightHawk 3G is installed with BTS Praefectus™ Mission Management Software, which automates configuration and management of the cellular network, and enables each KnightHawk to operate autonomously or as a scalable network with hundreds of nodes for increased range. This compatibility allows users in the battlefield to leverage existing applications, thereby enabling them to track a team's location, automatically translate foreign languages, and conduct remote training using existing advanced programs. KnightHawk 3G features UMTS High Speed Packet Access, providing extremely fast connectivity of 14.4 Mbps for downloads and up to 5.76 Mbps for uploads. It also offers the benefits of small size, weight and power (SWaP), making it ideal for mobile, multi-mission requirements in challenging environments.

"KnightHawk 3G is a landmark system that gives the US military immediate access to millions of low cost commercial devices already on the market while maintaining compatibility with future standards," said Dan Pearson, Executive Vice President and Chief Operating Officer for Harris. "Our unique solution blends the principle of interoperability with capabilities that use the current cellular tower model and enables the military to deploy it on a variety of platforms while on the move."

Richard Mumford, International Editor

Growth Strategy and Opening of ISIC Support UK Space Industry

The strength of the UK Space Industry, which is worth an estimated £7.5 B, has been doubly enhanced with the publication by the UK's Space Leadership Council of the National Space Technology Strategy for the UK and the opening by the International Space Innovation Centre (ISIC).

The National Space Technology Strategy for the UK details priority research and technology areas to help the UK space sector grow, including telecommunications and access to space. This will support the National Space Technology Programme announced in the Growth Review and help UK businesses make the most of foreign markets. It is the result of a six-month process, working with all areas of the space sector and taking a range of views and expertise onboard. A series of "roadmaps" have been produced, giving the industry clear, actionable guidance needed to drive innovation and increase market share in areas such as telecommunications, sensing, exploration and access to space.

David Willetts, Minister for Universities and Science and Space Leadership Council Co-chair, said, "The UK's space sector is a key driver of economic growth and is increasing rapidly each year." He added, "Today's strategy is an excellent example of the value of working closely with industry, and I am confident it will provide our space sector with the advice and guidance it needs to truly flourish."

The International Space Innovation Centre is located at Harwell alongside the Rutherford Appleton Laboratory and the European Space Agency's UK office. It is a not-for-profit company with partners from industry and the public sector. ISIC industrial partners include Astrium Satellites, SSTL, Logica and VEGA Space. Public sector partners include STFC, NERC, TSB and the UK Space Agency, as well as the University of Surrey.

Dr. Barbara Ghinelli, Executive Chair of ISIC, stated, "We are very excited about ISIC; we believe it is the catalyst that will bring UK space activities and capabilities together and position us to win a larger share of a growing global market. ISIC integrates four cutting-edge facilities – an Earth Observation Hub, a Security and Resilience Unit, a Visualisation and Application Centre, and a Concurrent Design Facility as well as linking to the wider Harwell Space Cluster which includes the ESA Centre, the ESA-STFC Business Incubator Centre and a growing number of commercial companies."

The COST of European Research is Raised by €30 M

The European Commission Directorate-General for Research and Innovation has informed the European Cooperation in Science and Technology (COST) and the European Science Foundation (ESF) of its decision to allocate an additional €30 M to COST.

COST implements networking activities for researchers, contributing to the European Research Area (ERA) goals and participating in the delivery of the Europe 2020 agenda. The additional funding raises the total budget for COST to €240 M for the EU Seventh Framework Programme (FP7) and an additional €10 M may be released depending on developments in the EU budget.

"This is a clear vote of confidence in COST's governance..."

"This is a clear vote of confidence in COST's governance and our intergovernmental framework's ability to contribute to building a globally competitive ERA. COST's potential to be an important driver in delivering excellence and leading innovation has been recognised and fuelled for future growth," stated Dr. Ángeles Rodríguez-Peña, President of the COST Committee of Senior Officials.

"ESF, as implementing agent for COST, recognises this additional budget allocation as an acknowledgment of a successful partnership between ESF and COST," said Marja Makarow, Chief Executive of the European Science Foundation. "It also reflects the valuable contribution COST can make tomorrow, by enhancing capacity building in Europe. ESF will continue to support COST in achieving its goals and increasing the competitiveness of the ERA."

Joint Standards Initiative on Intelligent Transport Systems

The International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) have announced the creation of a partnership in the burgeoning field of intelligent transport systems (ITS) and the instigation of a new Joint Task Force for ITS Communications.

The involvement of international standards bodies is seen as critical to easing bottlenecks resulting, in part, from poor communication between overlapping sectors – automotive, ITS players, telecom suppliers and operators. The Joint Task Force will engineer better collaboration

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between these sectors and pool resources within ITU and ISO, linking existing work and avoiding duplication.

Dr. Hamadoun Touré, ITU Secretary-general, said, "There is a will from manufacturers to implement these technologies, but as yet there has been no real breakthrough in terms of the technical standards needed to roll this out on a global scale. Vehicle manufacturers do not want to create different versions of this technology for every different market. They do not want regional or national standards. They want global standards, and through this initiative, ITU and ISO are proving that we are willing and able to provide them."

Rob Steele, ISO Secretary-general, stated, "There is a need for harmonization of standardization of essential technologies to provide a solid base for further innovation and the economies of scale for commercialization of technologies. Most interestingly of all, is the urgent need to consider the interoperability of all of this technology, not only in the vehicle, but in the wider infrastructure that is needed to support this revolution. The value of the solutions proposed is magnified when they are globally relevant."

"The value of the solutions proposed is magnified when they are globally relevant."

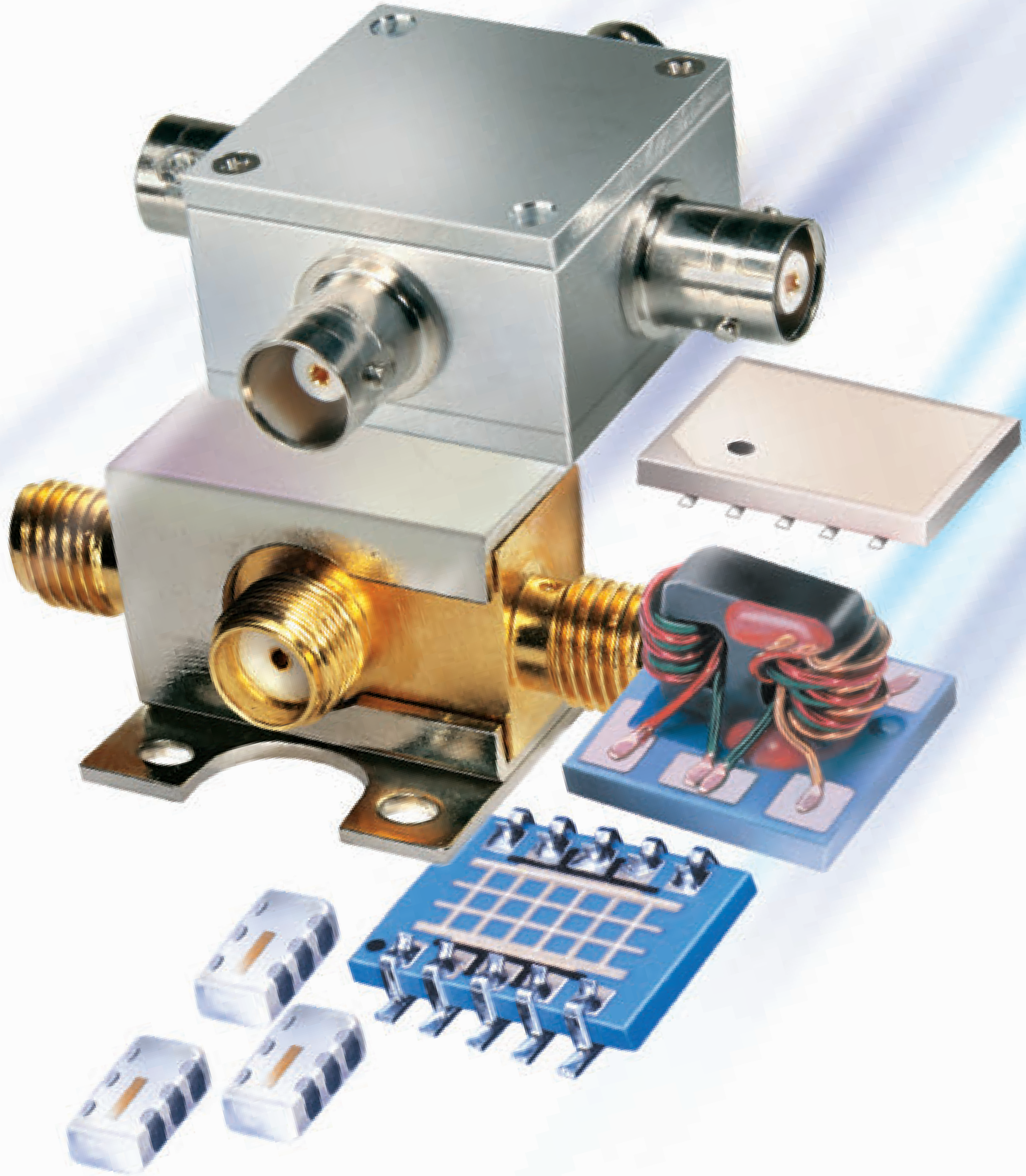
NGMN Alliance Joins 3GPP as Partner

The Next Generation Mobile Network (NGMN) Alliance has joined 3GPP as a Market Representation Partner. With its high level representation from the world's leading operators and manufacturers, NGMN will support 3GPP to ensure that mobile broadband services continue to meet the expectations of end users.

The Partnership Agreement was signed with Standards Organisations – ARIB, ATIS, CCSA, ETSI, TTA, TTC – and other 3GPP Market Representation Partners. In its role as Market Representation Partner, the NGMN Alliance will give advice to 3GPP and will contribute to 3GPP standardisation activities in the future.

"…the NGMN Alliance will give advice to 3GPP and will contribute to 3GPP standardisation activities…"

Peter Meissner, Operating Officer of the NGMN Alliance, stated, "The NGMN Alliance is happy to support 3GPP as a Market Representation Partner. Our contributions to 3GPP have always been based on NGMN's strong experience in mobile broadband. As a Market Representation Partner, NGMN will add its support to the common objective of all 3GPP partners to achieve a consensus view on the market requirements for services in the scope of 3GPP."



Dan Massé, Associate Technical Editor

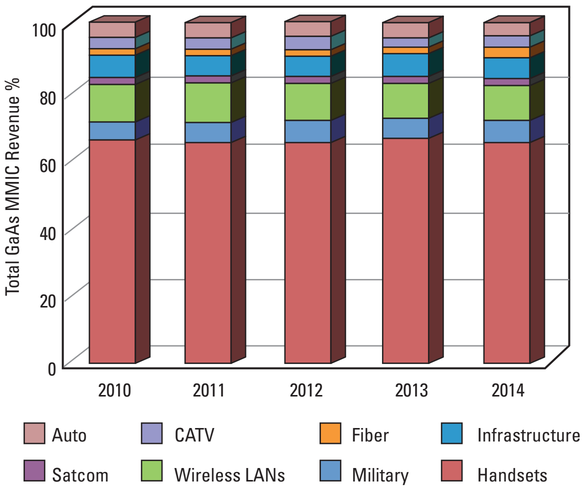
Compound Semiconductor Market Product Development Efforts Reflect Diversification

Even while the handset portion of the compound semiconductor market remains the largest revenue producer, Strategy Analytics sees that leading device suppliers are diversifying their portfolios by developing additional products for infrastructure, broadband and military applications. The recently published Strategy Analytics GaAs and Compound Semiconductor Technologies Service viewpoint, "Compound Semiconductor Industry Review March 2011: Microelectronics," captures March 2011 product, financial, contract and technology announcements for microelectronic companies such as RFMD, Skyworks Solutions, Hittite Microwave, ANADIGICS, TriQuint Semiconductor, Analog Devices and NXP.

"The handset market continues to drive compound semiconductor volume, but rapid price erosion poses a challenge for suppliers," noted Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "The March product announcements show activity aimed at CATV, fiber, military and test and measurement markets, as companies try to capture higher margin opportunities." Asif Anwar, Director, Strategy Analytics Strategic Technologies Practice added, "Some companies are expanding product lines into defense and broadband, which uses new processes to diversify market penetration."

This viewpoint summarizes March 2011 financial, product, contract and employment developments from major GaAs and silicon suppliers, which address a variety of commercial and military applications that use gallium arsenide (GaAs), gallium nitride (GaN), silicon carbide (SiC), and complementary metal-oxide-semiconductor (CMOS) technologies.

% of Total GaAs MMIC Revenue by Market Segment



4G Equipment Spending on Base Stations Will Approach $3 B in 2011

Around the world, operators are starting to move out of 4G trials and switching to commercial services. With 4G, there will not be the generous allocation of spectrum to which the 3G licensees were lucky enough to have access. The re-farming of spectrum and its reallocation from alternative applications such as broadcast TV and military communications will be necessary.

"Provisioning 4G services and spectrum re-farming will provide a welcome boost to the wireless infrastructure market. ABI Research estimates that 4G equipment spending on base stations will reach almost $3 B in 2011 and potentially $16.5 B in 2016," says Jake Saunders, VP for Forecasting.

"Provisioning 4G services and spectrum re-farming will provide a welcome boost to the wireless infrastructure market."

According to ABI Research, in 2011 approximately 32,000 base stations will be upgraded and retrofitted to support 4G services. Approximately 19,000 base stations will be deployed onto new sites to help infill capacity and remove dead spots and poor coverage zones for 4G enterprise and residential users. A considerable amount of that equipment will be in the 2.5 GHz and related bands, but operators will be keen to deploy into lower frequency bands. In a number of countries, regulators are clawing back the spectrum generously allocated to analog broadcast television and auctioning off the "digital dividend" frequency bands (790 to 862 MHz) to help support the rollout of 4G mobile network services, especially for more widely scattered towns and villages.

"Innovative technologies such as HSxPA, HSPA+, LTE, and LTE-Advanced are helping operators make the best use of the spectrum at their disposal," adds Mobile Networks Practice Director Aditya Kaul. "However, engineers are increasingly approaching the limit of how many bits of information can be carried per Hertz of spectrum. You just cannot get away from the advantages of having additional spectrum to boost capacity."

It is not just mature telco markets such as France, Portugal, the UK, and Switzerland that are in the process of allocating 4G spectrum in the 800 MHz band, but also India, Chile, Argentina and Poland. More will follow.

Smart Phones Will Account for 53 Percent of Global Handset Sell-through in 2015

Total handsets sold to end-users globally will reach 1.46 billion in 2011, while smartphone sales will account for 27 percent of total handset sell-through. Driven

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Total handsets sold to end-users globally will reach 1.46 billion in 2011.

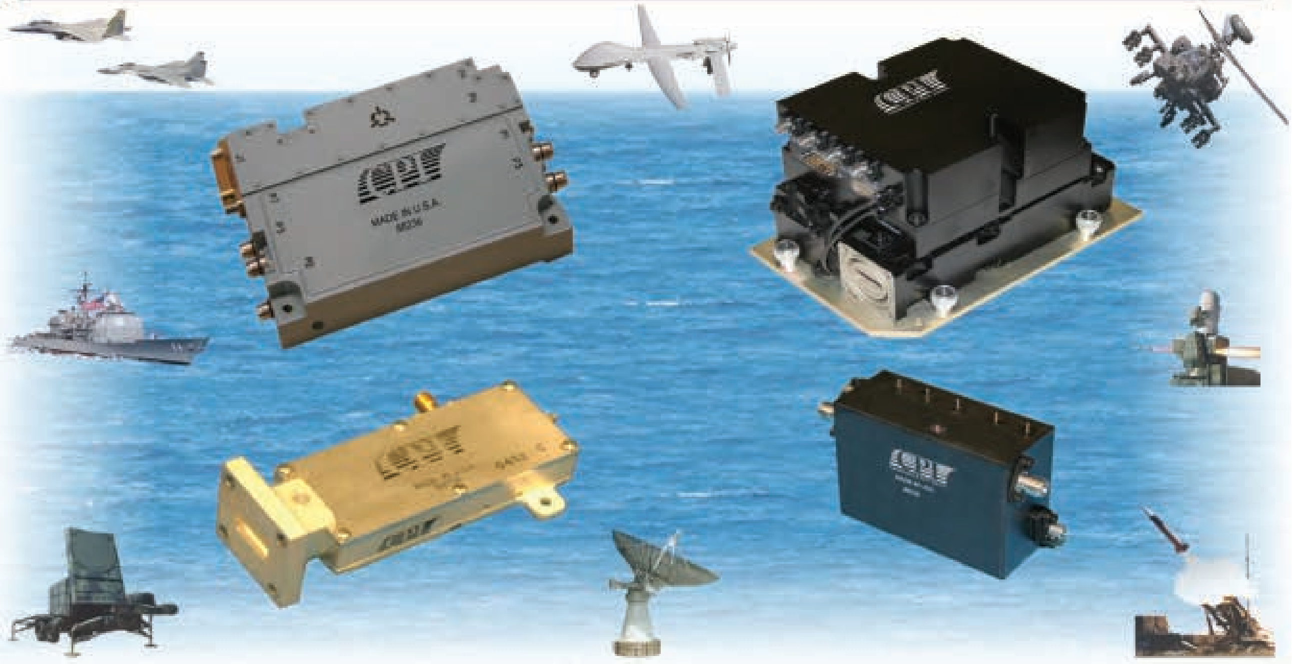
by demand for inexpensive Android models, this figure will almost double to 53 percent in 2015, according to Pyramid Research's quarterly smartphone forecast. Offered as a quarterly-updated subscription or as a one-off resource, Pyramid's Smartphone Forecast provides annual sell-through of total mobile handsets and smartphones for a ten-year period, including five historical years and five forecast years. Smartphone sell-through data is also segmented by vendor and by operating system. Granular data is provided for key emerging and developed markets, with ten new countries added to its coverage in its latest release, making Pyramid's smartphone forecast the most detailed on the market today.

"Much of the projected total market growth in 2011 will come from the Africa and Middle East (AME) region, which will see a strong demand for low-end smartphone models, ultra low-cost handsets and dual-SIM and full touch-screen feature phones," says Stela Bokun, Senior Analyst and Practice Leader for Mobile Devices at Pyramid Research. "The main drivers of the demand in the developed markets will be the launches of a number of flagship high end devices and new features and technologies," Bokun explains. "However, inexpensive smartphone models, particularly those from Huawei and ZTE, also will be in high demand in some of the richest Western European, Asian and North American markets." Android-based smartphones will continue to shake the smartphone world, but Pyramid's recent findings predict that by 2015, Windows Phone will overtake Android and other major competitors and establish itself as the leader in the smartphone OS space.

Surge in Video Will Drive Global Data Traffic to More Than 60,000 Petabytes

In 2011, the world's annual data traffic volume will total almost 8,000 petabytes. That will grow at a CAGR of 50 percent over the following years, exceeding 60,000 petabytes in 2016 – over seven times more than in 2011. The year-on-year growth will be the fastest in 2012 (58 percent) and 2013 (56 percent), slightly slowing down thereafter. While as of 2011 the web and Internet traffic category is the largest source of traffic, one of the main reasons for the future robust growth is the increasing amount of video traffic. ABI Research Practice Director Neil Strother says, "There are basically two types of video use cases that drive heavy traffic: clips from YouTube (and similar sites) that are often shared via other social media, as well as lengthier content like series and even films (e.g. Netflix). Video and TV streaming should surpass web and Internet traffic in 2015."

Integrated Microwave Assemblies



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Around the Circuit

Kerri Germani, Staff Editor

INDUSTRY NEWS

May was another big month for mergers and acquisitions in the microwave industry. Just as the Journal was about to go to press with our June issue, **Skyworks Solutions**, the subject of this month's cover feature, announced that it would be acquiring **SiGe Semiconductor**. The acquisition gives Skyworks greater access to the lower performance but high volume WiFi and home automation markets where the company's GaAs expertise faces stiff cost pressures from silicon-based products. Shoring up its position in the WiFi market should help the company deepen its relationship with computer-makers like Apple.

Test measurement software (Labview) and hardware provider **National Instruments (NI)** stunned the RF/microwave industry as well with two separate, yet simultaneous announcements regarding the acquisitions of RF/mW EDA leader **AWR Corp**., developers of Microwave Office, and **Phase Matrix Inc**., a manufacturer of T&M instruments, subsystems and components. The purchase of Phase Matrix, which recently introduced a family of PXI RF/mW modules (an area of increasing product development for NI), will immediately strengthen the company's RF talent, technology portfolio and manufacturing capabilities. The acquisition of AWR further illustrates the industry's move to more tightly integrated simulation (MWO, NI Multisim) and test solutions in design and verification flows.

M/A-COM Technology Solutions announced it has acquired privately held **Optomai Inc.**, a fabless semiconductor company that develops high performance integrated circuits and modules for next generation 40 and 100 Gbps fiber optic networks. Based in Silicon Valley, CA, Optomai's product portfolio and expertise in GaAs and InP circuit design complements M/A-COM Tech's existing CATV/broadcast and point-to-point/infrastructure businesses, and accelerates its penetration of the rapidly growing optical communications market. Financial terms of the transaction were not disclosed.

Ducommun Inc. announced it has entered into a definitive agreement to acquire all outstanding stock of **LaBarge Inc.** LaBarge, with revenue of $324 M for the twelve months ended January 2, 2011, is a widely recognized supplier of electronics manufacturing services (EMS) operating across many high growth industries. The acquisition will nearly double Ducommun's revenue base, improve the company's position as a Tier 2 leader in both aerostructures and electronics, and bring access to new customers and markets.

Rogers Corp.'s Advanced Circuit Materials Division (ACMD) opened a new production facility April 13 in Asia, one of its largest market regions. Rogers' new Suzhou, China manufacturing facility represents a major investment in the modern China Suzhou Innovation Park. This ACMD-dedicated production facility significantly increases Rogers' global capacity for its high performance RO4000® circuit laminates by about 50 percent, with room for additional growth.

Agilent Technologies Inc. announced the opening of a new calibration center in Sunrise, FL. Now owners of Agilent electronic measurement instruments in that area can receive true local OEM calibrations, such as actual measurements performed using OEM procedures for every data-sheet specification, each time they use the center.

AWR® Corp. announced the continuation of its AWR Graduate Gift Initiative for calendar year 2011. This initiative provides qualified electrical engineering graduates with a free, fully functional, one-year term license of AWR's Microwave Office™ and Visual System Simulator™ software suites, including AXIEM™ 3D planar EM simulator. The software gift, while restricted to the graduate's personal use (node locked versus floating license), is not restricted to educational use but rather open for commercial use at the graduate's current/future employer.

The Royal Institute of Technology (KTH), Stockholm, Sweden, has signed a three-year site license agreement with **COMSOL** to provide all the Schools within KTH with COMSOL Multiphysics simulation software. More than 16,000 teachers, researchers and students will now have access to the entire suite of tools. COMSOL Multiphysics enables engineers and scientists in a wide array of engineering fields to conduct real-world simulations of any physics-based system for product design and development.

Modelithics now offers its customers nonlinear X-parameter measurement and modeling services. This technology is enabled through use of **Agilent Technologies'** PNA-X Series Nonlinear Vector Network Analyzer (NVNA) and provides circuit board designers with mathematically correct extensions of S-parameters for large signal conditions for devices such as amplifiers, mixers and RFIC/MMIC functional blocks.

TRU Corp., a provider of RF and microwave cable assemblies and interconnects, announces a year-long celebration of its 60-year heritage of innovation. TRU Corp. was incorporated by James O'Neil on April 20, 1951 in Peabody, MA, and continues to be owned primarily by the O'Neil family. TRU, like many pioneering RF companies of the time, became integrally involved in the early support of military programs targeted at the development of radar technologies for the war effort. The emergence of wireless technologies diversified TRU into a growing number of commercial markets and products.

CONTRACTS

Raytheon Co. received a $173 M US Army fiscal year 2010 contract for the production of Excalibur precision-guided

HIGH POWER PRODUCTS

POWER DIVIDERS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.] ◦	Package
2-WAY								
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	5	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	5	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316

◊ In excess of theoretical split loss of 3.0 dB
◦ With matched operating conditions

HYBRIDS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180° (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ◦	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322

* Add suffix - LF to the part number for RoHS compliant version.
◦ With matched operating conditions

Unless noted, products are RoHS compliant.

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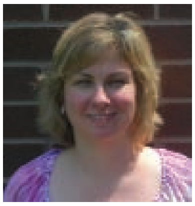
projectile rounds for in-theater use. This contract marks the beginning of full rate production for Excalibur Ia-2. Successfully fielded in 2007, Excalibur is a 155 mm precision-guided artillery round with extended range that is currently in use with the US Army and Marine Corps. Using GPS precision guidance technology, Excalibur provides first round fire-for-effect capability with accuracy well within 10 meters (32.8 feet) of its target.

Integral Systems Inc. announced that its wholly owned subsidiary, **RT Logic**, has been awarded more than $30 M in multiple government, military and commercial contracts during the past three months. Under the terms of the contracts, RT Logic will provide its commercial-based Telemetrix® signal processing systems that are used by more than 85 percent of US space missions.

AAI Test & Training, an operating unit of **Textron Systems**, announced it has been awarded $9.7 M to deliver an electronic warfare (EW) radio frequency simulator for the US Air Force's EW Avionics Integration Support Facility (EWAISF). Located at Robins Air Force Base in Georgia, the EWAISF facility tests critical components, subsystems and systems for compatibility and performance, as well as evaluates hardware and software interactions in both EW systems and integrated suites. AAI's advanced architecture utilizes multiple, high fidelity synthetic stimulus instruments to replicate an operationally realistic electromagnetic environment that EW systems might face during combat missions. The simulator will be integrated onto the larger EWAISF Simulator Network for simultaneous testing of multiple EW systems.

Giga-tronics Inc. announced it received a $1.2 M order from the US Marines for its VXI synthesizer, the Giga-tronics model 5008A.

PERSONNEL


▲ Kerri Germani

Microwave Journal announced the hiring of Staff Editor **Kerri Germani,** who brings with her more than 20 years of writing and editing experience. She has worked as an editor for several MA newspapers, including *The Patriot Ledger* in Quincy, *The Sun Chronicle* in Attleboro and *The Herald News* in Fall River. Germani holds a master's degree in public administration and a bachelor's degree in journalism and political science from the University of Rhode Island. She lives in Lincoln, RI, with her husband and three children. Germani replaces Jenn DiMarco, who was promoted to Managing Editor. Germani will be handling PR submissions and can be reached at kgermani@mwjournal.com.

Trilithic Inc., a provider of RF and microwave components, is pleased to welcome **Doug King** to the Trilithic team as Regional Sales Manager for Trilithic's RF and Microwave Division. In his new role, King will be responsible for worldwide sales of RF and Microwave components. Previously with Antenna Research Associates and Alan Industries, King is a 15-year veteran of the RF and microwave industry, and has held several sales management positions throughout his career.

TRU Corp. is pleased to announce the appointment of **Chuck Saba** to the applications engineering team. Based in Peabody, MA, Saba will provide technical support for Tru Corp.'s customer base to facilitate proper product selection, critical translation of requirements to design/manufacturing and the development of new innovative products for emerging applications in the market. Saba has more than 20 years of experience in the RF and microwave industry, having worked in engineering and sales roles for companies, including M/A-COM, Axon Cable and Interconnect and Haverhill Cable and Manufacturing.

REP APPOINTMENTS

Norden Millimeter Inc. announced the appointment of **TGI Ltd.** and **Microwave Components Marketing** (MCM) as its technical sales representative in the United States. MCM will represent Norden in FL while TGI Ltd., will represent Norden in IL, MO and WI. Both MCM and TGI Ltd. have more than 30 years experience in the electronic industry and the expertise in solving customer design challenges. Norden designs and manufactures amplifiers, transceivers, frequency multipliers, frequency converters and oscillators for the military, scientific, commercial, and test equipment markets.

Richardson RFPD Inc. announced it will continue offering former **Vincotech** embedded GPS receiver modules and evaluations boards that are now part of the **Maestro Wireless Solutions** product family, including the newly launched SiRFstarIV A2100 GPS receiver module. Richardson RFPD recently signed a global distribution agreement with Maestro Wireless to offer its extensive line of industrial modems and integration services for the Machine-to-Machine (M2M) markets, including the GPS receiver assets of Vincotech, which Maestro Wireless acquired in October 2010.

Harmon & Sullivan Associates Inc. has been appointed as the **Times OEM** rep group covering upstate NY. Established in 1987 in Rochester, NY, Harmon & Sullivan Associates brings with it an extensive history in sales of interconnect solutions and strong relationships with the military subcontractors in the region. The outside sales team consists of Mary Lou Bianchi, who started with the firm in 1991 and is now a partner, and Steve Harmon, President and one of the founding partners of the firm. Bianchi has outside sales responsibilities for customers in Rochester and the central and eastern parts of the state, including BAE Systems. Harmon has outside sales responsibilities for customers in Rochester and northern and western parts of the state.

Electronic components distributor **Digi-Key Corp.** and radio frequency integrated circuit (RFIC) manufacturer **Peregrine Semiconductor** announced the two companies have finalized a global distribution agreement involving Peregrine's UltraCMOS™ RFIC products. A number of Peregrine's most popular RFICs – RF switches, digital step attenuators, PLL frequency synthesizers, mixers and prescalers – are now available for purchase on Digi-Key's global websites and will be featured in online catalogs.

RF SOI Solutions as a Platform for Wireless Front-end Applications

The consumer wireless market has seen a "rebirth" of sorts in the last few years, as new data-hungry, mobile devices infiltrate the market and compete for bandwidth on the network. The resurgence in WiFi has been in large part due to the inability of the cellular network to keep up with this demand and provide a back-up solution to users who require always-on network connectivity. All of this has placed a greater emphasis on a key system in these mobile devices known as the "RF front-end."

The RF front-end is a set of components in a mobile device, which functionally sits between the antenna and the wireless transceiver. Its job is to close the radio link (transmit and receive) between the user and the network and maintain that link as the user goes about his daily activities. A simplified block diagram of an RF front-end is shown in ***Figure 1***.

The transition into 3G/4G and the requirement to maintain compatibility with legacy networks has necessitated that mobile devices support multi-mode/multi-band (MMMB) operation. This has significantly increased the complexity of the front-end in relation to the rest of the electronics in the radio. Statistics suggest that greater than 50 percent of all cellular handsets past 2011 will support three or more frequency bands[1] in order to support this transition. These new "smart phones" are achieving a level of complexity that likely rivals sophisticated military radios of several years ago and are entering an era when the demand for performance, reduced complexity and lower cost are all driving a move toward silicon-based technologies.

Until now, the development of these RF front-ends has relied on III-V technologies for the majority of the functionality, with CMOS and passives technologies playing a lesser role. The III-V's cut their teeth during the late 1970s and early 1980s, as the darling technology of the defense industry and became more mainstream in the 1990s, as they were applied to more consumer-oriented applications. They provide a very good combination of power density, reverse breakdown, f_t and isolation, all of which are key figures of merit when addressing the RF front-end application space.

As radio complexity increases, cost becomes a major factor and drives the need to seek alternative architectures or technologies. Published work[2-4] on advancements in silicon-based technologies and specifically silicon-on-insulator (SOI) technologies, suggest that silicon can provide competitive performance to traditional

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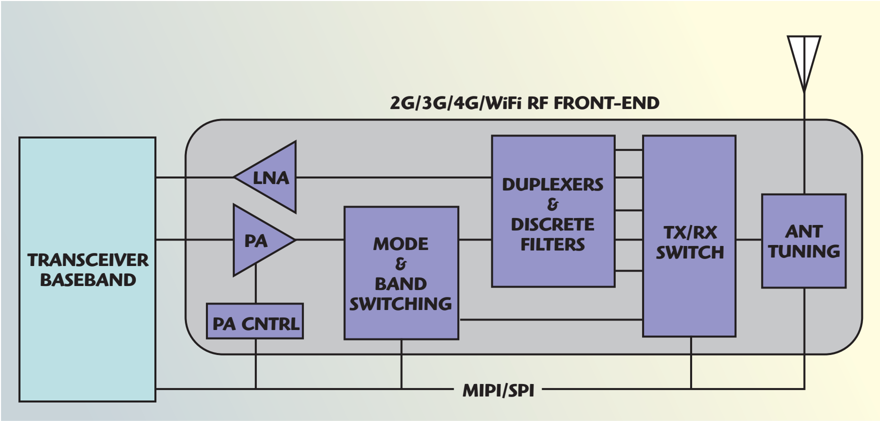
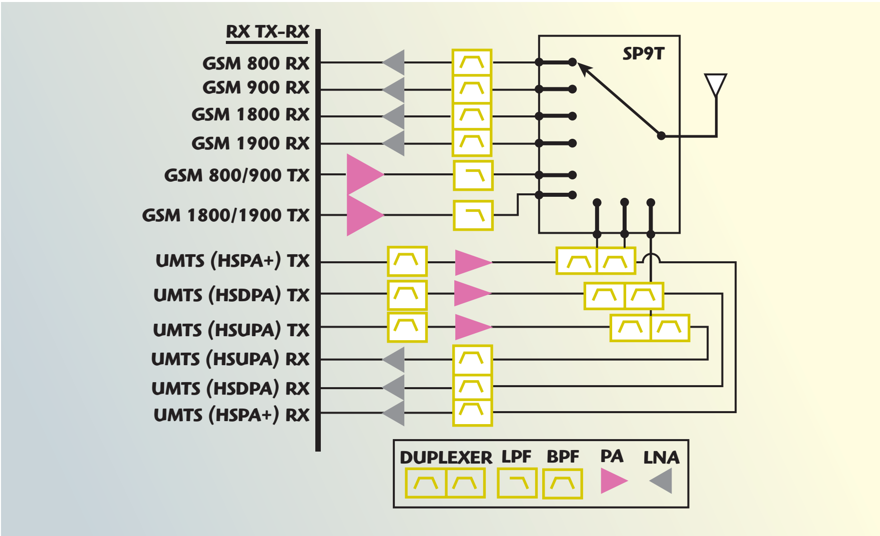


▲ *Fig. 1 Simplified block diagram of a typical wireless RF front-end.*



▲ *Fig. 2 Block diagram of a quad-band EDGE/tri-band UMTS cellular front-end components.*

III-V's with the added advantages of lower cost, greater integration capability and virtually unlimited capacity. Moreover, the differentiating features these silicon technologies provide can lead to innovative architectures and solutions, which help in rethinking traditional approaches.

As shown in ***Figure 2***, a MMMB smart phone can have several GSM and UMTS/WCDMA bands, whose transmit and receive chains are hooked up into an antenna through a single-pole nine-throw switch (SP9T). Today's solution for this FE includes several power amplifier modules (PAM), a switch module, and several discrete filters. This complexity can quickly grow in future smart phones and needs to be addressed by integration for lower cost and a smaller form factor. Fundamentally, this is an opportunity for silicon technologies that have demonstrated capability in switches and power amplifiers. Several areas where SOI is addressing functionality in the RF front-end, specifically the switch, the PA and the LNA, will be explored.

RF SWITCH SOLUTIONS

In the context of RF switches, minimizing insertion loss (IL) and maximizing isolation (ISO) is a concern, while maintaining low harmonics. To support GSM power levels in a low voltage CMOS technology, numerous FETs in a series or a shunt branch must be stacked. The optimization of IL and ISO then depends on the number of FET stack and the width of the FET in the switch branch, which has been discussed previously.[2]

The SOI technology uses a 2.5 V NFET in the 180 nm process as described by Botula et al,[3] which has demonstrated a capability to attain a $R_{on} \cdot C_{off}$ of 250 fs. Single-pole single-

throw switch branches, built with 12-stack FETs with each FET having 4 mm width, show second and third harmonics levels of -67 dBm and -59 dBm, respectively, in the OFF mode. Further investigation is under way to improve the $R_{on} \cdot C_{off}$ product, while maintaining low harmonics and high reliability.

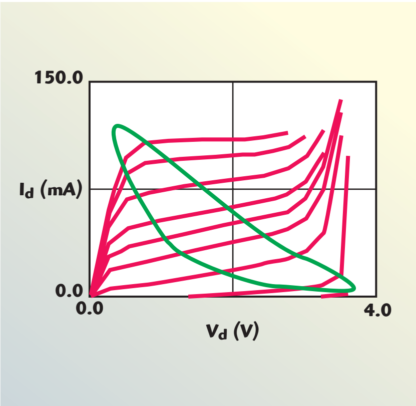
Switch branches were arranged in a series-shunt combination to design an SP8T switch.[4] An RF measurement at 890 MHz and 35 dBm input power on port-6 to antenna shows that an IL of 0.8 dB can be achieved, with a P_{2fo} at -50 dBm, and P_{3fo} at -58 dBm. The IIP2 measured using a 1829 MHz blocker frequency shows 108 dBm. IIP3 measured higher than 66 dBm for all bands. These results are quite compelling to meet many product applications.

POWER AMPLIFIER SOLUTIONS

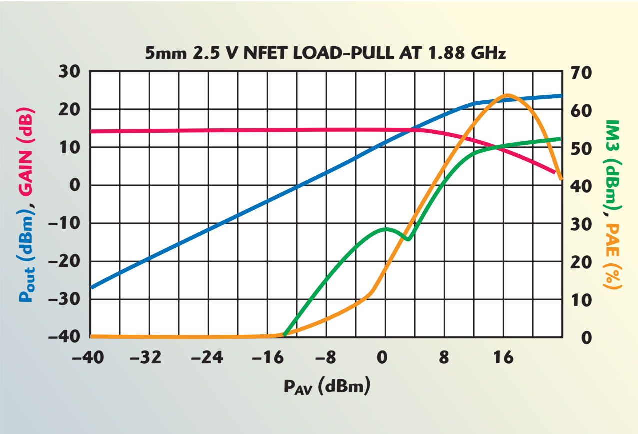
The PAs are one of the highest power consuming elements in the radio and poses a formidable challenge for FEM integration. Highly efficient and linear PAs are desirable to make sure that the talk time and data throughput are maximized. The RF output power obtained from a transistor is directly proportional to the square of the output voltage delivered to the load impedance. A higher breakdown voltage device can, therefore, more easily provide the required output power and would be capable of improved robustness. In the context of PA technologies, several previous works have compared the performance of GaAs HBT, Si BJT, SiGe HBT, and n-MOSFET.[5, 6] It can be observed that while silicon technologies are not the best in class, the silicon based transistors are very capable to achieving the cellular PA performance targets by careful layout and design considerations.

A 2.5 V NFET, with a BVdss, approaching 5 V is available in this technology, which has an R_{on} / f_t / f_{max} performance similar to a switch optimized device. Several single stage common source 2.5 V NFET power cell structures were load-pulled with second and third harmonic load matching. ***Figure 3*** shows a 1.95 GHz operating area, overlaid on the DC IV, curve for a 500 µm device biased and impedance matched for maximum class AB output power. This device can operate in a safe operating area up to 3.6 V on the drain. It was noted that the load line became more oval shaped as the fundamental and harmonic load matching was moved from 50 Ω to the optimal P_{out} matching. This device obtained a 1 dB compressed output power of 16 dBm with a gain of 16 dB and an efficiency of 66 percent.

Figure 4 shows a load-pull plot for a 5 mm total gate width structure, which produced a P_{out} of 22.5 dBm and a gain of 10 dB at the peak PAE of 63.7 percent. The measured IM3 was based on a 1 MHz tone spacing. Backing off by 6 dB to a P_{out} of 16.5 dBm for a more linear operation, shows that this device measured a gain of 14 dB, an IM3 of -14 dBm and a PAE of



▲ *Fig. 3 500 µm 2.5 V NFET DC IV curves with load line.*

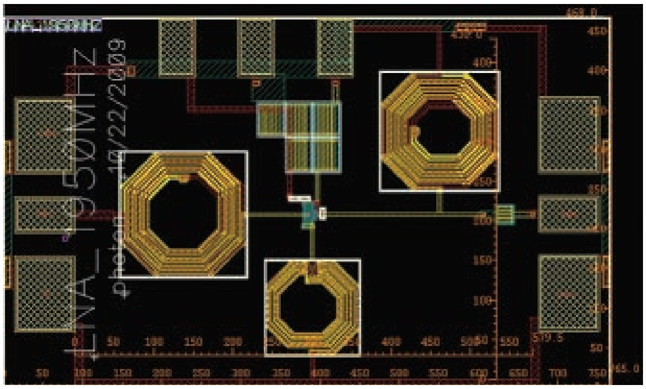


▲ *Fig. 4 5 mm 2.5 V NFET load-pull optimized for PAE.*

31 percent. These results demonstrate that a CMOS based power amplifier solution for RF applications can be made a reality in SOI processes.

LOW NOISE AMPLIFIER SOLUTIONS

Low noise amplifiers, having low power consumption, yet requiring high Q matching components to maintain a low noise figure, can be ideal to integrate on the same SOI device as the switch. The 1.8 V 180 nm NFET provides sufficient gain and high enough compression for the cellular and WLAN frequency bands. Thick Cu metallization, placed further away from the substrate, allows for high-Q inductors. A simple cascode LNA, which was optimized at 1.95 GHz for model to hardware correlation, is used to demonstrate its feasibility. The layout, including on chip matching and probe pads, is shown in ***Figure 5***. The dimensions, excluding the pads, are 500 × 360 μm.



▲ *Fig. 5 1.95 GHz LNA layout with on-chip matching.*

An example of the high Q achievable on this process is the inductor on the left, which is a 7.5 turns 160 μm diameter, 5 μm wide, octagon that provides 8.74 nH and a Q of 15.1, peaking at 2.95 GHz for the input match. Biasing this LNA, at 1.5 V and 3 mA, provides 12.4 dB of gain, a noise figure (NF) of 1.7 dB and an input P1dB of -8 dBm, while maintaining a return loss better than 15 dB for both ports. Increasing the current to 6.5 mA will increase the gain and P1dB to 13.7 dB and -2 dBm, respectively, and decrease the NF to 1.4 dB.

CONCLUSION

SOI technology solutions are becoming well positioned for FEM integration in advanced wireless communication systems. Today, SOI CMOS provides a cost-effective solution for RF switches. Obtaining the necessary LNA performance is easily achieved in SOI because of the low loss substrate positive effect on matching and the active devices. With progressive advancement in cellular PA SOI solutions, the pathway for further FEM integrated solutions can soon be a market reality. ■

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and support of various groups within IBM for the success of various FEM technologies and testing.

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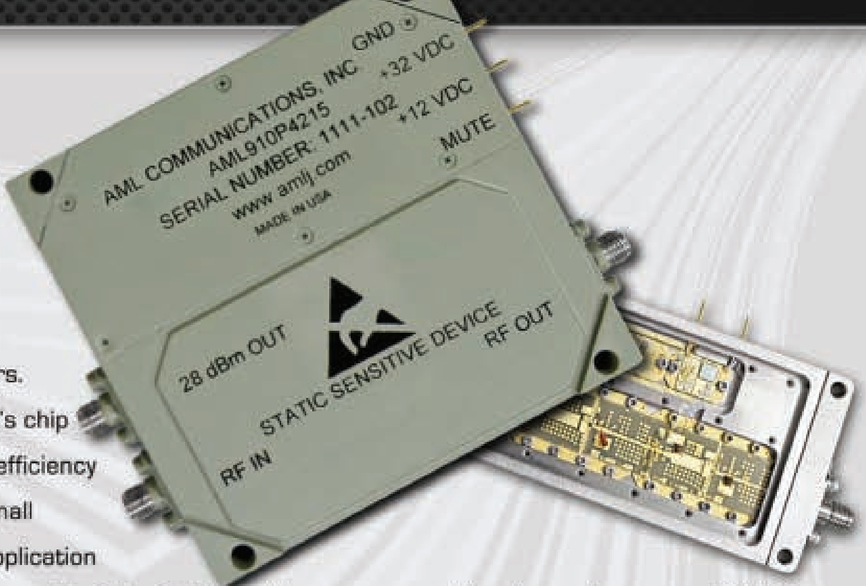
AML Communications



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GaN Power Amplifiers

Model Number	Frequency (GHz)	Gain (dB min)	Psat (dBm min)	Psat (dBm typ)	Psat (Watts typ)	Voltage (V) Current (A)	PAE
AML056P4013	0.5 - 6.0	40	35	36	4	28V, 0.5A	22%
AML056P4014	0.5 - 6.0	40	37	38	6	28V, 1.0A	20%
AML056P4511	0.5 - 6.0	45	39	40	10	28V, 1.3A	25%
AML056P4512	0.5 - 6.0	45	43	44	25	28V, 2.5A	25%
AML13P5013	1.0 - 3.0	50	46	47	50	28V, 4.8A	25%
AML16P4511	1.5 - 6.0	45	39	40	10	28V, 1.0A	26%
AML16P4512	1.5 - 6.0	45	42	43	20	28V, 2.6A	25%
AML16P4513	1.5 - 6.0	45	44	45	30	28V, 4.8A	25%
AML26P4011	2.0 - 6.0	40	40	41	12	28V, 1.0A	30%
AML26P4012	2.0 - 6.0	45	43	44	25	28V, 2.5A	35%
AML26P4013	2.0 - 6.0	45	46	47	50	28V, 4.8A	35%
AML59P4512	5.5 - 9.0	45	45	46	40	28V, 3.6A	38%
AML59P4513	5.5 - 9.0	45	48	49	80	28V, 7.2A	38%
AML910P4213	9.9 - 10.7	43	37	38	6	32V, 0.5A	30%
AML910P4214	9.9 - 10.7	43	39	40	10	32V, 0.8A	30%
AML910P4215	9.9 - 10.7	46	41.5	42	15	32V, 1.3A	30%
AML910P4216	9.9 - 10.7	46	42	43	20	32V, 1.3A	30%
AML811P5011	7.8 - 11.0	45	43	44	25	28V, 2.6A	30%
AML811P5012	7.8 - 11.0	50	46	47	50	28V, 5.5A	30%
AML811P5013	7.8 - 11.0	50	49	50	100	28V, 11A	30%

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TRENDS IN MULTI-FUNCTIONAL MMIC DESIGN

The age of single microwave components as the fundamental building blocks of microwave subsystems is rapidly coming to an end. Desires for smaller-sized systems, higher reliability, and most urgently, lower-cost systems, are driving an accelerating shift toward higher levels of integration. This is seen in multiple levels of the supply chain, including the MMIC and the system level.

In the MMIC arena, microwave functions previously achieved with a chain of multiple single-function MMICs are being replaced with more highly integrated, application-specific, multi-function MMICs. As a result, functions recently requiring 10 to 15 individual MMICs are now being designed with as few as four MMICs.

Similarly in the system area, multiple connectorized module microwave subsystems have given way to single printed circuit board assemblies utilizing high frequency surface-mount packaged MMICs. This technology evolution significantly reduces the required skill level, dedicated resources, and cost of the microwave subsystem assembly, shifting much of the specialized technical burden to the MMIC supplier. With this shift, an optimal result requires the balance of new tradeoffs in addition to those with which system designers have become accustomed.

PERFORMANCE DRIVERS

Customers for point-to-point systems are increasing their performance demands based on several aspects, including network upgrades through 4G. In developed areas, higher data users with spectrum intensive smart phone applications are pushing past the available capacity in the installed network base. The need to expand capacity results in required upgrades to support higher data efficiency in bits/Hz of available spectrum. This is being accomplished through a migration to packet-based architectures while using higher ordered, linear modulation schemes through 256 QAM and replacing predecessors, which used lower ordered QPSK through 64 QAM modulations. The higher ordered schemes deployed currently require more linear power (higher TX P1dB and IP3), while "green" base stations have less DC power available. In addition, while the higher ordered modulation schemes can carry more data in ideal conditions, they are not as robust in adverse weather conditions. To account for this, new systems have the added complexity of adaptive modulation techniques. The wireless link will operate at full capacity in good conditions and drop to a lower capacity but more reliable modulation, such as 16 QAM in adverse conditions. This will preserve voice transmission while slowing but preserving data access. Enabling this system level-flexibility requires a significant TX power adjustability and allows a wide dynamic range, while maintaining required performance levels.

The higher modulation schemes also require lower synthesizer phase noise, and more sensi-

ANTHONY SWEENEY
Endwave Corp., San Jose, CA

tive receivers to be able to decode the weaker signals that are closer to the thermal noise floor than ever before. In short, real demands are pushing higher TX output power and linearity at reduced DC current budgets, higher dynamic range, lower phase noise synthesizers and lower noise figure for better receiver sensitivity. This daunting set of challenges is not uncommon for system designers across multiple industries.

BUSINESS CASE DRIVERS

The developed world's appetite for data continues to grow, while typical smart phone plans bill for the number of minutes of talk time plus a fixed fee for access to data. This "all-you-can-eat" mentality has pushed networks to their limits for capacity as data traffic has overcome voice traffic, and some providers are rethinking the service and product offering as a result to better monetize data charges. At the same time, while the developed world is looking to increase data rates for faster and reliable access to information, the developing world is the largest area of growth in terms of added cell phone users. This high growth is typically through an enormous user base, while the average revenue producing unit/user (ARPU) is literally an order of magnitude lower than in the developed world. While this group is using less data today, higher levels of sophistication are expected quickly – such that high performance hardware is being deployed even in developing areas in order to plan for near term expansion. This combination of factors has created a heavy downward price pressure with fierce competition to enable penetration into the developing markets including China, India and others.

At the same time, there is pressure to reduce soft costs as well as direct costs by stocking fewer part types, and using fewer parts in more locations. Engineering teams across the industry have responded by migrating toward higher levels of integration and higher bandwidth devices in order to minimize the number of parts to be purchased, which has also had the effect of shrinking engineering design cycles through reuse of parts in multiple systems at multiple frequency bands.

Finally, disruptive innovation through high frequency SMT packaging development has enabled a significant paradigm shift, as companies look to outsource the build and test of millimeter-wave subsystems to low cost offshore contract manufacturers. These SMT packages have eliminated the barrier to entry created by chip and wire manufacturing technology formerly required to build millimeter-wave subsystems. This has caused an accelerating acceptance by design engineers to trade some performance due to SMT package losses for significantly lower costs.

While these SMT-based contract manufacturers may be able to build complex systems, performing RF troubleshooting of large cascaded chains of single function MMICs remains elusive in many cases. Thus, not only are small size and higher reliability enhanced by reducing parts count through higher levels of MMIC integration, but the ability to produce the parts through test and troubleshoot with high Cpk in a low cost offshore environment all critically depend on the ability to make the operation as simple as possible.

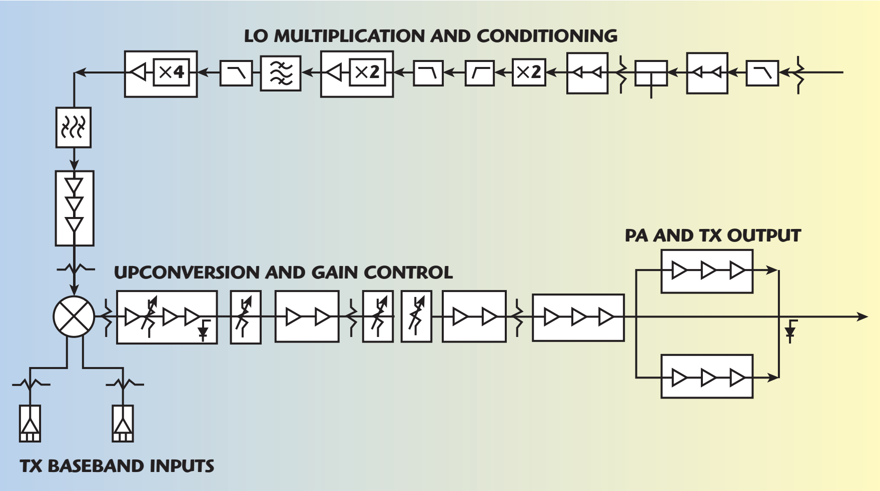
STATEMENT OF PROBLEM

All of the above arguments culminate into the need for massive consolidation of the number of MMIC devices or packaged modules used per system via higher levels of integration with higher performance and broader bandwidth. MMICs must be available in SMT packages to enable low cost offshore CM business models to solve cost, performance and logistic problems. Again, these are a daunting but all too-commonly heard set of requirements.

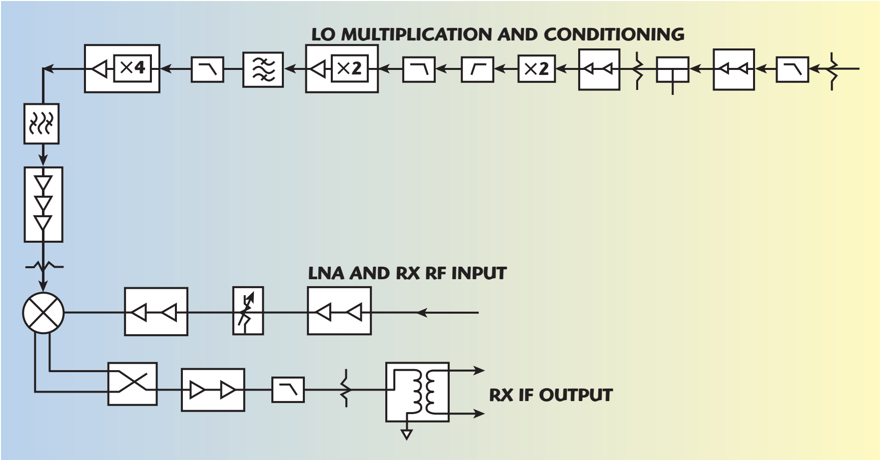
DESIGN TRADEOFFS AND SOLUTIONS

Figures 1a and ***1b*** show a set of block diagrams of a typical millimeter-wave transmitter and receiver for point-to-point applications, respectively. The design is the result of many tradeoffs that are completed at the system level. Tradeoffs exist between several areas.

Systems require a wide linear TX output power range that is achieved through strategically placing high linearity voltage variable attenuators (VVA) within the gain partitioning of the TX chain. TX output noise power and TX linearity both need to be optimized over this output power range,



▲ *Fig. 1a Typical transmitter block diagram.*



▲ *Fig. 1b Typical receiver block diagram.*

creating a conflict in positioning the VVAs. Moving the VVAs toward the final power amplifier will reduce TX output noise in lower power states, but system linearity is adversely impacted as the VVAs are subjected to higher power levels closer to the power amplifier, and thus create more intermodulation products.

Another significant tradeoff is that TX output power and linearity must be increased while reducing DC current. Here, the choice of MMIC design topology is critical – minimizing mixer conversion loss, relying on low noise buffer amplifiers where possible and ensuring that filtering is adequate to avoid premature linearity degradation due to undesired signals entering the TX power amplifiers. Judicious MMIC topology selection can help avoid a common mistake, boosting the RF high power amplifier requirements (and DC consumption) to increase linearity when these other topology changes can increase system linearity with a much lower DC current increase. In addition, IF gain is far more efficient than RF gain, so use of a high linearity mixer can allow lower RF gain and higher DC efficiencies as a result. Another key area is to ensure that SMT package losses are minimized to avoid the costly addition of a gain block to compensate the extra RF loss introduced. Thus another reason to reduce the total number of MMICs in an RF chain through integration is to eliminate the number of high frequency transitions and the associated loss – creating a powerful performance-based argument pushing higher integration levels.

Figure 2 shows the result of a successful model development for a high frequency low loss package, that is realized as an air cavity QFN (quad flat no-lead). Note that the package was designed using EM modeling software, enabling the use of coplanar

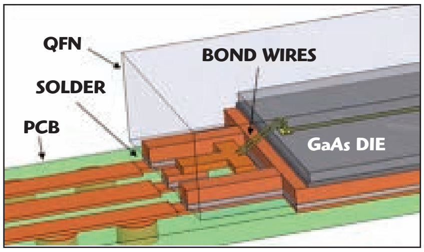


Fig. 2a *Internally matched design.*

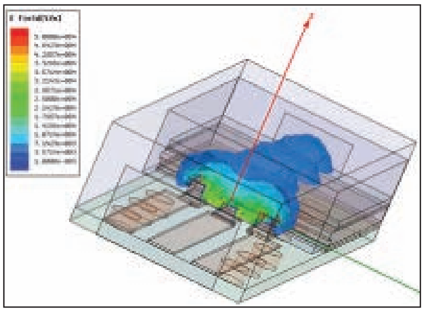


Fig. 2b *Internally matched EM 3D analysis.*

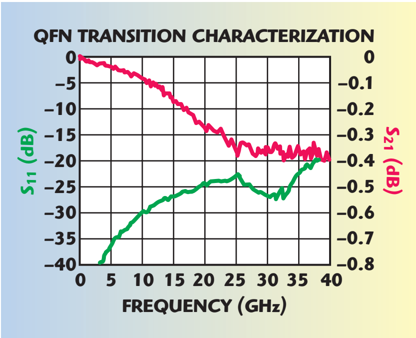


Fig. 2c *Resulting performance.*

launches to achieve very low RF transition loss, under 0.4 dB at 40 GHz. A low loss air cavity QFN package is highly useful as it enables the existence of surface mountable passive components like filters, power combiners and couplers to be leveraged in even an all SMT design.

Filter incorporation per the block diagrams in Figure 1 help to ensure spectral purity requirements are met, although they add loss which can degrade DC efficiency and overall linearity as active devices overcome these losses. At lower microwave frequencies, below 15 or 18 GHz, the filters are generally fabricated on the PCB, but repeatability of this type of filter on a board-to-board basis is generally not acceptable above 23 GHz. This is due to difficulties in operating at or beyond the wet etching process capability used to fabricate accurate coupling gaps that are needed to realize these filters. Endwave has found that if printed filters are incorporated

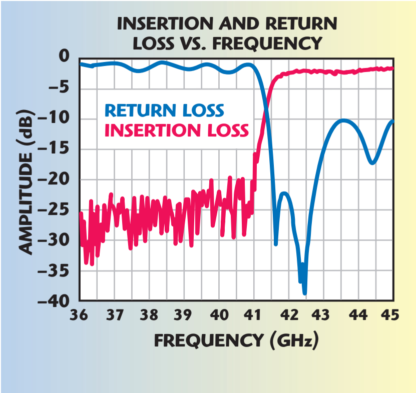


Fig. 3 *42 GHz SMT packaged filter response.*

into the PCB, several adverse impacts to cost, performance and on-time delivery can occur as these features become the yield drivers for the PCB manufacturer. This is in direct conflict to the widely held idea that printed features are essentially at zero cost, and must be considered strongly when examining the cost tradeoff between purchasing an additional filter versus printing a "free" one on the PCB.

Because higher frequency passives in SMT packages are not available through most MMIC suppliers, the need for passive packaged filters previously drove another tradeoff. A choice was made previously to use a wire bond process to allow an alumina filter at the expense of no longer enabling an all-SMT business model. Endwave launched the new SMT filter product to avoid this tradeoff – made possible through the use of the innovative packaging developments. Results of a typical 42 GHz filter are shown in ***Figure 3*** demonstrate the process capability through 45 GHz to reduce spurious, harmonics and RX image rejection while preserving the ability to build an all-SMT transceiver.

These same LO harmonic and TX spurious considerations push voltage-controlled oscillator frequencies higher to minimize LO multiplication factors and the resulting close in hard-to-filter spurious signals. However, the state of the art in low phase noise MMIC VCOs has a high end frequency of approximately 16 GHz, due to the nature of the hetero-junction bipolar transistor process — where the device performance begins to suffer above this range. Based on this, system designers tend to go as high as possible in VCO frequency while remaining under the 16 GHz limit in

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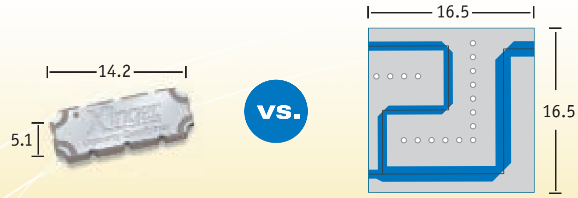

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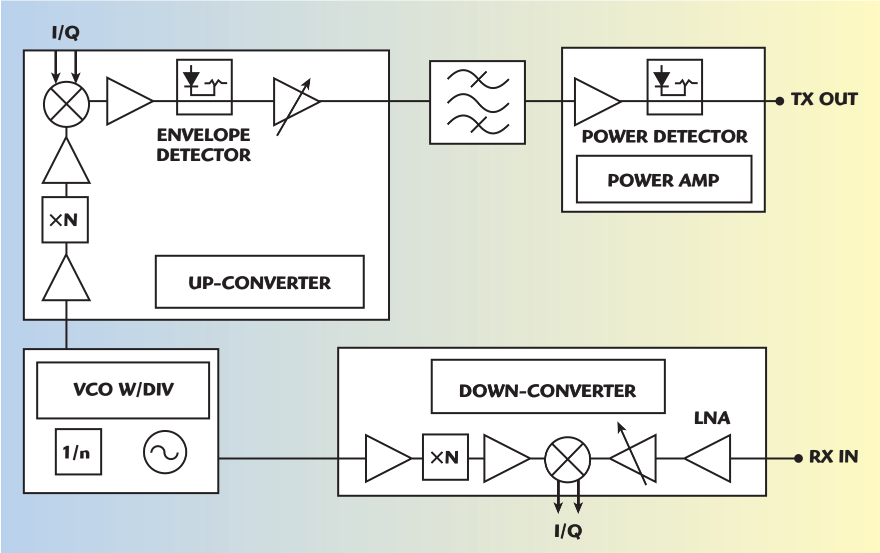

▲ *Fig. 4 Simplified transceiver block diagram via integrated MMICs.*

order to ensure that adequate phase noise is maintained. Moving toward higher frequency VCOs is a clear trade against optimal phase noise that can be obtained through use of a lower VCO frequency with higher LO multiplication factors.

As Figure 1b shows, RX noise figure can be minimized while maximizing RX linearity by protecting the first downconverting mixer from high input power levels. This protection is recommended to be incorporated via the addition of a VVA between the LNA and the mixer. The VVA thus provides a low loss path to the downconverter when the received signal strength is weak. Conversely, the dynamic range of the VVA protects the RX mixer in the case where the received signal is stronger. Note that this tradeoff has been solved through the addition of another tradeoff – where added complexity was incorporated at a slightly higher cost.

At the system level, a strong desire exists to perform system level integration of functions into a single module to reduce cost, while preserving enough isolation between functions to eliminate spurious degradation and instability. This requires a major shift from system complexity to MMIC complexity. Traditional systems have been based on complex systems built from simple MMICs, but today's trend is toward simpler systems based on more complex MMICs. This has a clearly positive effect on manufacturability of the transceiver module, while putting significant pressure on the MMIC designers.

In any given RF chain, both test yield and margin are directly proportional to the product of variances of the cascaded components (and interconnecting bond wires). Mathematically, the yield of the chain is $Y_T = y_1 y_2 \ldots y_N$, such that limiting the number of MMICs in the chain inherently provides increased overall yield. Since it is also true for the case of addressing variance in performance caused by a shift in any given MMIC, moving to a higher integration level for devices can present some clear advantages.

Specifically, fewer components in cascade can allow for tolerances on individual devices to be loosened, while having fewer interconnects improves reliability and performance. In addition, an integrated approach like that shown in ***Figure 4*** can enable migration toward a full SMT solution to be far easier than could be done in the block diagram in Figure 1. This is because the high losses would result when adding in 0.4 dB per transition at two or more transitions per MMIC.

In the past, the system design engineer had the freedom to choose single function MMICs from many vendors to gain best in class performance for each slot in the cascade of MMICs. For example, each MMIC function in the block could be from a different vendor, a different process, or both. A PHEMT process upconverter could be chosen with high linearity MESFET-based VVAs, as an example.

However, a key penalty that exists in pushing system complexity to the MMIC level of the supply chain is that grouping multiple functions into a single device forces all those functions to be made by one vendor with one technology (0.15 µm PHEMT low noise process, for example). This is a strong disadvantage from a performance perspective because best-in-class devices from multiple technologies or vendors cannot be chosen when several functions are combined into a single chip – placing an even higher challenge on the MMIC designer.

For this reason, not all functions are likely to be placed on a single chip without dramatic technology development. Figure 4 demonstrates a four MMIC solution which leverages optimal partitioning of functions per technology (note that some systems will use two VCOs for flexibility of frequency planning). In this case, the HBT-based VCOs are fabricated in InGaP, the PHEMT-based integrated converters are fabricated in GaAs, and the power amplifier is fabricated in GaN. A packaged SMT filter is also shown assuming optimal spurious performance is desired. The block diagram, therefore, demonstrates the current state of the art in RF MMIC device integration based on available processes. As mixed process solutions become available, consolidation to fewer MMICs is likely.

DETAILED DESIGN PROCESS

In order to design a set of converters that will fulfill the difficult set of tradeoffs listed previously, the design must be approached more like a system design than that of a single function MMIC. System engineers use cascaded analysis tools, which are now gaining popularity with MMIC designers. Cascaded analysis tools are popular, where several critical requirements are calculated simultaneously, including output power, gain, linearity and noise performance as well as variation versus temperature, which allow for rapid optimization.

By applying similar cascaded analysis techniques to the MMIC converters as would normally be done at the system level, significant improvements can be made to yield and performance. Additionally, 2nd spin redesign of the MMICs due to surprises are minimized because there are fewer chances for error. Once an initial cascaded analysis is completed to partition the requirements, the detailed design of the individual pieces can be completed. It should be noted that the SMT interconnects as well as the effect of the plastic overmold must be heavily modeled using 3D simulators and included in the cascaded models as well to properly account for parasitic effects and additional losses.

A key area of focus is gain partitioning between the IF and RF sections. This will ensure the best trade-off between linearity and noise figure (output noise levels) versus dynamic range of the converters as well as spurious implications while maximizing DC efficiency. In addition, choice of mixer architecture as well as on chip LO multiplication factor become crucial. There is little opportunity to filter out undesired LO harmonics that can reach the mixer – as could be done if separate multiplier and converter MMICs were used in a subsystem design.

A secondary consideration is that both LO and image rejection must be suppressed to ensure that these leakage tones do not prematurely degrade linearity of the RF amplifiers that follow the on-chip mixer. Suppression of these tones can be achieved through use of DC feedback injected through the IF inputs of the upconverter. However, in order to achieve the best case performance, the use of SMT-based filters are recommended prior to the power amplifier. Once all individual functions are designed, the detailed specific analysis using linear and nonlinear simulators, as well as 3D and cascaded tools can then be finalized.

CONCLUSION

A detailed discussion has been presented outlining the business and performance drivers that are the root cause for the fundamental shift in the complexity of RF systems to MMICs design area. In addition, a set of tradeoffs has been presented with solutions enabled by disruptive SMT technology, which is changing the manufacturing paradigm to enable a fully outsourced model. While the case study analyzed was the front-end of a point-to-point radio telecommunications link, the concepts are broadly applicable to several industries that depend on similar technologies. ■

NEW GENERATION HIGH LINEARITY NAVIGATION FRONT-END DEVICES COVERING GPS AND GLONASS

Receiver front-ends for Global Navigation Satellite Systems are required to provide the lowest noise figure, even in the vicinity of high power jammer signals. The design challenges are illustrated and solutions, which comply with the requirements of high-end handheld devices, are presented.

Today, a Global Navigation Satellite System (GNSS) is much more than GPS, which was introduced for civilian use more than a decade ago. Nations around the world are working on their own navigation satellite systems for strategic reasons and also to offer improved user experience. Today, two GNSS systems are operational: the United States GPS and the Russian GLONASS. The Galileo positioning system being developed by the European Union is expected to be functional by 2014 and Chinese COMPASS is also expected to follow.

From a civilian usage point, additional systems added to GNSS bring with them the advantages of increased satellite signal reception, increased coverage, higher precision and the facility for additional features such as search and rescue (SAR). This article considers only GPS and GLONASS and ***Table 1*** summarizes some the basic GPS and GLONASS characteristics.

TABLE I

GPS VS. GLONASS DATA

Parameter	GPS	GLONASS
Total no. of satellites (for complete functionality)	24	24
Number of orbital planes	6	3
Fundamental clock frequency (MHz)	10.23	5.0
Signal separation technique (between diff. satellites)	CDMA	FDMA
Carrier Frequencies (MHz)		
L1 band	1575.42	1598.0625 - 1605.375
L1 center frequency	1575.42	1602
L2	1227.6	1242.9375 - 1248.625

WHY THE GNSS FRONT-END IS IMPORTANT

Consolidation of different wireless connectivity features and the advent of GLONASS on today's handheld devices pose challenges on the GNSS receiver design at two levels: to enable the GNSS solution to work uninterruptedly in the vicinity of high power GSM/EDGE/UMTS/LTE signals active on the same device and to design a broadband solution covering the complete frequency range required by the two systems together.

To achieve this, cutting edge-design and technology capabilities are required to offer these features:

DANIEL KEHRER AND DEEPAK BACHU
Infineon Technologies AG, Munich, Germany

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Frequency	1 MHz–20 GHz	1 MHz–13.6 GHz	100 kHz–7 GHz
DANL	-155 dBm/Hz	-155 dBm/Hz	-164 dBm/Hz
Sweep time	< 0.9 s	< 0.7 s	< 0.4 s
Weight with battery	3.6 kg (7.9 lbs)	3.6 kg (7.9 lbs)	3.6 kg (7.9 lbs)

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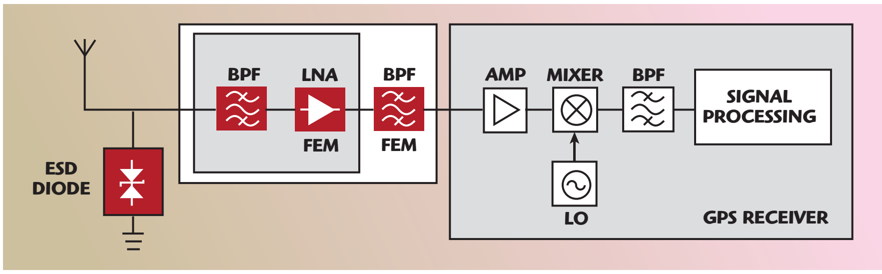


▲ *Fig. 1 An application schematic of a GNSS front-end.*

- High linearity to avoid interference of high power cellular signals
- Broadband design to cover the frequency range from 1575 to 1605 MHz
- Gain optimization to achieve state-of-the-art sensitivity
- Low noise figure to achieve state-of-the-art sensitivity
- High integration to have a small form factor and excellent cost position.

Although many current GNSS chipsets rule out the need for an external LNA and filters, this article offers a detailed guide through the various challenges faced by the system designer and explains the necessity of a high performance RF front-end to achieve hassle-free user experience.

GNSS RF FRONT-END CONFIGURATIONS

Typically, a GNSS front-end consists of an antenna, a pre-filter, a LNA and a post-filter. After this chain, the received signal is fed into the GNSS receiver IC. ***Figure 1*** is an application schematic of a GNSS front-end. Today we can find different integration levels of GNSS front-end modules that suit different phone or personal navigation device (PND) configurations.

These include a pre-filter +LNA+post-filter, which offers highest integration level thus can save PCB space, reduce design complexity and assembly costs, and a pre-filter+LNA, where the module can be placed very close to the antenna to minimize losses, at the same time a discrete post-filter can be placed in front of the GNSS IC. If the GNSS IC requires either single ended input or differential input, only the discrete post-filter needs to change – the GNSS module can be the same for the whole product portfolio, and a LNA+post-filter. This configuration enables the choice of a discrete pre-filter with different rejection levels for different designs, if the pre-filter is already integrated into the antenna switch module.

DESIGN CHALLENGES AND SOLUTIONS

Sensitivity: GNSS satellite signals are transmitted from orbits 20,000 km away from the earth's surface. With typical antenna gain, the received power at the GNSS device can be calculated as given in ***Table 2***.[1]

The receive power of -130 dBm is below the thermal noise level for a bandwidth of 10 MHz. Conventional GNSS receivers integrate the received GPS signals for 1 ms. This results in the ability to acquire and track signals down to around the -130 dBm level. High sensitivity GPS receivers are able to integrate the incoming signals for up to 1000 times longer than this and, therefore, can acquire signals up to 1000 times weaker. State-of-the-art high sensitivity GPS receivers are expected to track signals down to levels approaching -160 dBm.[2] The sensitivity of the GPS receiver can be significantly enhanced with a very low noise RF front-end.

Noise Figure: The noise figure of the front-end directly influences the sensitivity of the receiver, as well as the time-to-first-fix (TTFF) and time-to-subsequent-fix (TTSF). These parameters are directly visible to the end-user and, therefore, are a major focus for design. The noise factor, F, of a GNSS front-end, according to Friis's formula for a cascade of stages, each with its own noise factor F and gain G is given by:

$$F = F_{pre} + \frac{F_{LNA} - 1}{G_{pre}} + \frac{F_{post} - 1}{G_{pre} G_{LNA}} \quad (1)$$

where 'pre' denotes pre-LNA filter and 'post' denotes post-LNA filter.

The noise figure of the GNSS front-end is given by:

$$NF = 10 \mathrm{Log} F (\mathrm{dB}) \quad (2)$$

The noise figure of a filter is equal to the insertion loss (IL). As can be seen from the formula above, IL of the pre-filter is directly contributing to the total noise figure and therefore needs to be minimized. However, IL and Out-of-Band (OoB) rejection is a tradeoff in filter design and, therefore, impacts other design constraints like jammer performance of the GNSS module, which will be explained later. The noise figure of the LNA directly influences the system noise figure (G_{pre} ~ 1), whereas the post-filter being located after the amplifying stage does not contribute to the total noise figure (NF).

Typical insertion loss of a pre-filter can be in the range of 0.5 to 1.1 dB. State-of-the-art LNAs show a noise figure as good as 0.6 dB. The noise figure contribution of the post-filter is typically lower than 0.05 dB – here the tradeoff winner is clearly OoB rejection. In fact, the matching network in front of the LNA can also contribute up to 0.1 dB of noise figure depending on the quality factor (Q) of the external components used.

To summarize, the pre-filter and LNA define the noise figure of a GNSS module. There are modules with a noise figure as low as 1.1 dB (low OoB rejection) and as high as 2.0 dB (high OoB rejection).

TABLE II

CALCULATION OF GNSS RECEIVE SIGNAL STRENGTH

Carrier L1 = 1575.42 MHz	Coarse/Acquisition Code	Precision Code
Satellite antenna input power	21.9 W = 43.4 dBm	11.1 W = 40.4 dBm
Satellite antenna gain [1]	13.4 dB	
Satellite EIRP	56.8 dBm	53.8 dBm
Propagation loss [2]	184.4 dB	
Atmospheric loss	0.5 dB	
Typical polarization mismatch loss	3.4 dB	
Typ. Rx antenna gain [3]	3.0 dB	
Rx received power	**-128.5 dBm**	**-131.5 dBm**

1) @ worst-case off-axis angle of 14.3°
2) Minimum received power is @ 5° from users horizon
3) Users antenna gain pattern is typically max@zenith and min@5°

WORKING NEAR JAMMER SIGNALS

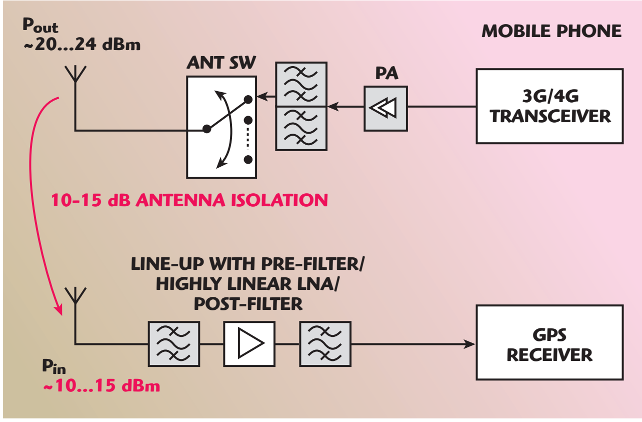
GNSS modules with the lowest noise figure satisfy one necessary selection criterion, but this does not necessarily guarantee good sensitivity and TTFF. Another concern regarding low power satellite signals is the presence of high power jammers in the GNSS device. Today's highly integrated smart phones are subject to a variety of wireless links that are transmitting or receiving signals with high power like GSM, 900 MHz, UMTS, 1.8 to 2.2 GHz, Bluetooth and WLAN, 2.4 GHz and WiMAX, 2.5 to 2.7 GHz. ***Figure 2*** shows a simplified block diagram of a mobile phone with the main path (GSM, UMTS) and the GNSS path.

If the strength of these signals is sufficiently high, it can drive the GNSS LNA into saturation and the gain in the GNSS band is lowered. The lower gain and increased total noise figure of the system is called desensitization.[3] Depending on the isolation conditions in the phone a certain OoB compression point is required. The built-in GSM power amplifier can transmit power levels up to 33 dBm.

If we assume an antenna isolation of 10 dB between main antenna and GNSS antenna, we can directly derive the necessary GNSS module compression point at 900 MHz to be P1dB_900 = 33 dBm – 10 dB = 23 dBm. The GNSS LNA cannot achieve this compression point performance and, therefore, the pre-filter needs to attenuate the 900 MHz signal. Assuming the LNA has a compression point of 3 dBm at 900 MHz the pre-filter needs to have a rejection of minimum 20 dB at 900 MHz. At this point, it should be mentioned again that in

filter design the IL and OoB rejection is a tradeoff (see Noise Figure section).

The second gain stage in the chain is the GNSS IC, which has a compression point of ~ -40 dBm and is much lower compared to a GNSS module. Here the post-filter comes into play, which should attenuate the jammer by 40 to 60 dB. However, desensitization is not only caused by driving the gain stages into saturation. Much before compression, an increase of noise figure can be noticed in many LNAs in the presence of a jammer.

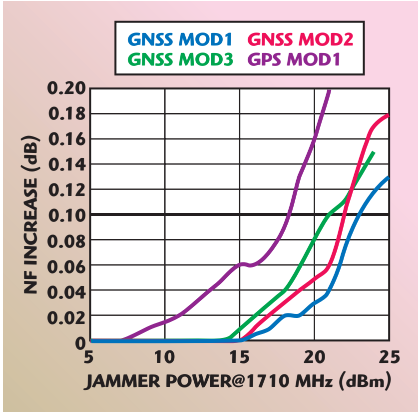


▲ *Fig. 2 Interference from mobile path to GNSS path.*

Figure 3 shows the desensitization performance of a GNSS module. The jammer, in this case, is at a frequency of 1710 MHz. The acceptable noise figure increase here is 0.1 dB, which is shown as a black line. The jammer, in this case, is at the frequency of 1710 MHz. The acceptable noise figure increase here is 0.1 dB shown, as black line. The newest generation of modules is hitting this line beyond the 20 dBm jammer power level. We can see that this module is hitting the black line a little earlier, at +17 dBm jammer level.

One more detailed study that illustrates the everlasting demand for more wireless bandwidth and higher data rates in mobile phones should be discussed. Just recently the Federal Communications Commission (FCC) gave conditional approval to the use of the L-band for terrestrial LTE applications. The downlink frequency is 1525 to 1559 MHz, which is directly neighboring the frequencies of GPS and GLONASS. The base station will transmit a maximum power of 62 dBm equivalent isotropically radiated power (EIRP).

Depending on the base station antenna elevation and tilt angle, a jam-



▲ *Fig. 3 Desensitization performance of Infineon's GNSS modules: noise over 1710 MHz jammer power.*

mer power of up to -20 dBm can be received at the GNSS antenna in close proximity (~200 m).[4] The GNSS module itself will withstand that jammer level but it must protect the GNSS IC against the jammer. If we again assume a maximum allowed jammer level of -40 dBm at the GNSS IC and 20 dB gain of the GNSS LNA, we can calculate the necessary rejection of pre-filter + post-filter together:

$$-20\text{dBm} - Att_{pre} + 20\text{dB} - Att_{post} \le -40\text{dBm} \Rightarrow Att_{pre} + Att_{post} \ge 40\text{dB} @ 1559\text{MHz} \qquad (3)$$

This requirement is not fulfilled for existing GNSS equipment and it is a very hard requirement for new GNSS

TABLE III
INTERMODULATION PRODUCTS

User Case	f1	f2	Mixing product
GSM + WLAN	825 MHz	2400 MHz	f2-f1 = 1575 MHz
GSM1800 and UMTS Band-2	1712.5 MHz	1850 MHz	2f1–f2 = 1575 MHz
LTE Band-13 harmonic	787.5 MHz	n/a	2f1 = 1575 MHz

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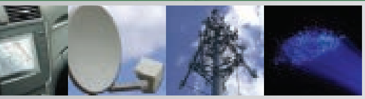

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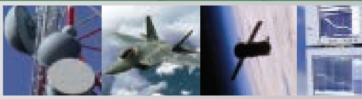

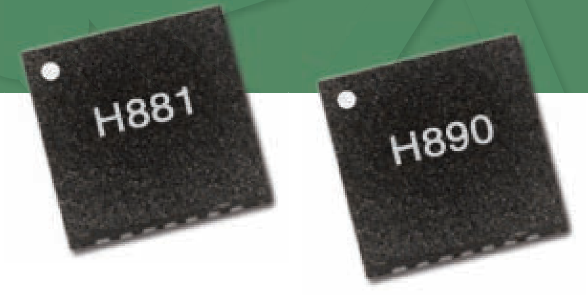

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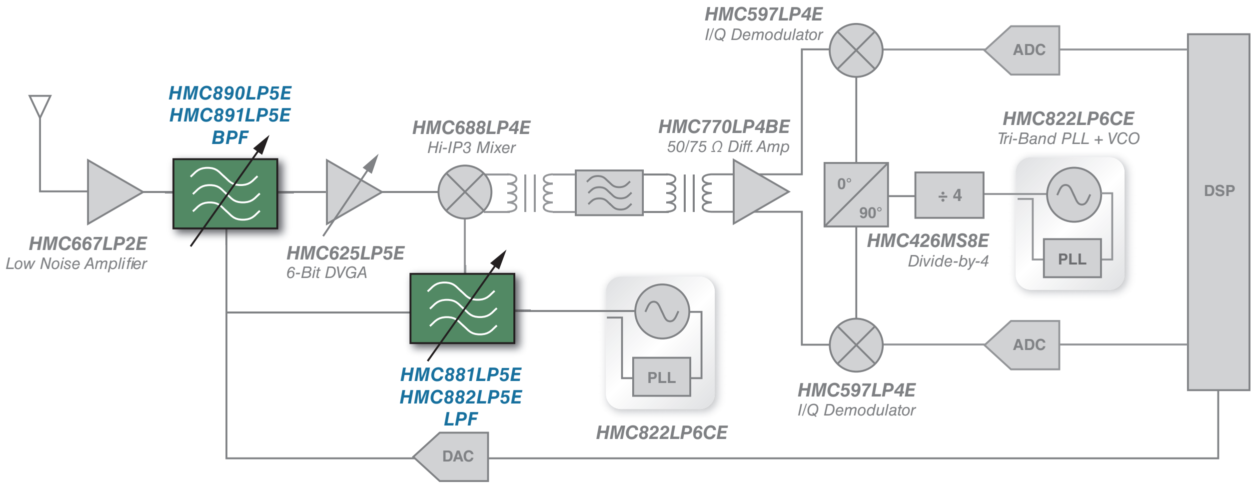

BAND PASS

	Freq. Range (GHz)	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
	1 - 2	10	11	0.8 x Fcenter	1.2 x Fcenter	200	**HMC890LP5E**
	2 - 3.9	10	9	0.9 x Fcenter	1.15 x Fcenter	200	**HMC891LP5E**
	4 - 7.7	15	9	0.9 x Fcenter	1.13 x Fcenter	200	**HMC892LP5E**
	4.8 - 9.5	7	6.5	0.9 x Fcenter	1.1 x Fcenter	200	**HMC893LP5E**
NEW!	5.9 - 11.2	7.5	6	0.92 x Fcenter	1.08 x Fcenter	200	**HMC894LP5E**
	9 - 19	9.5	18	0.81 x Fcenter	1.17 x Fcenter	200	**HMC897LP4E**
NEW!	18.5 - 37.0	10	18	0.81 x Fcenter	1.20 x Fcenter	200	**HMC899LP4E**

LOW PASS

Freq. Range (GHz)	Return Loss (dB)	Cutoff Frequency Range (GHz)	Stopband Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
DC - 4.0	10	2.2 - 4.0	1.25 x Fcutoff	150	**HMC881LP5E**
DC - 7.6	10	4.5 - 7.6	1.23 x Fcutoff	150	**HMC882LP5E**

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modules, due to its proximity to the GNSS frequencies.

Although there are no disturbing signals inherently in the GNSS band, due to nonlinearity effects in the LNA as well as in the filter, there are mixing products that can exactly fall in the GNSS band. Both 2nd order and 3rd order mixing products are relevant and should be taken into account. ***Table 3*** is a list of user cases that are critical in a mobile phone.

The OoB intercept point 3rd order (IP3) and OoB intercept point 2nd order (IP2) for the user cases needs to be optimized. The mixing can take place in each stage (pre-filter, GNSS LNA, post-filter, GNSS IC) due to nonlinear effects. The passive filters normally show higher linearity compared to the active devices. However, the pre-filter gets the biggest jammer level and can, therefore, also be the source of the mixing signal. The pre-filter OoB rejection can improve linearity if the dominant mixing already happens at the GNSS LNA. To improve OoB IP3 of the GNSS module, a high OoB rejection pre-filter should be used to lower the jammer power level at the LNA and, therefore, the power level of the mixing product. The post-filter can only limit the jammer power level to the GNSS IC. Typical maximum allowed mixing product levels at the GNSS IC input is -90 dBm.

BROADBAND OPERATION

Prior to the introduction of GLONASS, the filter in a GNSS module only had to cover the GPS center frequency and, therefore, bandwidth was not a problem at all. If we look now to GPS and GLONASS to be served by one filter, this needs to cover a bandwidth of ~40 MHz. The variation in IL within this bandwidth must be below 0.3 dB. Together with the same or even higher attenuation levels outside the band, this becomes a challenge especially for pre-filter design.

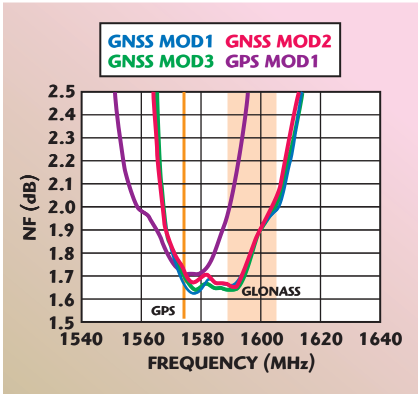
Yet, the focus in joint GPS/GLONASS designs is on the GPS system. The lowest IL and noise figure of the module can be found at GPS frequency. But not only a low noise figure over the complete GPS + GLONASS band is desirable, also a flat gain of the module is important to get good system sensitivity over all bands. Gain flatness with a typical value of <0.5 dB is necessary to achieve an acceptable performance over process variation.

One significant difference between GPS and GLONASS is that, unlike GPS, each GLONASS satellite is transmitting on a different center frequency. The position acquisition of these systems is based on signal runtime from the satellites to the receiver. The GNSS module now has a group delay, which is not flat over the bandwidth – so different GLONASS satellites see a different delay through the module.

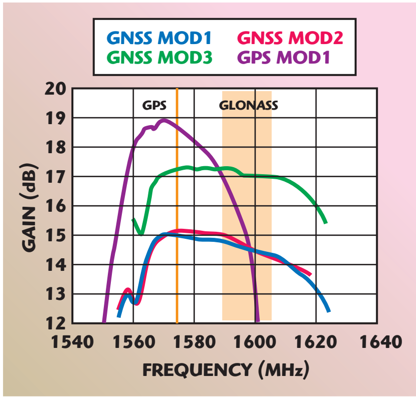
This was suspected to directly translate into position uncertainty. However, these small band dips (i.e. 5 ns within 1 MHz bandwidth) have a much smaller bandwidth compared to the GLONASS spectrum, so a strong averaging effect on the measured filter delay occurs. Therefore, the in-band group delay dips will not be detected by the matched filter or correlation receivers for GLONASS and will not significantly impact the accuracy.

RF CHARACTERISTICS

This section shows RF characteristics of GPS and GLONASS modules for in-band and out-of-band operation to meet the requirements described



▲ *Fig. 4 Noise figure over frequency of GNSS/GPS modules.*



▲ *Fig. 5 In-band gain of GNSS/GPS modules.*

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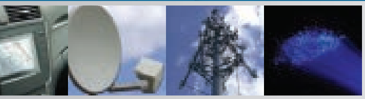

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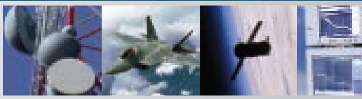

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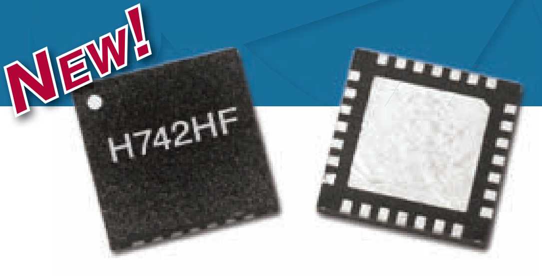

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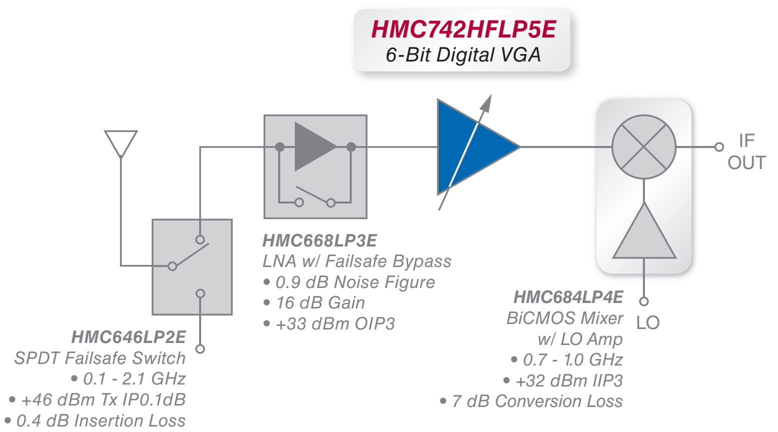

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	2.3 - 2.5	Analog VGA	-9 to +21	2.5	7	3	+3V @ 9mA	HMC287MS8E
	6 - 17	Analog VGA	0 to +23	6	30	22	+5V @ 175mA	HMC694LP4E
	DC - 1	6-Bit Digital, Serial & Parallel Control	-11.5 to +20	4.3	36	20	+5V @ 90mA	HMC627LP5E
	DC - 1	6-Bit Digital, Parallel Control	+8.5 to +40	4	36	20	+5V @ 176mA	HMC626LP5E
	DC - 1	6-Bit Digital, Serial Control	+13.5 to +45	2.7	36	20	+5V @ 176mA	HMC681LP5E
	DC - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	HMC625LP5E
NEW!	0.5 - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	HMC625HFLP5E
	0.7 - 2.7	6-Bit Digital, Serial Control	+6.5 to +38	4.4	45	25	+5V @ 218mA	HMC926LP5E
	0.07 - 4.0	6-Bit Digital, Serial & Parallel Control	-19.5 to +12	4	39	23	+5V @ 150mA	HMC742LP5E
NEW!	0.5 - 4.0	6-Bit Digital, Serial & Parallel Control	-19 to +12.5	4	39	21.5	+5V @ 150mA	HMC742HFLP5E
	0.7 - 1.2	6-Bit Digital, Serial & Parallel Control	-2.5 to +29	0.8	38.5	21	+5V @ 236mA	HMC707LP5E
	1.7 - 2.2	6-Bit Digital, Serial & Parallel Control	-2.5 to +29	1.0	37.5	21.5	+5V @ 252mA	HMC708LP5E
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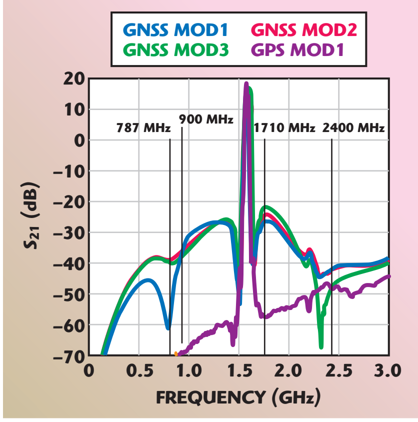

▲ *Fig. 6 Wideband performance of GNSS/GPS modules.*

earlier. In ***Figures 4, 5*** and ***6***, the GPS/GLONASS modules referred to are: GNSS Mod1: pre-filter + LNA for LTE platforms; mid-gain, GNSS Mod2: pre-filter + LNA for standard platforms; mid-gain, and GNSS Mod3: pre-filter + LNA for standard platforms; high-gain. The GPS Module is GPS Mod1: pre-filter + LNA + post-filter.

Figure 4 shows the noise figure of the modules over frequency. The GNSS modules are required to demonstrate a low noise figure in the whole bandwidth covering GPS and GLONASS and not exceeding 2 dB. Figure 5 shows the in-band gain of the modules. GNSS Mod3 and GPS Mod1 are high-gain modules, whereas, GNSS Mod1 and GNSS Mod2 are mid-gain modules. The gain ripple of GNSS modules is expected to be below 0.5 dB.

For good linearity and jammer performance, the OoB rejection is the key factor. Figure 6 shows the OoB performance of the modules. The GNSS modules, which are pre-filter + LNA configuration, offer an excellent suppression of all OoB jammers. The GNSS Mod1 is designed to address the LTE Band 13 jammer at 787 MHz, which is exactly half of GPS frequency. The 2nd harmonic of this LTE signal, generated at any non-linear device in the system would interfere directly with the GPS satellite signal. As a result, strong rejection is required to prevent the 787 MHz going into the GNSS path. GNSS Mod1 offers a 75 dBc rejection at 787 MHz and is, therefore, optimized for LTE Band 13 phones.

The GPS Mod1 is a pre-filter + LNA + post-filter module and, therefore, offers the highest rejection over the whole frequency band. It features more than 80 dBc rejection below GPS frequency and 70 dBc rejection above GPS frequency, and with its high integration level, it is an easy part to use.

SUMMARY

Integration of various GNSS systems and other wireless connectivity standards onto one platform results in increasing requirements on GNSS system design. The receiver performance can be significantly improved with proficient front-end design. The key performance criteria for the front-end are noise figure, gain, linearity and suppression of out-of-band signals. ■

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MEASUREMENT TIPS AND TECHNIQUES: KNOW THE WEAKEST LINK IN YOUR RF NETWORK ANALYSIS

A chain is only as strong as its weakest link and an RF measurement is only as reliable as the most uncertain component or practice. Increasing complexity of communication schemes are driving stringent performance requirements of today's RF components and networks. The vector network analyzer (VNA) is the instrument of choice for many RF measurements, including high volume semiconductor test systems in both validation and production environments. To fully realize the benefits of a VNA, one must understand the weaknesses of the measurement and correct for them where possible. In this article, four common sources of weakness encountered when using a VNA are covered and recommendations on how to best mitigate or remove these weak links from the measurements are presented.

CORRECT FOR SYSTEMATIC ERRORS

A discussion around network analyzer operation would not be complete if it did not include a heavy dose of calibration theory and methods. While understanding the calculations and error models behind system calibration can enable one to further improve the accuracy of the measurements, this article will focus more on the basic sources of error in an RF measurement and how to correct for them when possible.

All RF instruments, including network analyzers, require a periodic factory calibration to be performed by a certified calibration laboratory. These calibrations are typically performed yearly and ensure that the network analyzer meets the published specification. They also allow for adjustments to be made when damage or the changing physical characteristics of the VNA over time alter the expected performance. In the RF lab, a dynamic measurement environment creates its own unique challenges, introducing both random and systematic errors. Random sources of error, by definition, are not repeatable or predictable. They can typically be reduced by narrowing the IF bandwidth settings and through averaging. The key to the exceptional measurement accuracy achieved by network analyzers hinges on frequently performing a user calibration to reduce the systematic sources of error. ***Figure 1*** shows a simplified block diagram of a two-port, one-path T/R test set VNA and the sources of systematic error that can be corrected for during a properly performed user calibration.

DAVID BROADBENT
National Instruments, Austin, TX

To correct for these systematic errors, one performs a user calibration and measures a set of known standards, compares the measured value to the value of the known standard to calculate the error for each data point, and finally applies the appropriate error correction for each frequency point in the measurement. There is a long list of well-defined, industry standard calibration kits ranging from broadband short, open, load, through (SOLT) standards, suitable for RF frequencies, to transmit-reflect-line (TRL) kits when high accuracy over a narrow bandwidth is required. Additionally, automatic calibration modules are becoming increasingly popular, especially for automated network analysis in validation and production test. In production, maintaining high throughput is so important and excessive time spent calibrating can be costly.

Many factors determine how often a user calibration is performed, including the required measurement accuracy, environmental conditions, and repeatability of the DUT connection. A fresh user calibration may be necessary hourly or weekly. One should use verification standards to determine how often to calibrate. A less stringent practice of measuring a "golden DUT" to determine how often to calibrate can also be used when accuracy requirements are more relaxed.

Systematic Errors

Transmission and Reflection Tracking – Frequency response errors, or transmitted and reflected signal loss, result across all frequencies and must be characterized and corrected.

Source and Load Mismatch – Many RF systems have a characteristic impedance of 50 Ω. To properly measure the impedance of the device under test (DUT), any difference between this characteristic impedance and the impedance of the test port, or more specifically, the reference plane, must be accounted for.

Isolation – Errors can occur from cross-talk between various components in the test setup, VNA ports, and measurement reference planes. When this error is significant, it should also be included in the calibration procedure.

Coupler Directivity – VNAs rely on directional elements, often couplers, to separate the transmitted signals from the reflected signals. Ideally, a directional coupler would measure only the forward or reverse traveling signals and produce no output for signals traveling in the opposite direction. Because this is never the reality, the error introduced by coupler leakage must be measured and corrected.

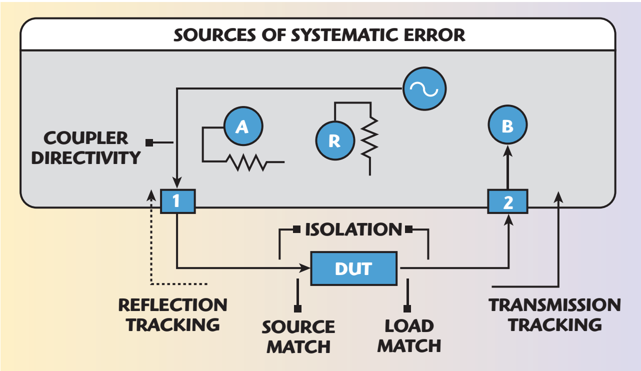


Fig. 1 Sources of systematic error can be corrected during a user calibration.

THROW OUT BAD CABLES AND ADAPTERS

Disposable is typically a word used to describe napkins and dental floss, so it understandably makes us cringe to think about throwing out the cables and adapter sets that carry pricetags easily exceeding a few months rent. Notwithstanding, RF cables and adapters must be regarded as disposable. Designing and producing high quality RF systems depends on the high measurement accuracy of the VNA; a weak or damaged cable or adapter compromises the result and should be discarded. This is simply a part of the expense of making highly accurate measurements.

Figure 2 breaks down a basic connector pair and calls out the important mating elements. By understanding how these connectors are meant to mate and operate, there are a number of ways one can extend the life of cables and connectors.

In addition to meticulous connector care, automatic calibration kits can be used to extend the life of RF adapters and cables. All RF cables and adapters are rated for a limited number of connections. With an automatic calibration module, only one connection is performed during calibration rather than the five to ten connections required for a comparable manual calibration.

MIND YOUR REFERENCE PLANE

In a VNA measurement, the reference plane is the location in the system where the user calibration is perfomed and, therefore, is the plane from which the measurement is being made. When calibrating a VNA using the SOLT method, for example, attaching the calibration standards to the ends of the cables that are connected to ports 1 and 2 establishes the end of those cables as the reference plane. As shown in ***Figure 3***, any adapters or a test fixture placed between those cables and the DUT are included as part of the measurement and can dramatically alter the results. Consider a 6 GHz sine wave with a 5

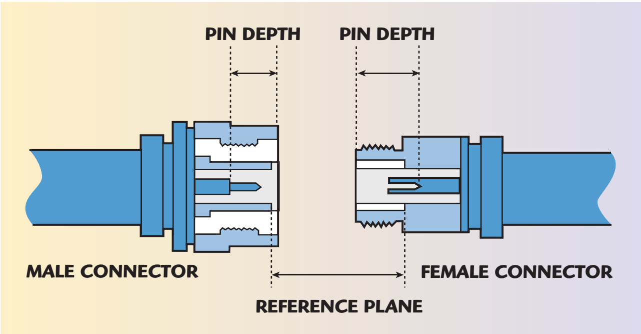


Fig. 2 Proper care can extend the life and reliability of expensive cables and adapters.

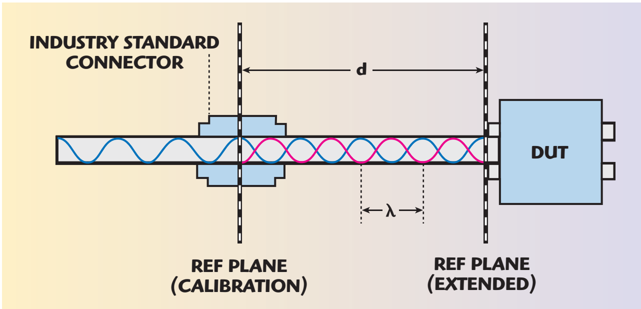


Fig. 3 Test fixtures are commonly used for automated semiconductor test. The DUT can be isolated from the test fixture by performing a reference plane extension.

Cable Care

Use proper torque – To avoid damage to the connector threads and, more importantly, the center pin, always use a torque wrench adjusted to the appropriate torque when tightening 2.92 mm, 3.5 mm, and SMA connectors while finger-tightening N-type connectors.

Frequently gauge the pin depth – Before mating a connector with another device or cable, measure the pin depths of the connectors using a calibrated pin depth gauge. Mating connectors with a pin that is too long will result in damage and compromised measurement results. Mating connectors with a pin that is too short, on the other hand, will degrade the measurement accuracy.

Tighten connectors without rotating the center pin – Never tighten the connectors, adapters, or cables such that the center pin rotates. A rotating center pin creates friction within the connector that can introduce tiny metal shavings into the connector and cause other mechanical alterations and, consequently, change the RF performance.

Avoid mechanical shock – Mechanical shock significantly reduces the connectors' service life. Handle the connectors carefully and avoid dropping them or storing them loosely in a drawer.

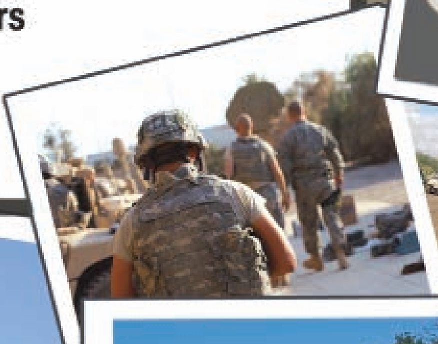
Regularly clean connectors – Avoid touching connector mating planes with bare hands as natural skin oils and microscopic dirt particles are difficult to remove. Even in very clean environments, there will be dirt and other debris introduced to the test system, so regularly clean the connectors with compressed air, foam swabs and alcohol.

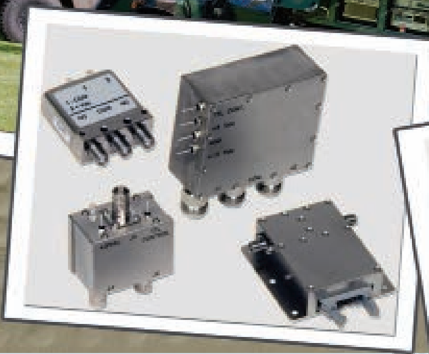
Properly store connectors – When not in use, keep the connectors covered with their protective dust caps.

cm wavelength, even a single millimeter difference in the actual and desired reference plane results in 7.2 degrees of phase error. When testing semiconductor components and RFICs an industry standard connector such as 2.92 or 3.5 mm, cannot be used, and test fixtures are always used in some fashion in order to connect to the DUT.

The use of a test fixture makes it necessary to use some method of de-embedding to isolate the DUT from the test fixture or the manufacture of custom calibration standards that connect to the test fixture in the same way as the DUT. When it is not feasible to create custom calibration standards matching the test setup, there are a variety of de-embedding techniques that can be used to extend the reference plane of the measurement. Two common and simple approaches to this are time domain gating and reference plane extensions.

Reference Plane Extensions – One can move the reference plane after calibration either automatically or manually. To automatically move the reference plane after calibration, insert an open or short calibration standard at the location in the test setup where the reference plane will be relocated. A crude open can be created, with certain accuracy limitations, by simply removing the DUT from the test system. Figure 3 shows the full reflection that is measured by the VNA when the DUT is replaced by an open or short standard. The VNA can then perform the calculations necessary to move the reference plane and adjust subsequent measurements to match the desired measurement setup. For increased accuracy, one





can use a VNA to characterize the test fixture and manually enter the values for trace length and frequency-specific loss. These are then removed (or added) to the measurement to relocate the reference plane.

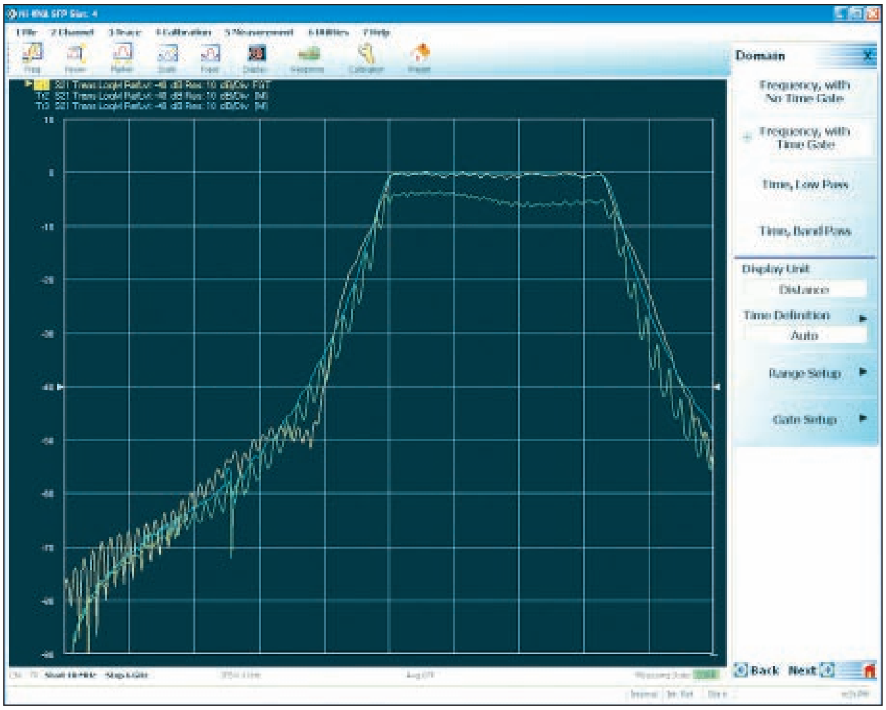


Fig. 4 The response of the DUT (blue) is estimated (yellow) by using time domain gating to remove the additional response of a test fixture (green).

Time Domain Gating – A VNA makes measurements in the frequency domain and then performs an inverse fast Fourier transform (FFT) to display the response in the time domain. This opens up a wide range of applications including time domain gating. By observing the varying impedance values through an RF signal chain, various components in the system can be identified (in time and distance). ***Figure 4*** shows that by gating only the desired components in the time domain and converting the data back to the frequency domain, the magnitude and phase response of only the DUT, and not the fixture or any additional adapters, can be estimated.

DON'T BE THE WEAKEST LINK

After taking special care to ensure that the instrument and test setup are properly calibrated and understood, it would be a shame to let poor measurement practices limit the accuracy and reliability of the results. In this way, the engineer becomes a part of the error model, and even the best network analyzer can be quickly rendered inef-

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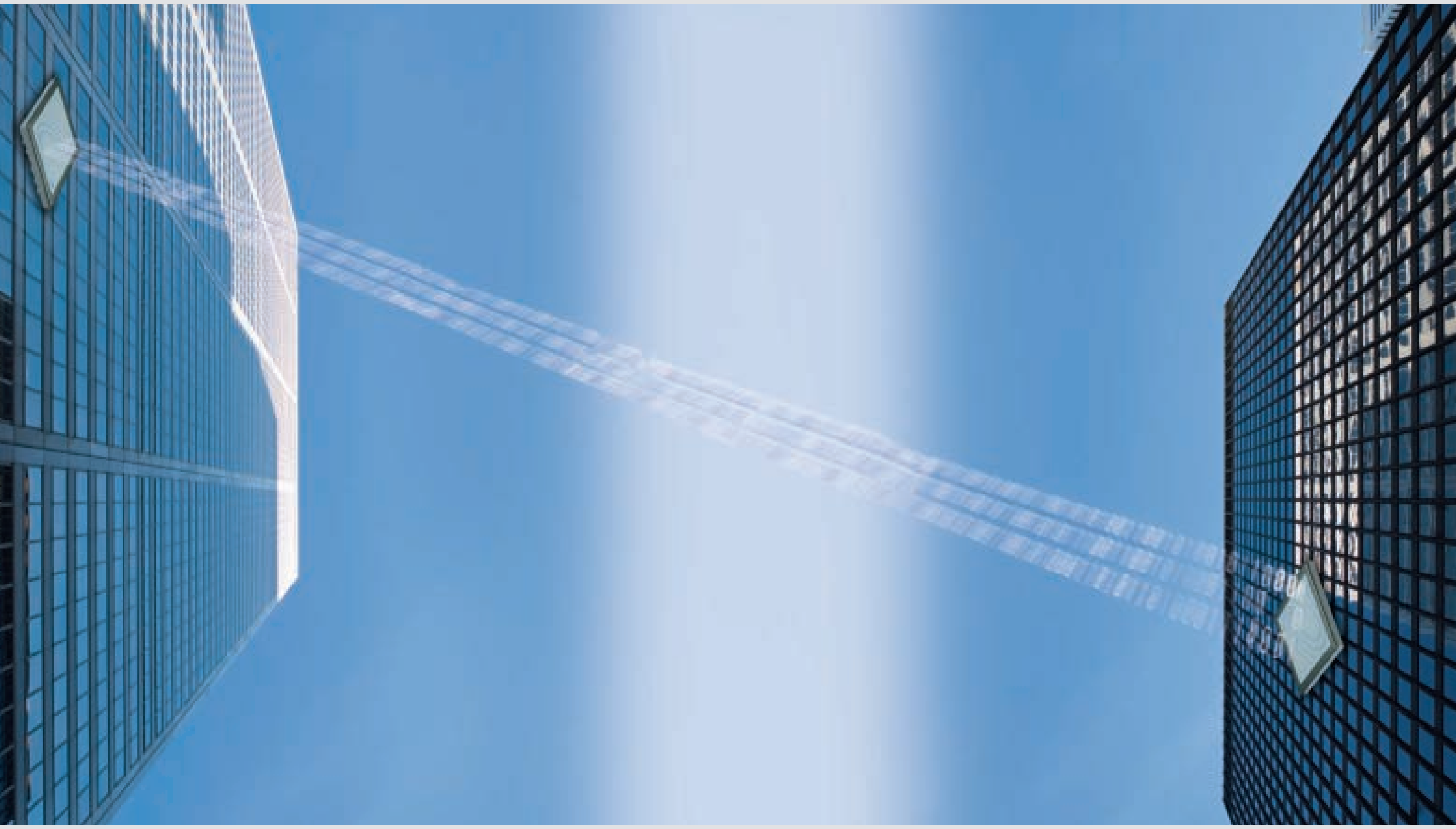

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fective by human error. For example, if proper torque is not used, the repeatability of the measurement and validity of the result are compromised.

It is easy to fall in the trap of adjusting the settings of your VNA until the expected results are achieved. Oftentimes, however, the expected results can differ significantly from the correct result and allow components that operate outside of the design specifications to pass through unnoticed. Following a well-developed process can ensure best practices are adhered to and dramatically improve the reliability and repeatability of the results. This recommended process can be tailored to specific needs and applied to the network analysis to ensure that consistent results are achieved.

VNAs are indispensable tools for accurately measuring the magnitude and phase response of complex RF networks. By understanding the weaknesses of a RF network analysis system, one can ensure that a weak link does not prevent achievement of highly accurate and repeatable VNA measurements. ■

Measurement Best Practices

Prepare

1. Warm up the VNA and DUT
2. Inspect and properly gauge all connectors
3. Select which S-parameters to measure over what frequency and power ranges
4. Identify the desired reference plane and the de-embedding method to be used to achieve this
5. Connect the appropriate cables and adapters to the VNA

Practice

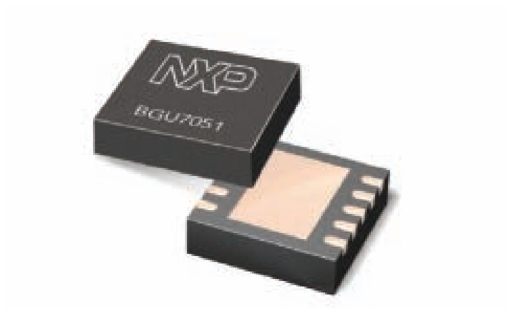
1. Set the frequency, power and IF bandwidth for the VNA
2. Connect the DUT and verify the setup
3. Extend the reference plane if necessary
4. Measure the desired S-parameters
5. Remove the DUT

Calibrate

1. Choose the proper calibration kit
2. Set IF bandwidth and averaging to minimize noise
3. Perform the calibration
4. Verify the calibration with a verification kit or a "golden DUT"
5. Save the calibration setup

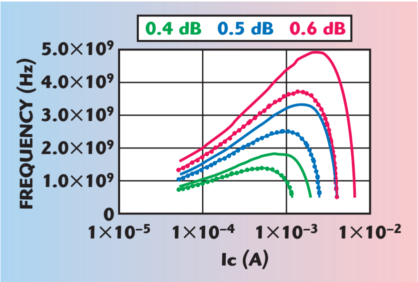
Perform

1. Connect the DUT
2. Apply the calibration performed
3. Measure and save the S-parameter data



NXP's High Performance SiGe:C LNAs for Wireless Infrastructure

Modern base station receivers for wireless communication infrastructures cope with extreme sensitivity and intermodulation characteristics, requiring sub 1 dB noise figures and high linearity for the low noise amplifier (LNA). Until recently, these specifications were only met using compound semiconductor technologies like GaAs PHEMT. However, NXP's latest developments with their SiGe:C BiCMOS process, i.e. the QUBiC4X technology, speeds the migration from Gallium Arsenide (GaAs) to Silicon (Si) by offering comparable or better linearity, DC power consumption, immunity against out-of-band signals, spurious emission performance and increased output power.



▲ *Fig. 1 Maximum frequency up to which a certain NF_{min} is maintained for a given current (dotted lines: BNX device, solid lines: BNA device).*

To meet the demanding application requirements for wireless communication infrastructures, NXP has developed low noise, high linearity amplifiers (BGU705x series) in this SiGe:C BiCMOS technology with a high cut-off frequency (f_t) of 130 GHz. A higher integration of circuitry is possible by this technology and covered in this product feature.

The first stage exists of a low-noise NPN BNX device with an emitter width of 0.4 µm and has an NF_{min} of 0.5 dB at 2 GHz for a current density of 0.25 mA/µm^2 (see ***Figure 1***). This current density will not deliver peak-f_t, but the related f_t is 30 GHz, still 10 times the operational frequency. Also, the available bandwidth for 10 times voltage gain is beyond 10 GHz for this current density. In other words, the device will certainly have more than 10 dB gain at 2 GHz. This low noise device can safely be operated at 3 V supply voltage. To achieve the high linearity performance requirements, a second stage is needed. Clearly, for sub 1 dB NF the noise contribution of the second stage remains important. If an overall NF of 0.6 dB is the target, the formula of Friis would require a NF of 0.7 dB for the second stage, assuming a realistic available gain of 15 dB in the first

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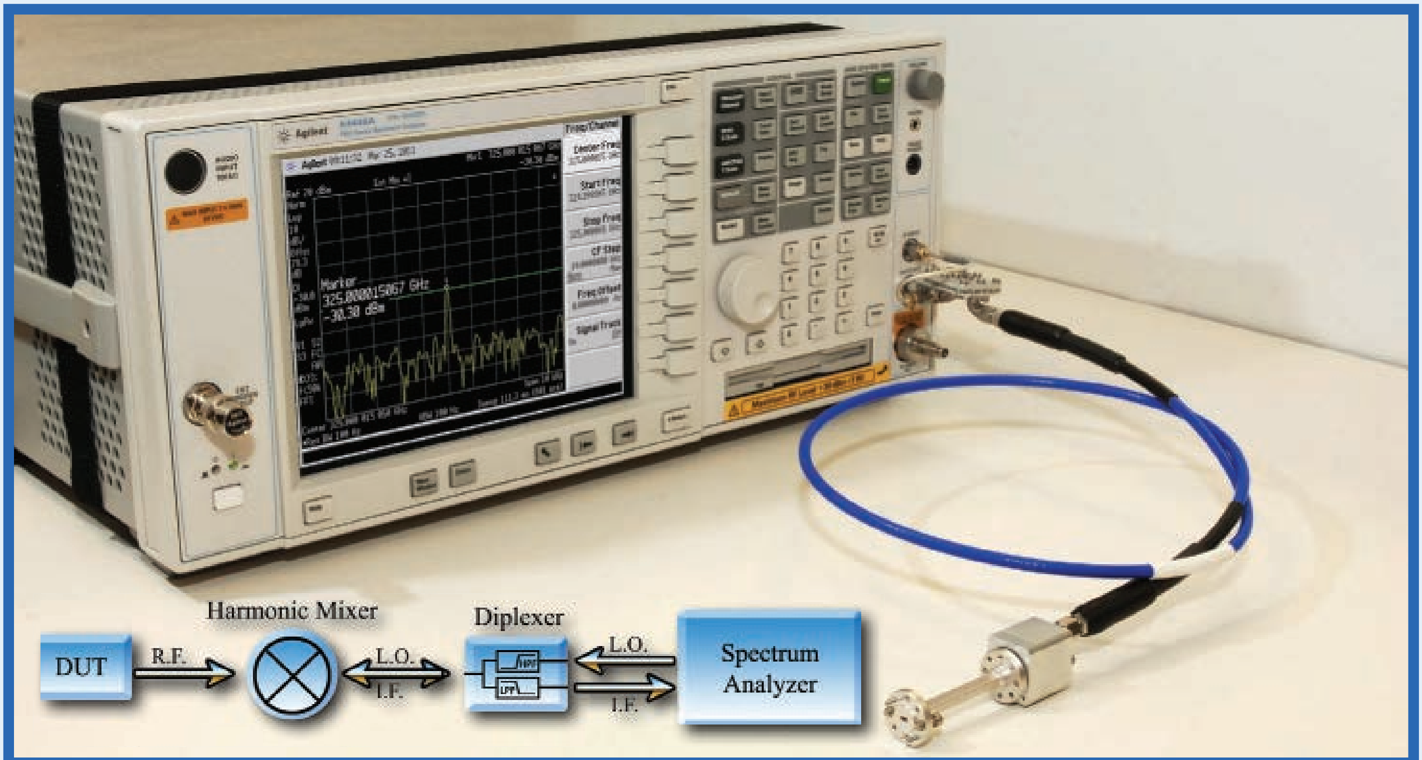
Millimeter Wave Spectrum Analysis
18 GHz to 325 GHz



Model	M42HWD	M28HWD	M22HWD	M19HWD	M15HWD	M12HWD	M10HWD	M08HWD	M06HWD	M05HWD	M04HWD	M03HWD
Band	WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-08	WR-06	WR-05	WR-04	WR-03
Conversion Loss	25 dB	31 dB	32 dB	32 dB	39 dB	43 dB	46 dB	50 dB	52 dB	59 dB	63 dB	74 dB
Sensitivity (1 kHz RBW)	-119 dBm	-113 dBm	-112 dBm	-112 dBm	-105 dBm	-101 dBm	-98 dBm	-94 dBm	-92 dBm	-85 dBm	-81 dBm	-70 dBm

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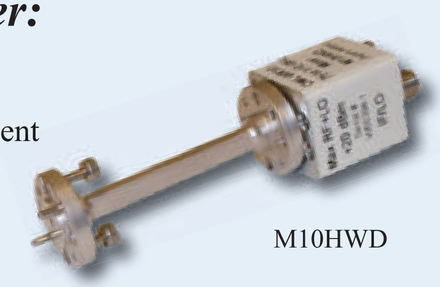

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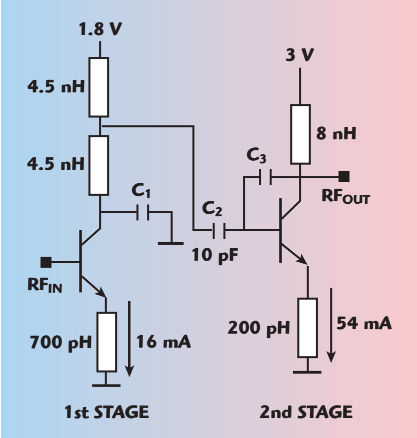
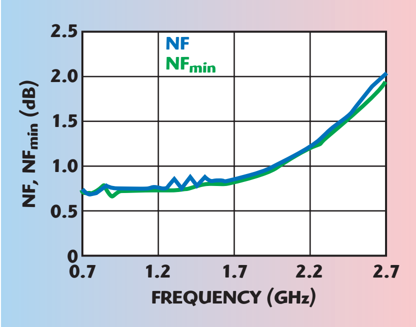
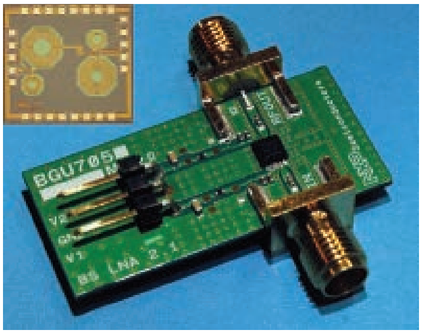


▲ *Fig. 2 Schematic drawing of the LNA (biasing circuitry not shown).*



▲ *Fig. 3 Measured NF and NF_{min} as a function of frequency at room temperature.*



▲ *Fig. 4 Micro photograph of die (left) and demo board (right).*

stage. The high voltage BNA device in this technology can still reach such a NF value, requiring a current density of 0.21 mA/μm². The cut-off frequency for this device is then still 30 GHz.

The first stage uses inductive degeneration to get the input matched to 50 Ω. Inductive loading has been applied to realize 15 dB gain. Inter stage matching happens at a few ohms in order to improve linearity in the second stage. The second stage uses high voltage devices and measures an output third-order intercept point of +40 dBm, meanwhile having a noise figure of 0.7 dB. The output stage is directly matched to 50 Ω. A coarse overview of the design is shown in **Figure 2** (biasing circuitry excluded).

Additional aspects such as ESD protection circuitry and I/O bond pads will influence the final design parameter choices. To minimize layout parasitic effects, routing has been performed in the thick top metal layer only. High quality MIM capacitors with 5 fF/μm² density have been used. The implemented inductors have Q-factors above 15 at 2 GHz. The LNA is housed in a 10-terminal small, thin plastic outline package.

The resulting low noise, high linearity amplifiers meet the requirements of sub 1 dB noise figures (see **Figure 3**) and high linearity for wireless communication infrastructures. Additionally, compared to GaAs based discrete equivalents, these devices offer better DC power consumption, high immunity to high input level signals, spurious emission performance and increased output power. A demo board and die micro photo are shown in **Figure 4**.

The BGU7051 provides a typical low noise figure of 0.7 dB and high linearity output third-order intercept point of +32 dBm in the 750 to 900 MHz band. The associated gain is better than 20 dB typical and the 1 dB gain compression at the output is at 17 dBm. The input return loss is typically 25 dB.

Similarly, the BGU7052 operates between the 1.5 and 2.5 GHz with a NF of 0.8 dB at 1900 MHz. Linearity performance is similar to the BGU7051. The BGU7053 offers comparable performance levels in the 2.3 to 2.8 GHz band. With the BGU705x series, the cellular frequency bands from 700 MHz up to 3.5 GHz can be covered. The BGU705x series is unconditionally stable and consumes less than 200 mW.

A new family of LNAs has been developed by NXP with low noise figures and high linearity using the SiGe:C BiCMOS technology. These devices compare well to compound semiconductor equivalents offering comparable or better linearity, DC power consumption, immunity against out-of-band signals, spurious emission performance and increased output power.

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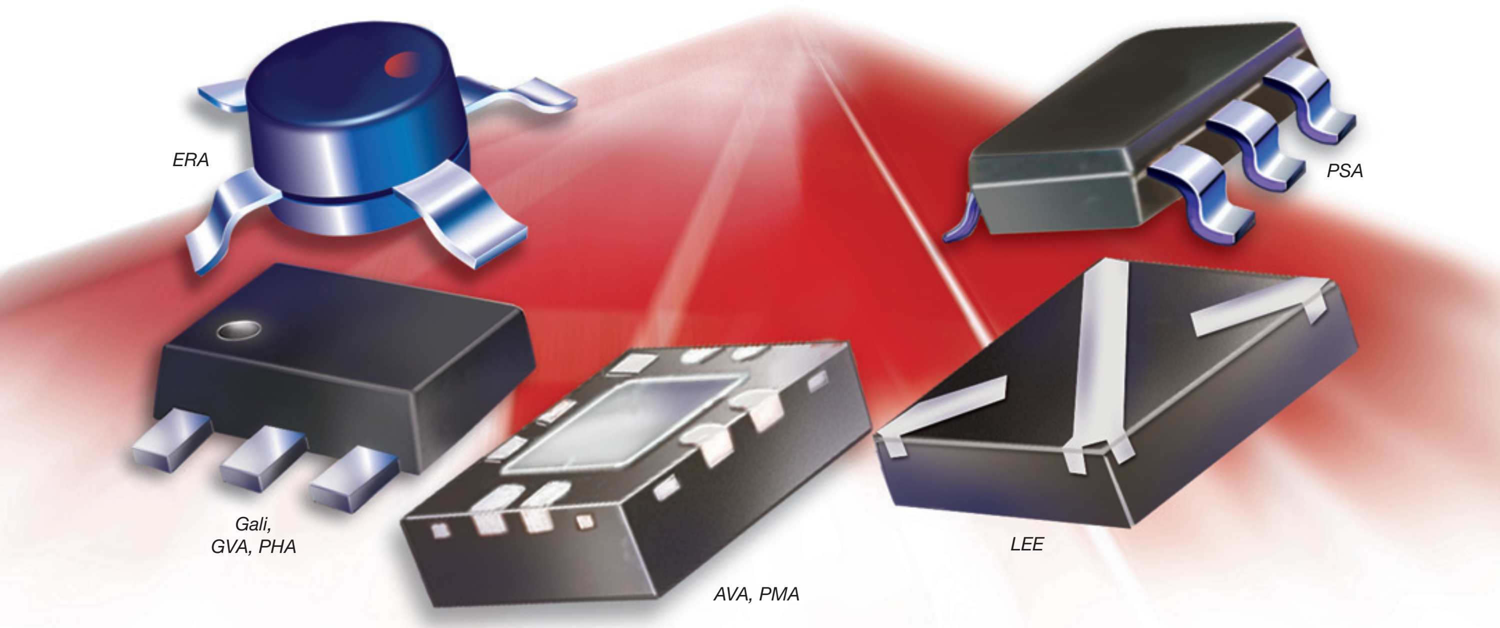

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REVOLVING CALIBRATION ADAPTER

The increasing demand for high frequency components with various applications and the need to test such components require effective and efficient calibration of the measurement systems that are used. In order to have a wide field of application calibration, devices need to be both economic and technical. In particular, the relationship between price and performance is an important consideration. The ideal is for the calibration to be quick and easy and carried out with as little disruption as possible. In many technical fields such as telecommunications, aerospace and military applications, a universal method of calibration is useful and sufficient, including calibration of portable VNAs for field applications.

To meet these requirements, Rosenberger developed a versatile OSL(M) Calibration Kit, which consists of components required to meet Open – Short – Load and Mismatch (optional) standards. The mismatch option makes it possible to verify the calibration directly with the same connection (transmission line), which yields an accurate measurement.

DESIGN AND OPERATION

Rosenberger has developed the new generation RPC-N Revolving Calibration Adapter, which is simple to use, has state-of-the-art operation and performance and has been designed for field applications. By rotating the hand wheel, which is mounted on the centre axis, the adapter can be adjusted into the appropriate position for the specific standard required (as shown in ***Figure 1***). Thus, the correct component is engaged and aligned with the coaxial transmission line. Springs ensure secure contact between coaxial components.

The RPC-N Revolving Calibration Adapter is available in two frequency ranges – DC to 8 GHz and DC to 18 GHz. It is simple to handle, with only one connector interface for all components. Also, it is versatile, has good electrical characteristics and is easy and quick to use, thus saving time.

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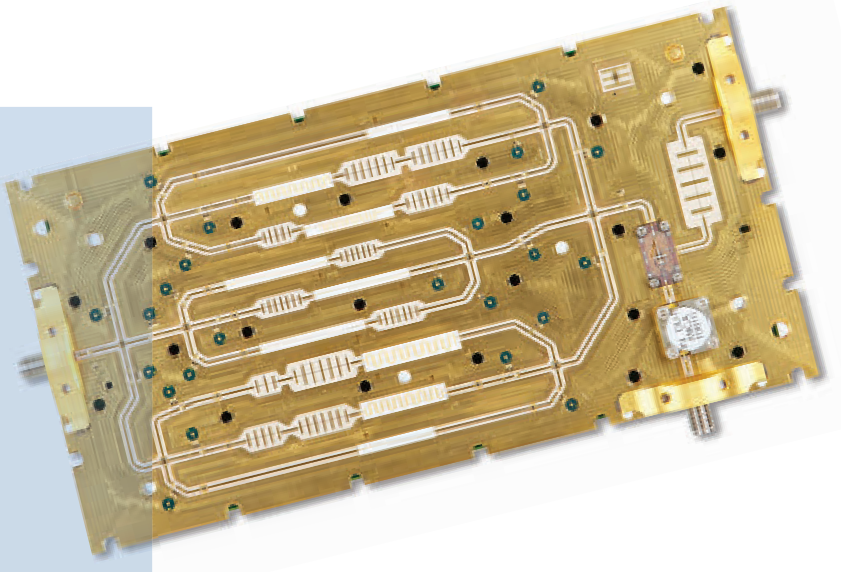

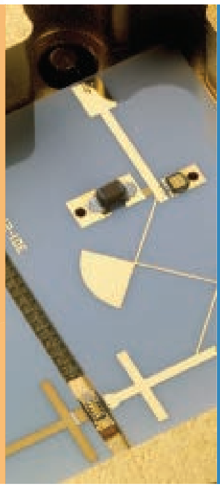

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REFLECTION COEFFICIENT

As has been mentioned previously, a mismatch will be used for direct verification. The magnitude of the reflection coefficient at the load is the result of the forward and backward voltage ratio. The reflection coefficient changes the phase, dependent on the distance to the load. The complex plane (see ***Figure 2***) shows the qualitative case of real mismatch reflection coefficient, as well as the verification mismatch that would be achieved after a successful calibration.

A key advantage is having the same transmission line for calibration and verification. The substrates for the load and the mismatch have the same resistive structure and only the load and mismatch at the end of line (at the load) are compared. ***Figure 3*** shows the results of measurements using a VNA, which shows a curve without ripple. The plot shows the difference between independent mismatch and verification mismatch after calibration using the RPC-N Revolving Calibration Adapter.

Particularly for verification with mismatching, a reasonable VSWR should

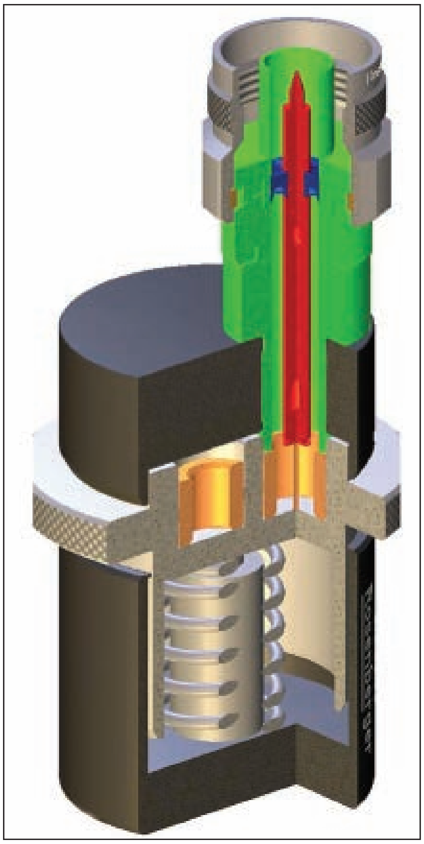

Fig. 1 Sectional view of the male revolving calibration adapter.

be applied. A VSWR of 1.2 is a good compromise between the difference to absolute magnitude of the calibration load (important for the upper frequency range) and possible error vector magnitude of the calibration error.

$$Z(1) = ZL(1 + r(1))/(1 - r(1)),$$

$$VSWR = 1.2 \rightarrow r = 0.091$$

$$\rightarrow R = 60\ \Omega = Z(1)$$

Additional error vector magnitude will be added to the reflection coefficient in the case of calibration error. The value of the resulting reflection coefficient depends on the kind of calibration error.

CALIBRATION AND VERIFICATION

Following are practical applications of the RPC-N Revolving Calibration Adapter. All applications were executed with a one port calibration on the VNA and the connecting interface was PC-N. Calibration standards for the Revolving Calibration Adapter were Open, Short and Load. Typical parameters were entered into the VNA, which was a basic industrial version that only uses electrical length of

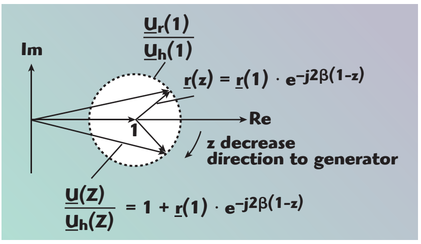

Fig. 2 The qualitative case of real mismatch reflection coefficient.

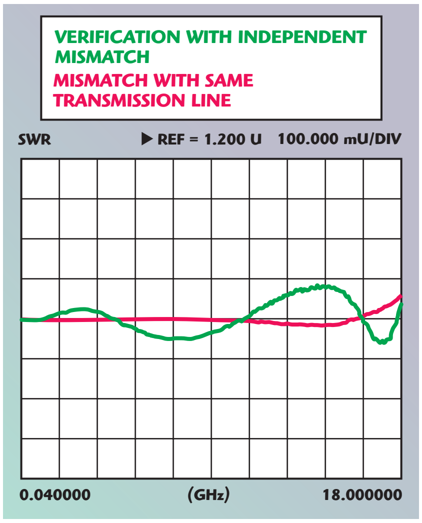

Fig. 3 The results of measurements using a VNA.

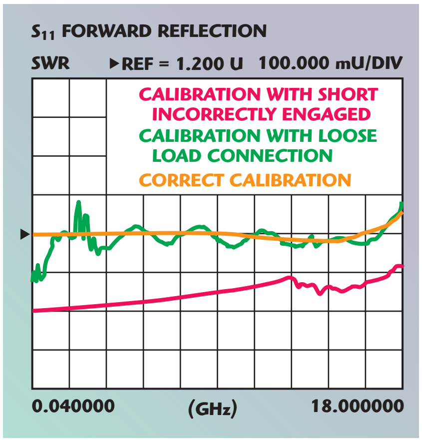

Fig. 4 Results of measurements for the DC to 18 GHz male RPC-N revolving calibration adapter.

open and short.

The next step, directly after calibration, is the mismatch measurement, which is a simple and useful verification of the calibration. This complete cycle of calibration and verification can be realized with only one connection.

Figure 4 shows the results of measurements for the DC to 18 GHz male RPC-N Revolving Calibration Adapter. All measurements are displayed in VSWR and clearly show the difference between successful and failed calibration. The plots show:

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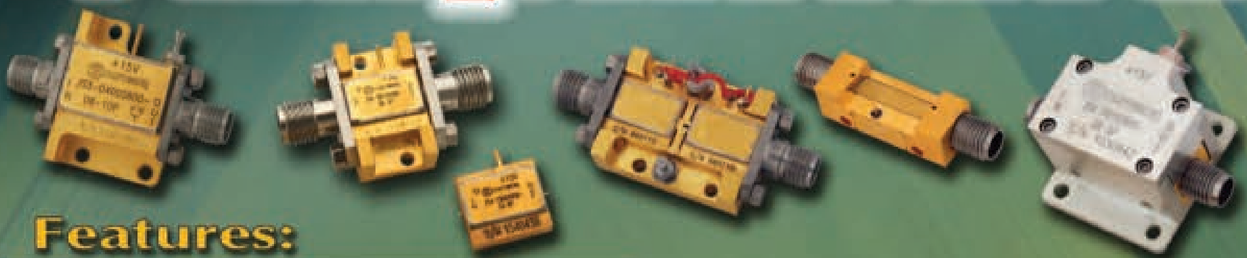

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- Small Footprint
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- Quick Delivery

Model Numbers	Frequency Range (GHz)	Gain (dB, Min.)	Gain Variation (± dB, Max)	Noise Figure (dB, Max.)	VSWR IN/OUT	Power Out @ 1 dB Comp (dBm, Min.)	DC Power @ +15 V (mA, Nom.)
JS2-00100800-13-8P	.1 - 8	23	1.7	1.3*	2.3:1	8	175
JS4-00101000-21-10P	.1 - 10	31	1.6	2.1*	2.5:1	10	200
JS4-00101200-22-10P	.1 - 12	31	1.7	2.2*	2.5:1	10	200
JS4-00101500-23-10P	.1 - 15	30	1.8	2.3*	2.5:1	10	200
JS4-00101800-24-10P	.1 - 18	29	1.8	2.4*	2.5:1	10	200
JS4-00102000-25-10P	.1 - 20	29	2.0	2.5*	2.5:1	10	200
JS4-00102600-30-10P	.1 - 26	28	2.5	3*	2.5:1	10	200
JS4-00104000-54-5P	.1 - 40	30	3.0	5.4*	2.5:1	5	200
JS2-01000200-06-10P	1 - 2	34	1.2	0.65	2.0:1	10	225
JS2-02000400-05-10P	2 - 4	34	1.2	0.55	2.0:1	10	225
JS3-04000800-08-10P	4 - 8	35	1.2	0.8	2.0:1	10	195
JS3-04002000-19-8P	4 - 20	31	1.7	1.9	2.2:1	8	195
JS3-05001000-15-15P	5 - 10	28	1.3	1.5	2.0:1	15	200
JS4-06001800-15-10P	6 - 18	34	1.8	1.55	2.2:1	10	200
JS4-08001800-15-10P	8 - 18	34	1.6	1.55	2.0:1	10	200
JS3-12001800-14-5P	12 - 18	27	1.5	1.4	2.0:1	5	200
JS4-12002600-24-10P	12 - 26	33	2.5	2.4	2.3:1	10	200
JS3-18002200-15-10P	18 - 22	26	1.3	1.5	2.0:1	10	150
JS4-18002600-22-10P	18 - 26	35	1.5	2.2	2.0:1	10	200
JS3-18004000-40-15P	18 - 40	32	2.7	4	2.6:1	15	400**
JS4-18004000-30-5P	18 - 40	23	2.5	3	2.5:1	5	200
JS42-18004000-31-8P	18 - 40	35	3.5	3.1	2.5:1	8	300
JS1-26004000-100-19P	26 - 40	17	2.5	10	2.5:1	19	400**
JS4-26004000-30-8P	26 - 40	23	2.5	3	2.5:1	8	200
JS42-26004000-31-8P	26 - 40	37	3.5	3.1	2.5:1	8	300
JS2-01200140-04-10P	1.2 - 1.4	34	0.7	0.45	1.8:1	10	225
JS3-17901920-14-10P	17.9 - 19.2	27	1.0	1.4	2.0:1	10	150
JS3-19202020-14-10P	19.2 - 20.2	27	1.0	1.4	2.0:1	10	150
JS3-20202120-14-10P	20.2 - 21.2	27	1.0	1.4	2.0:1	10	150
JS3-21002200-14-10P	21 - 22	27	1.0	1.45	2.0:1	10	150

*Above 800 MHz.
** Dual Voltage, -8V @50 mA.

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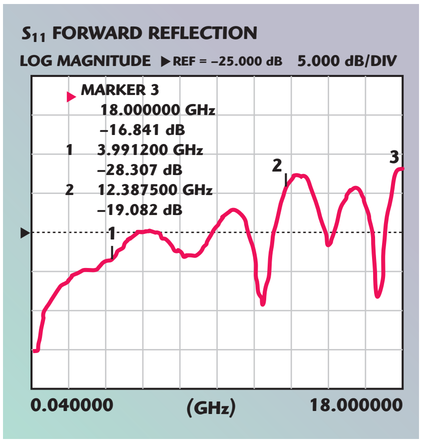
- Case 1 (shown in red): The short was not correctly engaged during calibration.
- Case 2 (shown in green): Calibration with a loose load connection.
- Case 3 (shown in yellow): A relatively flat curve without ripple indicates correct calibration.

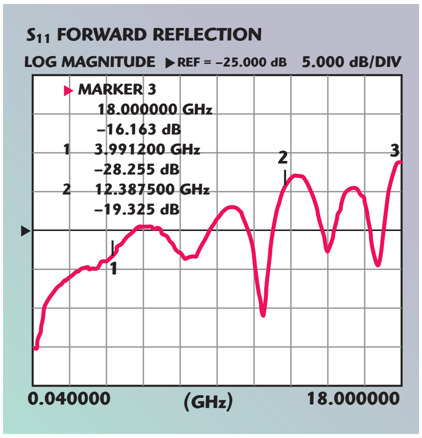
Figures 5 and ***6*** offer a comparison of the measurement of an independent DUT using LRL-calibration (Figure 5) and the RPC-N Revolving Calibration Adapter (Figure 6). The DUT is a long microwave cable with a 50 Ω termination and thus a typical application. The results show that OSL-revolving calibration is sufficient for normal requirements (not for precision standards).

DROP TEST

Ruggedness is particularly important to users who want to use the revolving calibration adapter when working in the field, so during evaluation the adapter was drop tested. Different heights of up to 3.5 m, with different points of impact of the adapter on the ground, were tested. After testing, the mechanical and electrical properties remained unaltered.



▲ *Fig. 5 Measurement with LRL-calibration.*



▲ *Fig. 6 Measurement with OSL-revolving adapter calibration.*

SUMMARY

The ingenuity of the RPC-N Revolving Calibration Adapter is its combination of good mechanical and electrical properties, excellent performance in industrial applications, and ease of use. A particular advantage is the facility for verification directly after calibration. Calibration using the revolving calibration adapter is considerably faster, than calibration with single standards, making it suitable for engineers who want an uncomplicated method for calibrating their network analyzers.

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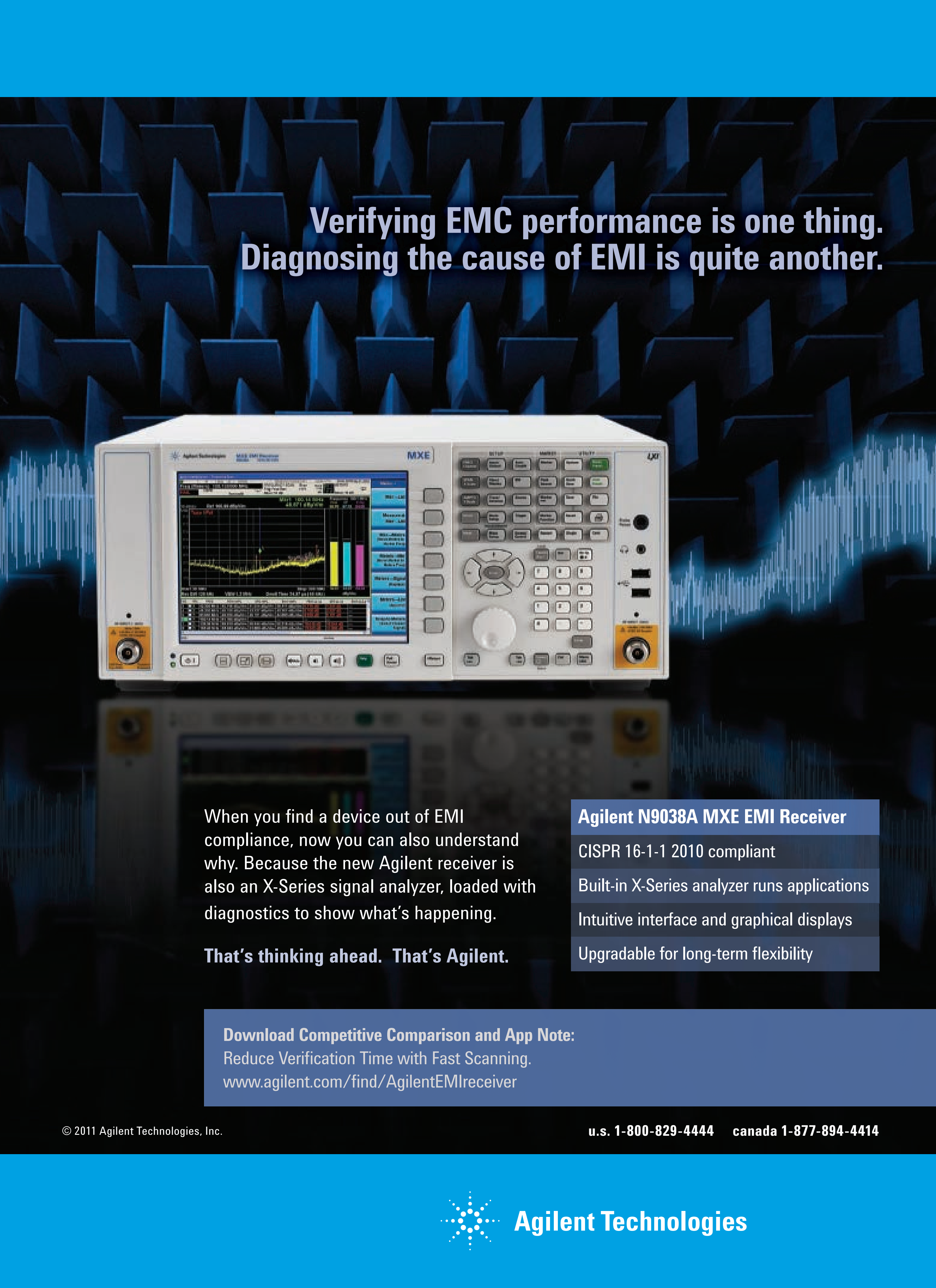
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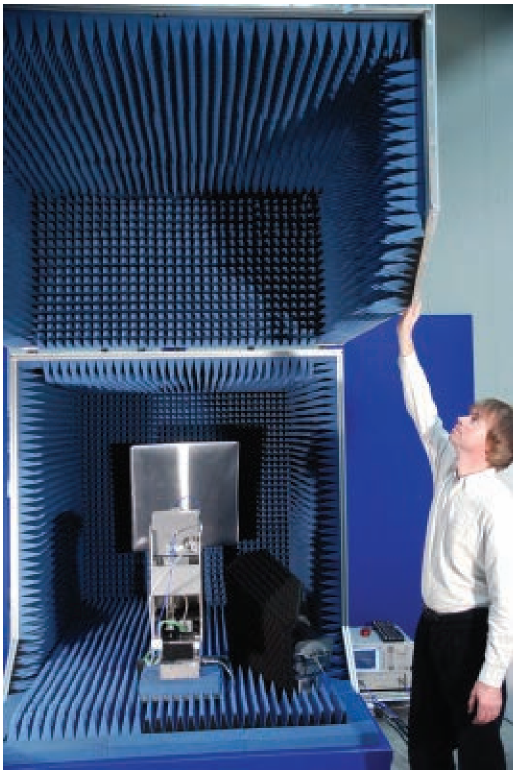
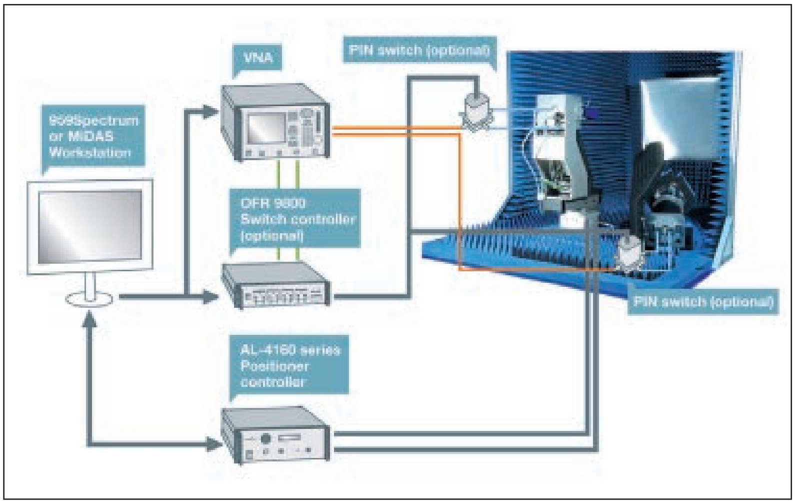


A COST-EFFECTIVE SOLUTION FOR TESTING SMALL-APERTURE ANTENNAS

An antenna measurement facility is typically one of the largest capital investments an antenna manufacturer makes. Therefore, companies commonly specify a test range that seeks to fulfill all requirements within a single chamber. In the resulting facility design, the overall physical dimensions are driven by the largest expected test antenna, typically in the lower frequency bands, while dimensional tolerances are driven by the high frequencies, where antennas tend to be small.



▲ *Fig. 1 Mini-compact range standard system block diagram.*

Such tradeoffs invariably lead to a large test facility having to meet tight electrical and mechanical tolerances. In addition to being costly, this type of system can be cumbersome and necessitate significant reconfiguration between high and low frequency operation. It also needs large antenna positioners, requiring operator time, personnel, and machinery to mount and align even small antennas. The compounding time lost on setup will impact range productivity and Return on Investment (ROI). A better approach is multiple test facilities dedicated to certain categories of antennas.

The Microwave Vision Group's CR-M mini-compact range is a complete, self-contained compact range test system targeting smaller aperture antennas. It provides no loss in accuracy and can be set up by just one person in a matter of minutes. Faster setup translates to improved test efficiency and productivity. CR-M offers a high performance solution for

MICROWAVE VISION GROUP,
ORBIT/FR
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testing antennas up to 50 cm in diameter and in frequencies above 4 GHz. With limited initial investment and high test throughput, it offers antenna manufacturers a high ROI.

CR-M is usable at frequencies up to 110 GHz, and potentially much higher. It is a perfect solution for a wide variety of applications, including small, high gain antenna characterization and millimeter-wave applications. The system's small size and portability makes it well-suited when space is at a premium, such as production testing or in multi-purpose test and research labs.

COMPACT RANGE TECHNICAL BACKGROUND

To characterize the performance of an antenna, we seek to measure its efficiency and radiated energy distribution in space. In most real-use scenarios, a receive antenna is far away from a transmitting antenna, such that the wave front near the receive antenna approaches a "plane wave." To replicate this in a far-field test range, a guideline for the minimum distance is $2D^2/\lambda$, where D is the maximum diameter of the antenna aperture and λ is the wavelength. At this distance, the deviation from a plane is only 1/16th of a wavelength. The far-field distance can grow very rapidly at higher frequencies. For instance, an antenna with a 40 cm diameter at 50 GHz already has a distance of 53 m.

A compact range reflector collimates the wave front of the feeding antenna such that the reflected wave in the test zone (quiet zone) represents a plane wave. In this way, it is possible to directly measure far-field performances in a very compact facility. For example, MVG's CR-M16 has exterior dimensions that do not exceed 3 m.

SYSTEM COMPONENTS AND SPECIFICATIONS

As mentioned earlier, the CR-M is a full compact range system contained in a smaller package. It includes an aluminum chamber enclosure lined with absorber, an aluminum-rolled edge reflector, a positioning subsystem complete with AUT and feed positioners and a positioner controller, and an RF subsystem. For ease of use, the system is also available with automatic door (hatch) open/close.

CR-M reflectors are precisely machined from a single piece of aluminum and result in accuracies that allow measurements into the hundreds of GHz. The lower frequency limit of a compact range is restricted by the stray signal level due to reflector edge diffraction. Through continuous improvements in edge design, the latest CR-M systems allow measurements as low as 4 GHz.

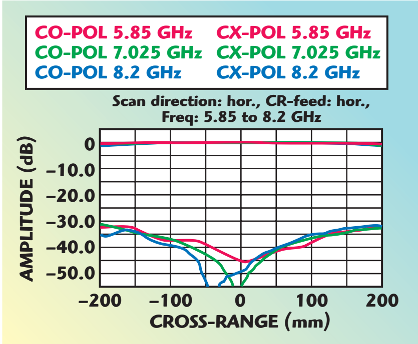
Three standard system sizes are available, based on desired quiet zone dimensions from 30 × 30 to 50 × 50 cm.

TYPICAL SYSTEM CONFIGURATION

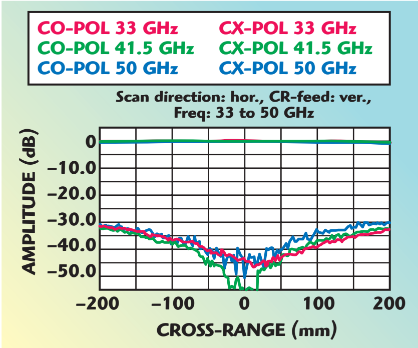
The CR-M's basic configuration (shown in ***Figure 1***) allows for single plane patterns to be collected using standard vector network analyzers. The chamber provides a modest level of shielding and allows for easy access to the AUT positioner and compact range feed area. The chamber is mounted on a caster assembly for convenient transportation.

A compact range feed polarization rotator allows the transmit polarization to be changed during a single test or between tests. Linked axis motion of the transmit rotator and optional roll axis allows for automatic acquisition of E and H plane patterns in a single test. An AL-4160 series po-

sitioner controller allows for control of up to four axes and simultaneous motion. The use of an OFR 9800 high speed switch controller permits collection of multiple channel data. An optional squint (elevation) axis allows E and H plane patterns through the peak of the beam in case electrical and mechanical bore sight do not coincide. The data acquisition workstation comes equipped with either 959Spectrum or MiDAS software (region-dependent), allowing for versatile and powerful data acquisition and analysis.



▲ *Fig. 2 Horizontal quiet zone scan showing co- and cross-polarization levels. Amplitude ripple: ±0.3 dB; phase ripple: ±0.5°.*



▲ *Fig. 3 Horizontal quiet zone scan showing co- and cross-polarization levels. Amplitude ripple: ±0.07 dB; phase ripple: ±1°.*

MEASURED SYSTEM PERFORMANCES ON CR-M16

The quality of the plane wave generated by the compact range is the key measure of range performance. It is measured by translating a probe antenna within the quiet zone while recording the received signal. ***Figures 2*** and ***3*** show examples of test data for a recently delivered system.

Results show the phase deviation at 50 GHz to be less than 3 electrical degrees peak-to-peak (1/120th wavelength), so that not until 750 GHz, well above maximum frequency spec, is the total phase variation in the order of 1/16th wavelength obtained. In a "real" far-field facility operating at this frequency, a 40 cm antenna would need a minimum distance of 800 m.

SUMMARY

Users of MVG's CR-M systems rapidly realize its benefits and enjoy increased productivity. These systems enable the full characterization of dozens of antennas in a single day. Brandon Hunter, Functional Test Manager at L-3 Communication Systems – West, has said of his CR-M, "The Mini-Compact Range has very quickly become an indispensible part of our ability to keep up with our antenna test needs. They (the technicians) already wonder how they ever got along without it."

Microwave Vision Group,
ORBIT/FR,
Horsham, PA,
(215) 674-5100,
www.microwavevision.com.

Adapters

East Coast Microwave Distributors has launched a new website to locate nearly every RF/microwave coax adapter. The website allows you to choose from a wide range of manufacturer's adapters, by separating commercial-grade adapters from Mil-Grade ones. All roads lead to ADAPTER CITY!

East Coast Microwave
70 Tower Office Park
Woburn, MA 01801

www.adaptercity.com

Cellular Design and Test Equipment

VENDORVIEW

Agilent Technologies has launched a new high speed cellular matrix web page, which shows Agilent's complete cellular design and test equipment offerings for development, verification manufacturing and installation. Gain greater insight into cellular design and test solutions with the new 24/7 Agilent high speed cellular matrix page, www.agilent.com/find/cellular.

Agilent Technologies
5301 Stevens Creek Blvd.
Santa Clara, CA 95051

www.agilent.com

AR's Orange Book of Knowledge

VENDORVIEW

AR's fourth edition of The Orange Book of Knowledge is now available to download from its website. The book contains articles and application notes on a wide range of topics and applications, including a reference guide for coaxial connectors and cables and harmonic measurement for IEC 61000-4-3. Download a copy or request one from your local sales associate.

AR RF/Microwave Instrumentation
160 School House Road
Souderton, PA 18964

www.arworld.us

Oscillators and Frequency Synthesizers

EM Research Inc. has unveiled a new website design, marking the company's 20th year in business. The new website features a fresh, sophisticated look and provides customers with the ability to sort and customize individual products to meet their specific requirements. One of the more exciting additions to the new website is the ability to search for a specific product based on the frequency and package type of interest, rather than a list of products.

EM Research Inc.
1301 Corporate Blvd.
Reno, NV 89502

www.emresearch.com

ICs, Modules, Subsystems and Instrumentation

VENDORVIEW

Hittite's website includes a dynamic homepage featuring full specifications for more than 925 products across 31 product lines, press releases and featured articles. Comprehensive product "Splash Pages" containing in-depth product information and technical content are located on one easy-to-navigate page. Engineers will find improved product support and streamlined quality & reliability pages containing invaluable reference materials.

Hittite Microwave Corp.
20 Alpha Road, Chelmsford, MA 01824

www.hittite.com

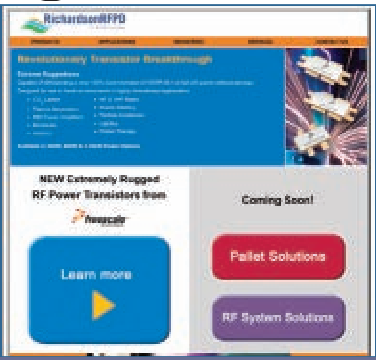
Filters, Diplexers and Sub-assemblies

VENDORVIEW

Reactel Inc. has revamped its website by offering a new look and much more information. Accessing information or issuing an RFQ for the company's products has never been easier, and is now just a click away. Reactel's full line of RF and microwave filters, multiplexers and multifunction assemblies catalog is available for download in support of its worldwide customer base.

Reactel Inc.
8031 Cessna Avenue
Gaithersburg, MD 20879

www.reactel.com



Microsite for Design Engineers

Richardson RFPD Inc. announced the launch of a new "microsite" to help design engineers incorporate Freescale's rugged 50 V LDMOS technology into either new or existing designs. The microsite contains a broad array of technical support material, such as white papers, reference designs, and links to ADS/AWR models. Please visit the new microsite at www.rell.com/ruggedldmos.

Richardson RFPD Inc.
40W267 Keslinger Road
LaFox, IL 60147

www.richardsonrfpd.com

Cable Assemblies and Interconnects

TRU Corp., a leading provider of RF and microwave cable assemblies and interconnects, announced the release of a new updated website. The new website provides fresh perspective on the company's product breadth and extensive support available to its customers. Navigation has been simplified and electronic requests for quotations, literature or technical support have been enhanced through the company's "TRU-Response" features on the homepage.

TRU Corp.
245 Lynnfield Street
Peabody, MA 01960

www.trucorporation.com

Amplifiers and Frequency Multipliers

Wright Technologies has updated its website. There are many new standard microwave amplifiers and frequency multipliers available that operate from 0.1 up to 96.0 GHz. The 2011 website update serves to illustrate the company's current capability, and dedication to manufacturing quality and reliable microwave products for the commercial and military markets. A majority of products ship in three to five weeks ARO.

Wright Technologies Inc.
1352 Blue Oaks Blvd., Suite 140
Roseville, CA 95678

www.wrighttec.com

Components

Millimeter-wave Balanced Mixers

Ducommun Technologies offers balanced mixers that are available in six waveguide bands to cover the frequency spectrum from 26.5 to 110 GHz. These mixers employ high power performance GaAs Schottky beam-lead diodes and balanced configuration to produce superior performance and a moderate LO pumping level. The mixers are designed for full RF waveguide band operation with extremely wide IF bandwidth. Typical conversion loss for these mixers is 5 to 10 dB. Ducommun mixers can be used for test equipment, communication systems and radar receivers where frequency down conversion is required.

Ducommun Technologies,
Carson, CA (310) 847-2859,
www.ducommun.com.

Narrow Band Width UHF Filter

EWT-11-0652 is a narrow bandwidth cavity filter with a passband from 460-465 MHz. Insertion loss over the passband is <1.5 dB and has >55 dB rejection at 455 MHz. VSWR over the passband is 1.5:1. This unit is designed to withstand 100 W CW. Supplied with SMA Female connectors, however other connector options are available. The overall size is 5.15"L × 4.00"W × 4.00"H.

Eastern Wireless TeleComm Inc.,
Salisbury, MD (410) 749-3800,
www.ewtfilters.com.

Tri-band Frequency PPLs

VENDORVIEW

The HMC837LP6CE and HMC840LP6CE include a wideband, low noise VCO with auto-calibration subsystem, low noise PFD and dividers, and a precision charge-pump. The HMC837LP6CE and HMC840LP6CE feature exact frequency mode operation, deliver exceptional phase noise and industry-leading spurious performance while consuming only 630 mW. Level of phase noise performance: -227 dBc/Hz Figure-Of-Merit (FOM) in fractional-N mode and -230 dBc/Hz FOM in integer-N mode. The integrated double-sideband phase noise for these products is lower than -50 dBc. The RMS jitter is less than 180 fs. Both the HMC837LP6CE and the HMC840LP6CE are housed in 6 × 6 mm plastic leadless surface-mount packages and provide excellent temperature stability from -40° to +85°C.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

Microwave Power Module

L-3 Electron Devices announced its new M1291 high power density Microwave Power Module (MPM). The M1291 is capable of producing 110 W of saturated RF output power at 33 percent efficiency over the 30 to 31 GHz frequency band and operates from 270 VDC prime power. A pre-distortion linearizer allows the M1291 MPM to provide 50 W of MIL-STD-188-164 linear power with excellent spurious performance at -60 dBc. Advanced packaging techniques provide an ultracompact 9" × 8" × 2.75" form factor, which features an integrated heatsink and is available with forced air cooling for airborne operation in the -55° to +85°C temperature range.

L-3 Electron Devices,
San Carlos, CA (650) 486-5585,
www.l-3com.com.

RF Switch Box

VENDORVIEW

Mini-Circuits' USB-4SPDT-A18 is a general purpose USB controlled RF switch box containing four electro-mechanical SPDT, absorptive failsafe RF switches constructed in break-before-make configuration and powered by +24 VDC with a switching time of 25 mSec typical. The four switches can be set up as: four independent SPDT switches, two SP3T switches, one SP4T switch and a SPDT switch, a single SP5T switch, or other configurations. The RF switches operate over a wide frequency band from DC to 18 GHz, have low insertion loss (0.2 dB typical) and high isolation (85 dB typical) making the switch box perfectly suitable for a wide variety of RF applications. The USB-4SPDT-A18 is constructed in a plastic case (size: 4.26" × 6.08" × 2.25") with 12 SMA(F) connectors (IN, J1, J2 for each switch), a 2.1 mm DC socket, and a USB type B port.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

Two-way Power Divider

VENDORVIEW

Narda, an L-3 communications company, introduced the model 4372-2, a two-way power divider that operates from 800 to 2500 MHz and is an excellent choice for a broad array of applications, including commercial wireless and defense systems. The model 4372-2 has an amplitude balance of 0.2 dB or less, phase balance of 3 deg. or better, insertion loss of 0.4 dB or less, isolation of at least 22 dB, and VSWR of no more than 1.35:1. The power divider can handle an RF input power of 30 W, has SMA female connectors, and measures 3.1" × 1.6" × 0.5". The model 4372-2 is in stock and available for immediate delivery.

Narda Microwave-East,
Hauppauge, NY
(631) 231-1700,
www.nardamicrowave.com/east.

18 GHz Cavity Filter

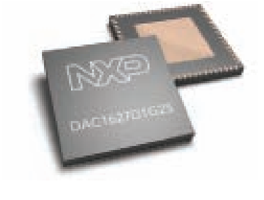
VENDORVIEW

NIC introduces a Ku-band Cavity bandpass filter designed for use in airborne, ship-mount and vehicle-mount applications in harsh military environments. This filter offers low insertion loss of < 1 dB and high selectivity in a small package size of approximately 1.4" × 0.5" × 0.35". These filters can be custom designed for center frequencies up to 20 GHz and 3 dB bandwidth from 1 to 50 percent. Custom designs are available up to K-band.

Networks International Corp.,
Overland Park, KS
(913) 685-3400,
www.nickc.com.

RF Digital-to-analog Converter

The DAC1627D is a 16-bit dual-channel LVDS DDR interface digital-to-analog converter (DAC) that supports output update rates of up to 1.25 Gsps. It is claimed to offer best-in-class single tone SFDR performance and two-tone intermodulation distortion over a broad output bandwidth of 200 MHz. Developed primarily for wireless infrastructure applications, the DAC1627D1G25 is fully compliant with the multi-carrier GSM spectral mask and the LTE and LTE-Advanced transmit specification, making it suitable for multi-standard radio base stations.



NXP Semiconductors,
Eindhoven, The Netherlands
+44 795 828 7483,
www.nxp.com.

Solid-state Switch

VENDORVIEW

PMI model no. P16T-0R5G18G-60-T-SFF is an absorptive, solid-state switch that covers the 500 MHz to 18 GHz frequency range. This model offers a low insertion loss of 6.5 dB typical and 7.5 dB maximum, very high

New Products

isolation of 70 dB typical and 60 dB minimum and a switching speed of 100 nsec maximum. This switch is supplied in a compact package and designed for commercial and military applications.
Planar Monolithics Industries Inc., Frederick, MD (301) 662-5019, www.pmi-rf.com.

Directional Coupler

Pulsar model CS20-53- 436-13 is a new 20 dB coupler covering the frequency range of 1 to 40 GHz with 1.6 dB insertion loss. Directivity is greater than 10 dB and flatness is ±0.6 dB, 1 to 20 GHz and ±1.5 dB, 1 to 40 GHz. The VSWR is 1.80:1 maximum and the unit can handle 20 W into a 1.20:1 load. Connectors are 2.92 mm female.
Pulsar Microwave Corp., Clifton, NJ (973) 779-6262, www.pulsarmicrowave.com.

High Power, Low Pass Filters

RLC Electronics is re-introducing another new product to its filter line. The cut-off frequency for the newest filter has been extended to 4000 MHz. The line of high power low pass filters are designed for high power systems in the frequency range of 100 to 2000 MHz. Conservatively rated at 500 W under extreme temperature and altitude conditions these filters have low VSWR and approximately $^2/_3$ the loss of the F-80 series. These filters offer the flexibility of choosing your cutoff as well as the number of sections for a truly custom high power low pass product.
RLC Electronics Inc., Mount Kisco, NY (914) 241-1334, www.rlcelectronics.com.

Dual Directional Coupler

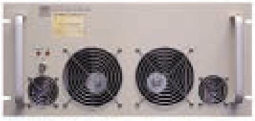
VENDORVIEW

Werlatone continues to set the standard in high power RF components with the model C8858. This small 40 dB dual directional coupler, measures only 2.86" × 1.16" × 0.535". While providing exceptionally low loss, 0.4 dB maximum, it covers a full 10 to 1000 MHz bandwidth and is rated at 250 W CW. This unit is suitable for commercial and/or military applications.
Werlatone Inc., Patterson, NY (845) 278-2220, www.werlatone.com.

Amplifiers

Rack-mount Amplifiers

Models C090105-50 and C090105-53 are X-band high power rack-mount amplifiers operating over the 9 to 10.5 GHz bandwidth. The model C090105-50 amplifier delivers 100 W minimum of output power across the entire bandwidth with greater than 52 dB of small signal gain. The model C090105-53 amplifier delivers 200 W minimum of output power across the entire bandwidth with greater than 52 dB of small signal gain. These amplifiers can be factory tuned to provide 100 or 200 W for adjacent bands including 8.5 to 9.6 GHz and 10.7 to 11.7 GHz. Enclosure size: 19" × 24" × 8.75" panel height.



AML Communications, Santa Clara, CA (408) 727-6666, www.amlj.com.

20 W Solid-state Amplifier

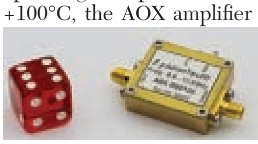
VENDORVIEW

AR's model 20S4G18, a 20 W solid-state amplifier covering 4 to 18 GHz, provides high gain, low noise, good linearity and excellent mismatch capability. The amplifier also delivers superior error vector magnitude performance. With a minimum of 43 dB gain and a typical noise figure of 6 dB, the 20S4G18 offers significant advantages over traveling wave tube amplifiers in this frequency range.
AR RF/Microwave Instrumentation, Souderton, PA (215) 723-8181, www.arworld.us.

Wideband Amplifier Range

VENDORVIEW

Spanning frequencies from 1 to 20 GHz and operating temperatures from cryogenic to +100°C, the AOX amplifier series features 21 different models, each offering one or more octaves of bandwidth. For all the models, the gain is typically in the 26 to 28 dB region with guaranteed minimums of 22 to 25 dB and variation with frequency for some bands of better than ±0.75 dB. Noise figure at +25°C and at 6 GHz is 3 dB and this reduces to around 0.5 dB at temperatures of 4°K. All the amplifiers deliver typically +13 dBm of output power at the 1 dB gain compression point while third order intercepts are up to +28 dBm and input/output VSWR is 2.0:1/2.3:1. Housings for all the amplifiers are 31.5 by 27.5 by 10.0 mm.



AtlanTecRF, Braintree, UK +44 1376 550220, www.atlantecrf.com.

"AB" Linear Amplifier

Comtech PST has announced the release of a solid-state Class "AB" linear amplifier that operates over the full 2500 to 6000 MHz frequency bandwidth and delivers a minimum of 150 W into a 2:1 load VSWR. This high gain amplifier uses the latest GaN technology and is packaged in a standard rack mountable enclosure measur-

ing 19" × 22" × 5.25". The unit has an internal power supply that operates from 100 to 265 VAC, 47 to 400 Hz single phase making it ideal for both laboratory and airborne applications.
Comtech PST,
Melville, NY (631) 777-8900,
www.comtechpst.com.

Low Noise Ka-band Amplifier

VENDORVIEW

MITEQ's new model JS3-18002200-15-10P is a low noise Ka-band amplifier with 1.5 dB maximum noise figure and 26 dB minimum gain in a small hermetically sealed Kovar chassis with field replaceable K-connectors. MIL-883 screening is also available. Different connector options are also available.

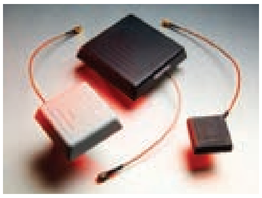
MITEQ Inc.,
Hauppauge, NY (631) 439-9469,
www.miteq.com.

QBS-560 Broadband Amp

Spectrum Microwave now offers a new broadband 800 to 2500 MHz, 25 W design to its family of S.M.A.R.T. power amplifiers with the new QBS-560. This power amp provides 25 W of output power with 2.5 amps of current at 28 VDC. With 39 dB of (Psat) gain, this 21 to 30 VDC unit offers ±1 dB of saturated gain flatness and automatically adjusts the active biasing to enhance efficiency under various load conditions. This advanced push-pull design incorporates an integral heatsink and is designed to withstand a 10:1 load mismatch. The QBS-560 broadband amp is for both military and communications applications.
Spectrum Microwave,
Philadelphia, PA (215) 464-4000,
www.spectrummicrowave.com.

Antennas

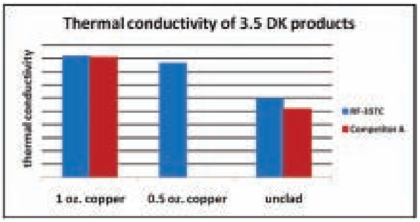
Radome-packaged Antennas



Spectrum Advanced Specialty Products announced its high performance radome antenna assemblies designed for Plug-n-Play use in ISM, Satellite and WiFi applications. These antennas are available in three basic antenna sizes, designed for specific frequency bands. Spectrum's radome-packaged antennas are ideal for medium and high gain applications, and include industry-standard cables such as RG-316 to MMCX or SMA connectors, with other options available.
Spectrum Advanced Specialty Products,
Fairview, PA (888) 267-1195,
www.specemc.com.

Material

Laminates for High Power Applications

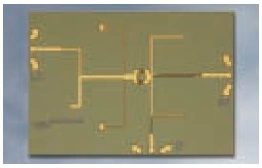


TSM-DS3 is the newest addition to the TSM-DS family of thermally stable, industry-leading low loss cores. This ceramic-filled laminate with low (~5 percent) fiberglass content has a dissipation factor of 0.0011 at 10 GHz and thermal conductivity of 0.65 W/M K. In addition to high power applications, TSM-DS3 was developed to have very low coefficients of thermal expansion for demanding thermal cycling. RF-35TC is suited for high power applications where every 1/10th of a dB is critical and the PWB substrate must diffuse heat away from transmission lines and surface-mount components. The low z axis coefficient of thermal expansion and temperature stable Dk make RF-35TC ideal for narrowband and broadband overlay couplers. RF-35TC has a dissipation factor of 0.0011 at 10 GHz and thermal conductivity of 0.92 W/M K (with 1 oz copper cladding).
Taconic,
Petersburgh, NY (800) 833-1805,
www.taconic-add.com.

Semiconductor/IC

Sub-harmonically Pumped Mixer MMIC

Endwave Corp. has announced the release of a new sub-harmonically pumped mixer (2 × LO) MMIC. Designed and manufactured in co-operation with WIN Semiconductor Corp.'s 0.1 µm PHEMT process development, model EWM9002ZZ offers a broadband frequency performance of 67 to 97 GHz with LO to RF isolation of over 30 dB and a conversion loss of 12 dB. The device, which can be used both as an upconverter or downconverter, also delivers RF return loss at better than 10 dB, LO drive level of +15 dBm, and is highly repeatable. Each die is visually inspected to MIL-STD-2010. The mechanical measurements of the die are 1.815 × 1.295 × 0.05 mm. Bare die prices at 1000 pieces are $45. Delivery is available directly from Endwave.



Endwave Corp.,
San Jose, CA (617) 803-9791,
www.endwave.com.

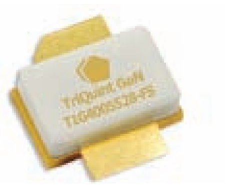
RF Power Transistor

VENDORVIEW

TriQuint announced a new packaged GaN discrete RF power transistor, the T1G4005528-FS. It offers more than 55 W of compressed output power and greater than 50 percent efficiency optimized

New Products

for the 3.1 to 3.5 GHz band. The new T1G4005528-FS is ideal for narrow and wide-band applications, offering exceptional performance from DC to 3.5 GHz. The T1G4005528-FS offers >14 dB of linear gain at 3.3 GHz and operates at 28 V; it is available in an earless ceramic package. Power, gain, and efficiency can be optimized for a particular application with simple matching networks external to the device. Applications for the T1G4005528-FS include military and civilian radar, professional and military radio communications systems, test instrumentation, avionics and wideband or narrowband amplifiers. Samples will be available in the third quarter.

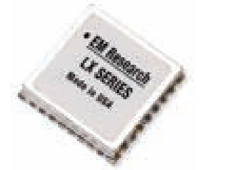


TriQuint Semiconductor,
Hillsboro, OR
(503) 615-9000,
www.triquint.com.

Sources

VSAT Frequency Synthesizer

The LX-1750 from EM Research is a cost-effective frequency synthesizer operating in the VSAT Block II IF frequency band from 950 to 1750 MHz housed in a miniature surface-mount package (0.75" square). The unit features 500 KHz step size, +7 dBm output power and +5 VDC supply voltage with extremely low power consumption (<60 mA). Locked to an external 10 MHz reference, the LX-1750 exhibits extremely low phase noise (<-100 dBc/Hz at 100 KHz). LX units are available from 50 to 6000 MHz as fixed frequency up to octave bandwidths. Custom units feature external references from 5 to 125 MHz or optional internal references, select supply voltages (+3, +3.3 or +5 VDC), 10 KHz to 10 MHz step sizes and optional wide operating temperature range (-40° to +85°C).



EM Research Inc.,
Reno, NV
(775) 345-2411,
www.emresearch.com.

Fully Integrated TCXOs

Rakon's fully integrated RTX-A TCXOs offer typical phase noise of -154 dBc/Hz at 100 kHz offset for a 50 MHz TCXO. The RTX7050A

(7.0 × 5.0 mm) and RTX5032A (5.0 × 3.2 mm) employ an analogue IC for both the oscillator and temperature compensation. Frequencies are available from 5 to 52 MHz. With exceptional frequency stability down to ±0.1 ppm, the RTX-A series is available over a wide temperature range of -40° to +85°C. Choose the RTX7050A or the RTX5032A when low phase noise is critical for your next requirement. These TCXOs are suitable for use in microwave communications.

Rakon Ltd.,
Auckland, New Zealand
+64 9 571 9216,
www.rakon.com.

Voltage-controlled Oscillator

Z-Communications Inc. announced a new RoHS compliant VCO model CRO2912A-LF in S-band. The CRO2912A-LF operates at 2875 to 2950 MHz with a tuning voltage range of 1 to 18 VDC. This VCO features a typical phase noise of -113 dBc/Hz at 10 KHz offset and a typical tuning sensitivity of 9 MHz/V. The CRO2912A-LF is designed to deliver a typical output power of 0.5 dBm at 8 VDC supply while drawing 25 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -15 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".

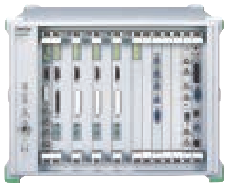
Z-Communications Inc.,
Poway, CA (858)
621-2700,
www.zcomm.com.

Test Equipment

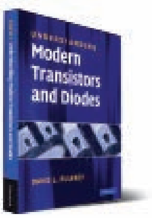
Testing For W-CDMA/GSM Devices

VENDORVIEW

The MX848001E-17 Simultaneous 64QAM/MIMO option enables the MD8480c Signaling tester to conduct protocol-based testing on new W-CDMA/GSM wireless devices that incorporate this feature. Simultaneous 64QAM/MIMO offers network operators and consumers 42 MB/s download speeds similar to DC-HSDPA, with the advantage that spectrum is conserved through use of a single 5 MHz channel rather than the two channels required for DC-HSDPA. With this option, the MD8480C now supports all W-CDMA data rates, from 12.2 kB/s voice calls to 42 MB/s data calls, including new category 17, 18, 19 and 20. The MD8480C is available in a range of configurations starting at $109,290, and the MX848001E-17 software option can be easily added to MD8480Cs with E-version base station cards. Upgrades to MD8480C testers with C-version base station cards and the MD8480B signaling tester are available.



Anritsu Co.,
Richardson, TX
(972) 644-1777,
www.anritsu.com.



Understanding Modern Transistors and Diodes

David L. Pulfrey

From GaAs HBTs in cell phones to Si MOSFETs in computers to base stations with LDMOS transistors, *Understanding Modern Transistors and Diodes* covers the various major semiconductor technologies used in modern electronics. The purpose of this book is to provide a rigorous and digestible theoretical basis from which the understanding of devices of the modern era and of the near future follows naturally. To understand the operation of all these devices and to provide the knowledge base that will enable the reader to understand and even design devices, a solid, physical understanding of semiconductors must be attained. The first part of this book is devoted to this with an emphasis on Quantum Mechanics, as this branch of physics is needed increasingly to understand transistors as they move from the micro- to the nano-realm, and also to understand interactions between electrons and holes and photons in optoelectronic diodes.

After covering the basics, the book moves onto devices focusing on solar cells, LEDs, HBTs, MOSFETs, HJFETs and CMOS. It also covers various applications of transistors for high frequency, memory, high power and low noise. Finally, it covers future technologies with a brief look at cylindrical nanotransistors.

This book is intended for students at the graduate or senior-undergraduate level who are studying electronics, microelectronics or nanoelectronics within the disciplines of electrical and computer engineering, engineering physics or physics. There is sufficient material on basic semiconductor theory and elementary device physics for the book to be appropriate also for a junior-level course on solid-state electronic devices. Additionally, the book contains materials of interest to practitioners and managers in the semiconductor industry. This book is a good single source on device physics and applications for several levels of courses on semiconductor devices as well as practicing industry professionals.

To order this book, contact:

Cambridge University Press
32 Avenue of the Americas,
New York, NY 10013-2473
(212) 924-3900
www.cambridge.org/us
335 pages; $64 (eBook), £45
ISBN: 978-0-52151-460-6

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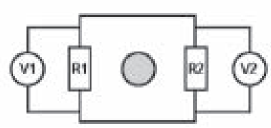
MATH, SCIENCE AND LOGIC PUZZLES FOR THE 'ENGINERD' IN ALL OF US

(RE-PRINTED WITH PERMISSION FROM PZZLS - WWW.PZZLS.COM)

VOLTAGE VOODOO



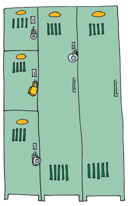
In the figure, an electrical circuit is drawn. In the middle of the circuit, an infinitely long metal bar is placed (indicated with the gray circle). In this bar, an oscillating magnetic field is induced by a coil, which is attached somewhere to the bar. Two resistors are located in the circuit with values R1 and R2. The alternating voltages, V1 and V2, are being measured with two perfect alternating voltages meters.

What is the relation between the two voltages, V1 and V2?

a) V1 : V2 = R2 : R1
b) V1 : V2 = 1 : 1
c) V1 : V2 = R1 : R2
d) V1 = V2 = 0
e) none of the above

LOCKERS

A high school has a strange principal. On the first day, he has his students perform an odd opening day ceremony:



There are one thousand lockers and one thousand students in the school. The principal asks the first student to go to every locker and open it. Then he has the second student go to every second locker and close it. The third goes to every third locker and, if it is closed, he opens it, and if it is open, he closes it. The fourth student does this to every fourth locker, and so on. After the process is completed with the thousandth student, how many lockers are open?

EINSTEIN'S RIDDLE

There are five houses in five different colors. In each house lives a person with a different nationality. The five owners drink a certain type of beverage, smoke a certain brand of cigar, and keep a certain pet. No owners have the same pet, smoke the same brand of cigar, or drink the same beverage.

Somebody owns a fish. The question is: Who?

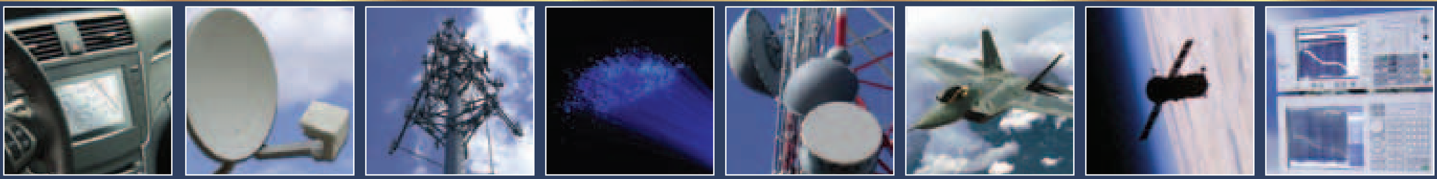
Hints

- The Brit lives in the red house.
- The Swede keeps dogs as pets.
- The Dane drinks tea.
- The green house is on the left and next to the white house.
- The green homeowner drinks coffee.
- The person who smokes Pall Mall rears birds.
- The owner of the yellow house smokes Dunhill.
- The man living in the center house drinks milk.
- The Norwegian lives in the first house.
- The man who smokes Blends lives next to the one who keeps cats.
- The man who keeps the horse lives next to the man who smokes Dunhill.
- The owner who smokes Bluemaster drinks beer.
- The German smokes Prince.
- The Norwegian lives next to the blue house.
- The man who smokes Blends has a neighbor who drinks water.

ANSWERS AVAILABLE ONLINE AT WWW.MWJOURNAL.COM

Product Selection Guide

Analog, Digital & Mixed-Signal ICs, Modules, Subsystems & Instrumentation, DC - 110 GHz



Automotive
Telematics & Sensors

Broadband
Cable Modem, CATV, DBS & VoIP
WiMAX, WiBro, WLAN & UWB

Cellular Infrastructure
GSM, GPRS, CDMA, TD-SCDMA,
WCDMA, UMTS & 4G/LTE

Fiber Optics & Networking
OC-48 to 100G

Microwave & mmWave Communications
Backhaul Radio Links
Multi-Pt Radios & VSAT

Military
C³I, ECM & EW

Space
Payload Electronics

Test & Measurement
Commercial & Industrial Sensors
Test Equipment

Hittite
MICROWAVE CORPORATION

June 2011

REF# SG-0611

Table Of Contents

Hittite Microwave Corporation is pleased to introduce our June 2011 Product Selection Guide summarizing over 925 products including 17 new products. This selection guide organizes Hittite's portfolio by product line as well as by market applications. Full specifications for each product are available at www.hittite.com. Click on "My Subscription" to receive the latest product releases.

Hittite MICROWAVE CORPORATION

How to Buy:

Hittite Microwave Corporation offers many convenient ways to order products and/or receive pricing and delivery information. Our order entry/MRP system assures customer sample requests and orders will be entered quickly, tracked easily, and completed accurately on-time.

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- **HMC Field Sales Offices:**
  You may contact our corporate or field sales offices listed on the back cover for assistance in purchasing Hittite products.

- **Purchase On-line: www.hittite.com**
  With Hittite Microwave's E-Commerce capability customers can enjoy the convenience of on-line ordering via a secure shopping cart interface. Products can be purchased using either a MasterCard, Visa, American Express or JCB card. Orders are confirmed within one business day with delivery information. Orders ship within 2 business days of confirmation, based on availability.

- **Purchase Orders via HMC Corporate Sales:**
  You may contact Hittite Microwave directly at (978) 250-3343. Purchase orders can be faxed to (978) 250-3373 or sent via email to sales@hittite.com. There is a minimum purchase order value of $500.00 (U.S. Dollars).

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You may purchase our products through our network of manufacturer representatives.

- ***European customers may also purchase products in Euros (€) directly from Hittite Microwave Deutschland GmbH.***
- ***Japanese customers may also purchase products in Yen (¥) directly from Hittite KK - Japan.***

Our Quality Policy:

Hittite Microwave Corporation is Committed to:

- *Being a supplier of products of the highest quality.*
- *Advancing state-of-the-art technology to support our products.*
- *Enhancing our competitive position with superior products.*

Hittite's Quality Policy Recognizes Responsibilities for Every Individual to:

- *Take the initiative to promote quality.*
- *Create an environment where the highest quality standards are maintained.*
- *Participate in continuous improvement practices.*

Quality & Product Support:

The Quality & Product Support Section of Our Web Site Includes:

- *Quality Assurance - Product manufacturing, qualification & screening flows.*
- *Product Reliability*
- *Qualification Test Reports*

Product Application Support

- *Application Engineering Support*
- *Application Notes*
- *Mixer Spur Chart Calculator, Parametric Search & PLL Phase Noise Calculator*
- *Package & Layout Drawings - Product outline, PCB land pattern and tape & reel drawings.*
- *Published Papers*
- *S-Parameter Files*

Data Sheets

- *Complete product data sheets can be found on our web site.*

HMC is ISO 9001:2000 and AS9100 certified. Every component is backed by every Hittite employee and subcontractor's commitment to total quality, thus providing our customers with products that meet or exceed all requirements, are delivered on-time and function reliably throughout their useful life.

What We Do

Hittite Microwave Corporation is an innovative designer and manufacturer of high performance integrated circuits (ICs), modules, subsystems and instrumentation for technically demanding digital, RF, microwave and millimeterwave applications covering DC to 110 GHz. The Company's standard and custom products apply analog, digital and mixed-signal semiconductor technologies, which are used in a wide variety of wireless / wired communication and sensor applications for Automotive, Broadband, Cellular Infrastructure, Fiber Optics & Networking, Microwave & Millimeter-wave Communications, Military, Test & Measurement, and Space markets. We offer over 925 products across 31 product lines.

Amplifiers	*Mixers*
Attenuators	*Mods. & Demodulators*
Broadband Time Delays	*Mux & Demux*
Comparators	*Passives*
Crosspoint Switch	*Phase Shifters*
Data Converters	*PLLs*
DC Power Conditioning	*PLLs with Integrated VCOs*
DC Power Management	*Power Detectors*
DROs	*Sensors*
Filters - Tunable	*SDLVAs*
Freq. Dividers & Detectors	*Signal Generators*
Freq. Multipliers	*Switches*
High Speed Digital Logic	*Transimpedance Amplifiers*
Limiting Amplifiers	*VGAs*
Interface	*VCOs & PLOs*
IF Signal Processing	

We design and supply custom ICs, modules, subsystems and instrumentation, combining multiple functions for specific requirements. We select the most appropriate semiconductor and package technologies, uniquely balancing digital and analog integration techniques.

Our custom and standard products support a wide range of wireless / wired communications & radar applications for the following markets:

Automotive
Telematics & Sensors

Broadband
CATV, DBS, WiBro,WiMAX, WLAN,
Fixed Wireless & UWB

Cellular Infrastructure
GSM, GPRS, CDMA, WCDMA,
UMTS, TD-SCDMA & 4G/LTE

Fiber Optic & Networking
OC-48 to 100G

Microwave & mmWave Communications
Backhaul Radio Links
Multi-Pt Radios & VSAT

Military
C^3I, ECM & EW

Space
Payload Electronics

Test & Measurement
Commercial / Industrial
Sensors & Test Equipment

AMPLIFIERS - Linear & Power

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
12.5 - 15.5	2W Power Amplifier	26	41	-	34	+7V @ 1200mA	LP5G	3A001.b.2.b	HMC995LP5GE

ATTENUATORS - Analog & Digital

Frequency (GHz)	Function	Insertion Loss (dB)	Attenuation Range (dB)	IIP3 (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
20 - 50	Analog VVA	3	0 to 35	33	0 / +3V	Chip	EAR99	HMC985

DC POWER CONDITIONING - Linear Voltage Regulators

Input Voltage (V)	Function	Output Voltage (V)	Output Current (mA)	Power Supply Rejection Ratio (PSRR) (dB)		Output Noise Spectral Density (nV/√Hz)		Regulated Outputs	Package	ECCN Code	Part Number
				1 kHz	1 MHz	1 kHz	10 kHz				
3.3 to 5.5	Low Noise, High PSRR	1.8 to 5.1	400	60	30	6	3	1	LP3	EAR99	HMC976LP3E

DC POWER MANAGEMENT - Active Bias Controller

Supply Voltage Range (V)	Function	VDRAIN Voltage Range (V)	IDRAIN Bias Current (mA)	IGATE Drive Current (mA)	VGATE Voltage Range (V)	Over / Under IDRAIN Current Alarm	Low VDD Alarm	Package	ECCN Code	Part Number
4 to 12	Active Bias Controller	4 to 12	0 to 200	-0.8 to 0.8	-2.5 to +2.5	-	-	LP3	EAR99	HMC981LP3E

FILTERS - TUNABLE - Band Pass Filter

Frequency Range (GHz)	Function	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	Package	ECCN Code	Part Number
5.9 - 11.2	Band Pass	7.5	6	0.92 x Fcenter	1.08 x Fcenter	200	LP5	EAR99	HMC894LP5E
18.5 - 37.0	Band Pass	10	18	0.81 x Fcenter	1.20 x Fcenter	200	LP4	EAR99	HMC899LP4E

MIXERS - I/Q Downconverters / Receivers

RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Noise Figure (dB)	Image Rejection (dB)	IIP3 (dBm)	Package	ECCN Code	Part Number
20 - 28	I/Q Downconverter / Receiver	DC - 3.5	14	2.5	21	1	LP4	EAR99	HMC977LP4E

MUX / DEMUX

Data/ Clock Rate (Gbps / GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vpk-pk)	DC Power Consumption (mW)	Power Supply (V)	Package	ECCN Code	Part Number
32 / 16	2:1 Mux with Programmable Output Voltage	15 / 15	-	1.25	480	±3.3	LC4B	3A001.a.11.b	HMC954LC4B
32 / 16	1:2 Demux with High Speed Invert & Programmable Output Voltage	19 / 18	<3	1.00	644	±3.3	LC4B	3A001.a.11.b	HMC955LC4B

PHASE SHIFTERS - Analog

Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	2nd Harmonic Pin = -10 dBm (dBc)	IIP3 (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
2 - 20	Analog	4	270° @ 2 GHz 180° @ 20 GHz	-45	30	0.5 to +11V	LP5	EAR99	HMC935LP5E

PHASE LOCKED LOOP - Fractional-N

Frequency (GHz)	Function	Max. PFD Frequency	Max. Reference Frequency	Figure of Merit (Frac/Int) (dBc/Hz)	Frequency Resolution with 50 MHz Ref.	Bias Supply	Package	ECCN Code	Part Number
DC - 8 GHz	Fractional-N with Sweeper	100 MHz	350 MHz	-230 / -233	3 Hz	+5V @ 6mA +3.3V @ 52mA	LP4	3A001.a.11.b	HMC703LP4E

PLLs with INTEGRATED VCOs - Microwave & RF PLLs with Integrated VCOs

Frequency (MHz)	Function	Closed Loop SSB Phase Noise @ 10 kHz Offset	Open Loop VCO Phase Noise @ 1 MHz Offset	Pout (dBm)	RMS Jitter Fractional Mode (fs)	Integrated PN Fractional Mode (deg rms)	Package	ECCN Code	Part Number
2fo									
9600 - 10800	Microwave VCO	-100 dBc/Hz	-135 dBc/Hz	9	185	0.7	LP6C	3A001.a.11.b	HMC778LP6CE
Wideband Continuous Tuning									
25 - 3000	Wideband RF VCO	-114 dBc/Hz @ 2 GHz Fract Mode	-141 dBc/Hz @ 2 GHz	5	180	0.13	LP6G	3A001.a.11.b	HMC830LP6GE

POWER DETECTORS - RMS Detector

Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV / dB)	RF Threshold Level (dBm)	Bias Supply	Package	ECCN Code	Part Number
DC - 3.9	Dual RMS, Single-Ended	70 ±1	38.5	-66	+5V @ 143mA	LP5	EAR99	HMC1030LP5E

SIGNAL GENERATORS - *Precise RF Signal Generation for ATE & Lab Environments*

Frequency (GHz)	Function	Frequency Resolution	Maximum Power Output (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Spurious (dBc)	Switching Speed @ 100 MHz Steps (µs)	Package	ECCN Code	Part Number
0.01 - 70	Signal Generator	1 Hz	+28 @ 1 GHz +2 @ 70 GHz	-118 @ 1 GHz -80 @ 70 GHz	< -60 Below 10 GHz < -65 @ 70 GHz	300	Rackmountable / Benchtop	3A002.d.3.e	HMC-T2270

VARIABLE GAIN AMPLIFIERS - *Digital*

Frequency (GHz)	Function	Gain Control Range (dB)	NF * (dB)	OIP3 * (dBm)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
0.5 - 4.0	6-Bit Digital, Serial, Parallel Control or Latched Parallel Control	-19 to +12.5	4	39	21.5	+5V @ 150mA	LP5	EAR99	HMC742HFLP5E
0.5 - 6.0	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	LP5	EAR99	HMC625HFLP5E

** Maximum Gain State*

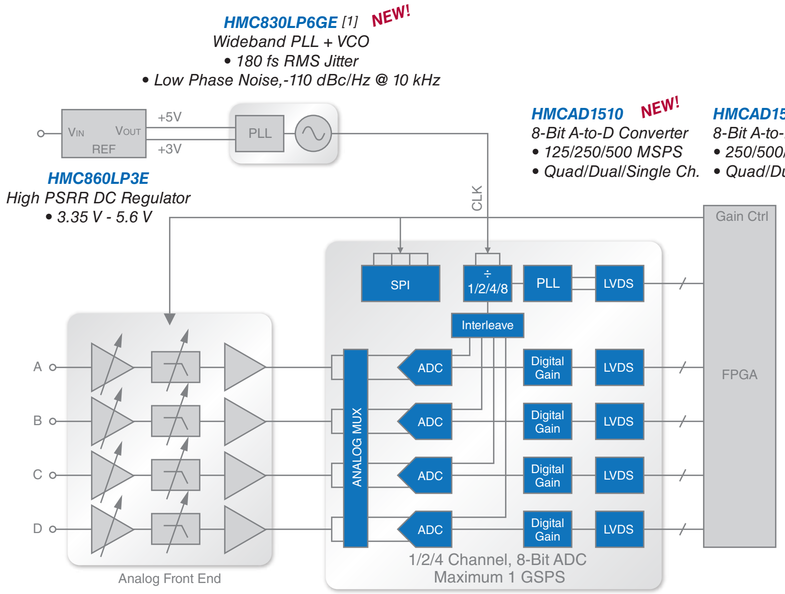
Low Power Multi-Channel Analog-to-Digital Converter!

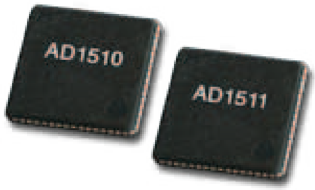
NEW!

Features

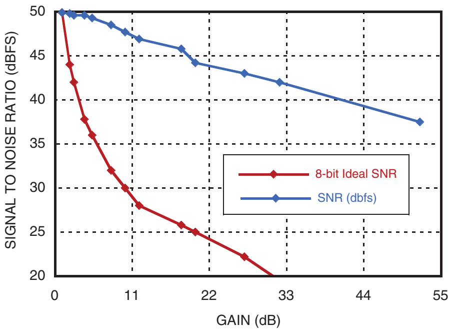
- ***Sampling Rates: 250 to 1000 MSPS***
- ***Resolution: 8 bits***
- ***CMOS & LVDS Outputs***
- ***Configurable Power Consumption & Functionality with SPI Settings***
- ***Integrated Instrumentation Functionality***

Digital Oscilloscopes Featuring the HMCAD1510 & HMCAD1511





SNR with Digital Gain Compared with Traditional Ideal 8-Bit Converter



Offers Lowest Power Consumption for Best SNR!

Tunable Band Pass Filters Cover 5.9 to 37 GHz!

NEW!

Features

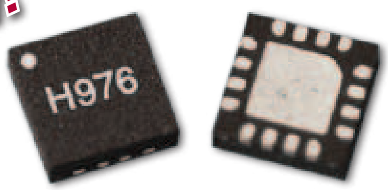
- ***Fast Tuning Response: 200 ns***
- ***Excellent Wideband Rejection***
- ***User Selectable Passband Frequency***
- ***Single Chip, Solid State Replacement for Mechanically Tuned & Switched Bank Filters***

Frequency Range (GHz)	Function	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	ECCN Code	Part Number
5.9 - 11.2	Band Pass	7.5	6	0.92 x Fcenter	1.08 x Fcenter	200	EAR99	**HMC894LP5E**
18.5 - 37.0	Band Pass	10	18	0.81 x Fcenter	1.20 x Fcenter	200	EAR99	**HMC899LP4E**

Ideal for Frequency Selection in Multi-Band Synthesizer Systems, Wideband Sensors, and Test & Measurement Equipment!

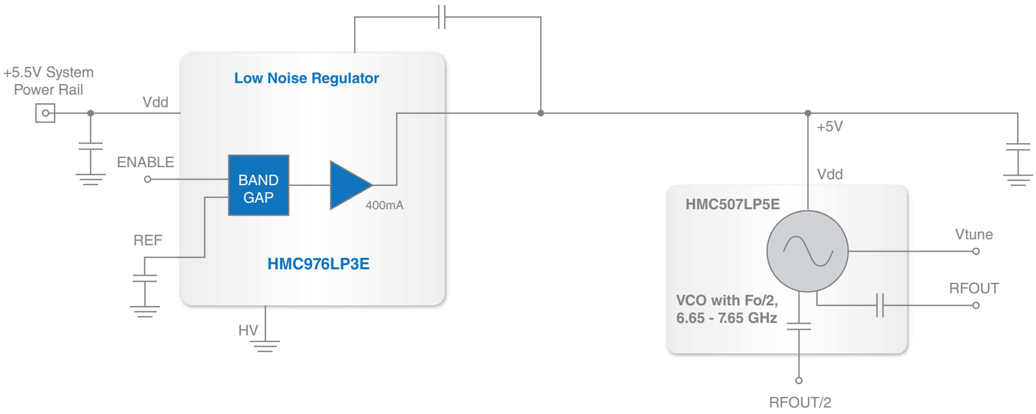
Linear Voltage Regulator Covers 1.8 to 5.1 Volts!

New!



HMC976LP3E

- *Low Noise Spectral Density:*
  3nV/√Hz at 10 kHz, 6nV/√Hz at 1 kHz
- *High PSRR:*
  >60 dB at 1 kHz, >30 dB at 1 MHz
- *Adjustable From 1.8V to 5.1V @ 400mA*

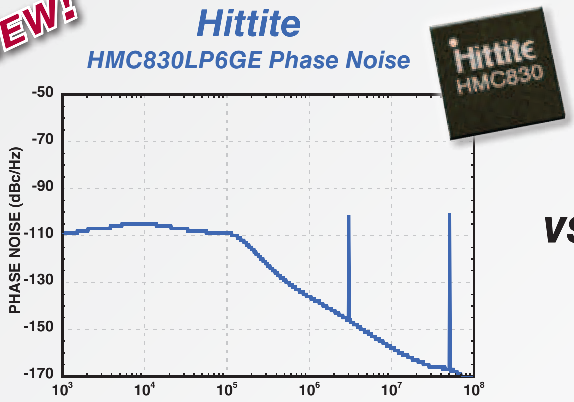


Ideal for Powering Hittite's Broad Line of Frequency Generation Products
Including Our Low Noise PLLs with Integrated VCOs!

Wideband PLL with Integrated VCO Covers 25 MHz to 3000 MHz!

New!

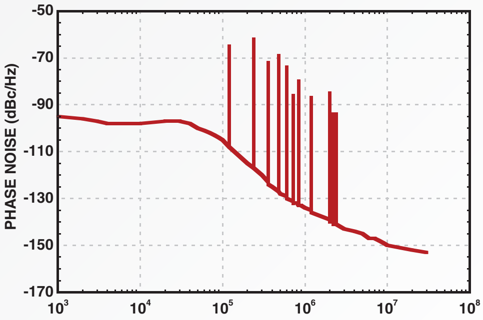
Hittite
HMC830LP6GE Phase Noise



2646.96 MHz, PFD= 50 MHz, Channel Spacing = 240 kHz, Jitter = 144fs

VS.

Typical Competitor
Product Phase Noise

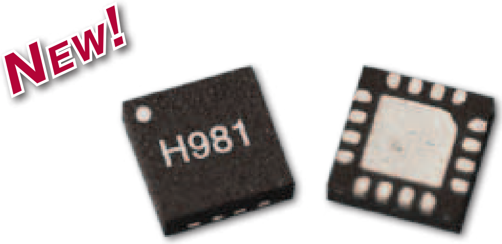


2646.96 MHz, PFD= 25 MHz, Channel Spacing = 240 kHz, Jitter = 310fs

Frequency (MHz)	Application	Closed Loop SSB Phase Noise @ 10 kHz Offset	Open Loop VCO Phase Noise @ 1 MHz Offset	Pout (dBm)	RMS Jitter Fractional Mode (fs)	Integrated PN Fractional Mode (deg rms)	ECCN Code	Part Number
25 - 3000	Wideband RF VCO	-114 dBc/Hz @ 2 GHz Fract Mode	-141 dBc/Hz @ 2 GHz	5	180	0.13	3A001.a.11.b	**HMC830LP6GE**

Ideal for Cellular/4G, Microwave Radio, Industrial / Medical
Test Equipment, Military Communications & Sensors!

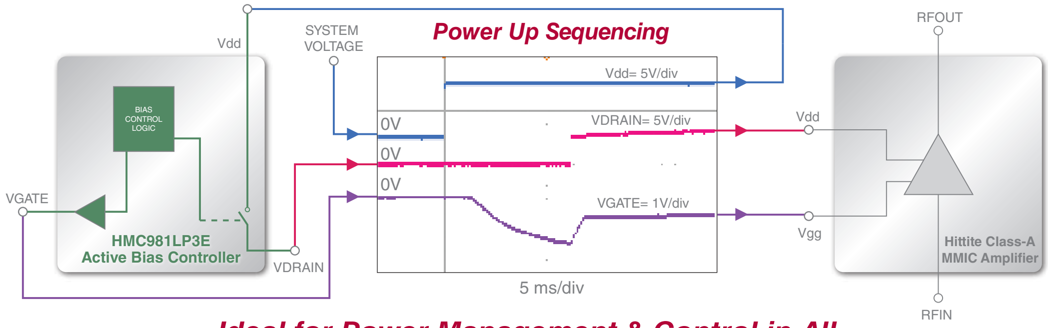
Active Bias Controller Cover 8 to 24 GHz!



Features

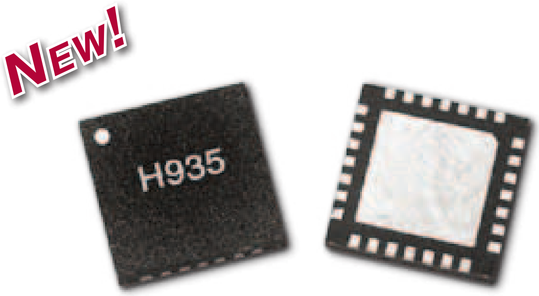
- Integrated Negative Voltage Generator
- Automated Power-up Sequencing
- Active & Adjustable Output Voltages & Currents:
  Drain Voltage: +4.0 to +12 Vdc
  Gate Voltage: -2.5 to +2.5 Vdc
- Stable Bias Current Over Temperature, Process Variation & Aging

Supply Voltage Range (V)	Function	VDRAIN Voltage Range (V)	IDRAIN Bias Current (mA)	IGATE Drive Current (mA)	VGATE Voltage Range (V)	Over / Under IDRAIN Current Alarm	Low VDD Alarm	ECCN Code	Part Number
4 to 12	Active Bias Controller	4 to 12	0 to 200	-0.8 to +0.8	-2.5 to +2.5	-	-	EAR99	**HMC981LP3E**



Ideal for Power Management & Control in All RF, Microwave, Millimeterwave & Fiber Optic Applications

Analog Phase Shifter Cover 2 to 20 GHz!



Features

- Low RMS Phase Error: as Low as 1.2°
- Low Insertion Loss as Low as 4 dB
- High Linearity: +30 dBm Input IP3
- Positive Control: 0.5V to +11V
- Die & SMT Versions Available From Stock

Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	2nd Harmonic Pin = -10 dBm (dBc)	IIP3 (dBm)	Control Input (Vdc)	ECCN Code	Part Number
2 - 20	Analog	4	270 @ 2 GHz 180 @ 20 GHz	-45	30	0.5 to +11V	EAR99	**HMC935LP5E**

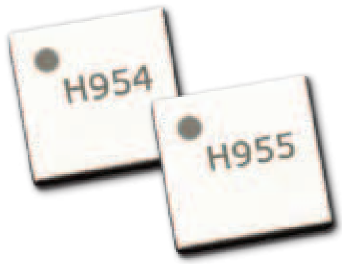
Ideal for Beamforming & Error Correction Applications to 20 GHz!

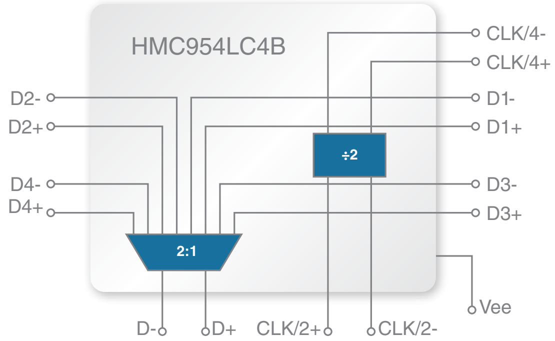
Hittite MICROWAVE CORPORATION

Multiplexer & RMS Power Detector ICs

New Multiplexer ICs for 32 Gbps Data Serialization!

NEW!





Features

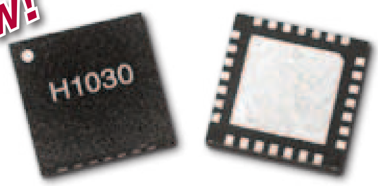
- ♦ *Differential & Single-Ended Operation*
- ♦ *1/2 Rate Clock Input & 1/4 Rate Ref. Clock Output*
- ♦ *Fast Rise and Fall Times: 16 ps*
- ♦ *Low Power Consumption: 510 mW typ.*
- ♦ *Programmable Differential Output Voltage Swing*

Data/ Clock Rate (Gbps / GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vpk-pk)	DC Power Consumption (mW)	Power Supply (V)	ECCN Code	Part Number
32 / 16	2:1 Mux with Programmable Output Voltage	15 / 15	-	1.25	480	±3.3	3A001.a.11.b	**HMC954LC4B**
32 / 16	1:2 Demux with High Speed Invert & Programmable Output Voltage	19 / 18	<3	1.00	644	±3.3	3A001.a.11.b	**HMC955LC4B**

Ideal for SONET OC-192, Broadband Test & Measurement, Serial Data Transmission & FPGA Interfacing Applications!

New Dual Single-Ended RMS Detector Span 70 dB Dynamic Range!

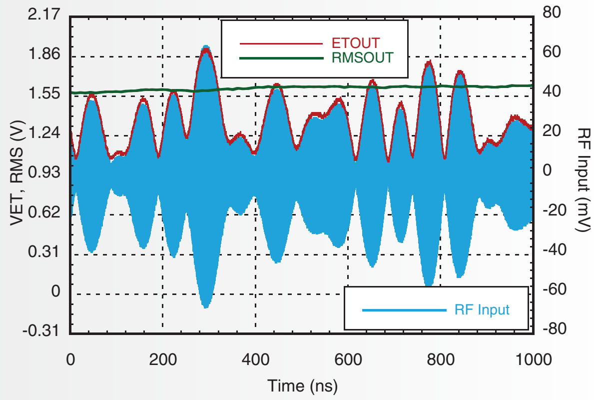
NEW!



Dual Channel Wireless Infrastructure Radio

- ♦ *Crest Factor (Peak-to-Average Power Ratio) Measurement*
- ♦ *±1 dB Detection Accuracy to 3.9 GHz*
- ♦ *Input Dynamic Range: -55 dBm to +15 dBm*
- ♦ *RF Signal Wave Shape & Crest Factor Independent*

HMC1030LP5E RMS & Envelope Response to WCDMA 4 Carrier; -20dBm RF Input @ 0.9 GHz



Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV / dB)	RF Threshold Level (dBm)	Bias Supply	ECCN Code	Part Number
DC - 3.9	Dual RMS, Single-Ended	70 ±1	38.5	-66	+5V @ 143mA	EAR99	**HMC1030LP5E**

Choose From Over 20 Power Detector & SDLVA Products!

AMPLIFIERS

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
Low Noise Amplifiers									
0.175 - 0.66	Low Noise	24	37	0.5	19	+5V @ 90mA	LP3	EAR99	HMC616LP3E
0.23 - 0.66	Low Noise, Dual Channel	22	37	0.5	19	+5V @ 97mA	LP4	EAR99	HMC816LP4E
0.3 - 3.0	Low Noise, High IP3	15	37	1.5	22	+5V @ 90mA	SOT26	EAR99	HMC374E
0.55 - 1.2	Low Noise	16	37	0.5	21	+5V @ 88mA	LP5	EAR99	HMC617LP3E
0.55 - 1.2	Low Noise, Dual Channel	16	37	0.5	20.5	+5V @ 95mA	LP4	EAR99	HMC817LP4E
0.6 - 1.4	Low Noise	32	40	0.9	21.5	+5V @ 254mA	LP4	EAR99	HMC718LP4E
0.7 - 1.2	Low Noise with Failsafe Bypass	16	33	0.9	13	+5V @ 57mA	LP3	EAR99	HMC668LP3E
0.7 - 2.2	Low Noise	22	36	1.7	24	+5V @ 227mA	LP3	EAR99	HMC758LP3E
1 - 11	Low Noise	17	30	1.5	18	+5V @ 55mA	LP4	EAR99	HMC753LP4E [1]
1 - 12	Low Noise	17	28	1.5	19	+5V @ 55mA	Chip	EAR99	HMC-ALH444 [1]
1.2 - 3.0	Low Noise	26	21	1.3	11.5	+5V @ 21mA	LP3	EAR99	HMC548LP3E
1.3 - 2.9	Low Noise	34	39	1	21.5	+5V @ 272mA	LP4	EAR99	HMC719LP4E
1.7 - 2.2	Low Noise	19	36	0.75	20	+5V @ 117mA	LP3	EAR99	HMC618LP3E
1.7 - 2.2	Low Noise with Failsafe Bypass	17	29	1.4	12	+5V @ 86mA	LP3	EAR99	HMC669LP3E
1.7 - 2.2	Low Noise, Dual Channel	20.5	35	0.85	21	+5V @ 112mA	LP4	EAR99	HMC818LP4E
2 - 4	Low Noise	10	36	2.6	21	+6V @ 100mA	Chip	EAR99	HMC594 [1]
2 - 4	Low Noise	10	36	3	21	+6V @ 100mA	LC3B	EAR99	HMC594LC3B [1]
2 - 4	Low Noise	20.5	36	3	21	+6V @ 170mA	Chip	EAR99	HMC609 [1]
2 - 4	Low Noise	20	36.5	3.5	21.5	+6V @ 170mA	LC4	EAR99	HMC609LC4 [1]
2 - 12	Low Noise	15	25	1.8	13	+4V @ 45mA	LC4	EAR99	HMC772LC4 [1]
2.1 - 2.9	Low Noise	19	33	0.9	19	+5V @ 95mA	LP3	EAR99	HMC715LP3E
2.3 - 2.5	Low Noise	19	12	1.7	6	+3V @ 8.5mA	SOT26	EAR99	HMC286E
2.3 - 2.7	Low Noise	19	29.5	0.75	16.5	+5V @ 59mA	LP2	EAR99	HMC667LP2E
2.3 - 2.7	Low Noise with Bypass	20	31	1.1	17	+5V @ 74mA	LP3	EAR99	HMC605LP3E
2.4 - 2.5	Transceiver, Front End	13	10	3	5	+3V @ 24mA	MS8G	EAR99	HMC310MS8GE
3.1 - 3.9	Low Noise	18	33	1	19	+5V @ 65mA	LP3	EAR99	HMC716LP3E
3.3 - 3.8	Low Noise with Bypass	19	29	1.2	16	+5V @ 40mA	LP3	EAR99	HMC593LP3E
3.4 - 3.8	Low Noise with Bypass	16	18	2	7	+3V @ 9mA	LP3	EAR99	HMC491LP3E
3.5 - 7.0	Low Noise	15.5	28	2.4	16	+5V @ 50mA	Chip	EAR99	HMC392
3.5 - 7.0	Low Noise	16	30	2.5	16	+5V @ 55mA	LC4	EAR99	HMC392LC4
3.5 - 7.0	Low Noise	15	28	3	16	+5V @ 65mA	LH5	EAR99	HMC392LH5
4.8 - 6.0	Low Noise with Bypass	15	26	1.5	14	+5V @ 42mA	LP3	EAR99	HMC604LP3E
4.8 - 6.0	Low Noise	16.5	31.5	1.1	18.5	+5V @ 73mA	LP3	EAR99	HMC717LP3E
5 - 6	Low Noise	9	13	2.5	2	+3V @ 6mA	MS8G	EAR99	HMC318MS8GE
5 - 6	Low Noise	12	10	2.5	9	+3V @ 25mA	MS8G	EAR99	HMC320MS8GE
5 - 10	Low Noise	20	28	1.7	16	+3.5V @ 80mA	Chip	EAR99	HMC902
5 - 10	Low Noise	19	28	1.8	16	+3.5V @ 80mA	LP3	EAR99	HMC902LP3E
5 - 20	Low Noise	13	26	2.2	16	+5V @ 30mA	Chip	EAR99	HMC-ALH435 [1]
6 - 17	Low Noise	18	25	1.7	14	+3.5V @ 80mA	LP3	EAR99	HMC903LP3E
6 - 18	Low Noise	19	26	1.6	15	+3.5V @ 80mA	Chip	EAR99	HMC903
6 - 20	Low Noise	22	20	2.3	10	+3V @ 53mA	Chip	EAR99	HMC565
6 - 20	Low Noise	21	20	2.5	10	+3V @ 53mA	LC5	EAR99	HMC565LC5
6 - 26.5	Low Noise	22	18	2.5	10	+3.5V @ 45mA	LC4	EAR99	HMC963LC4
7 - 13.5	Low Noise	17	24	1.8	12	+3V @ 51mA	Chip	EAR99	HMC564
7 - 14	Low Noise	17	25	1.8	13	+3V @ 51mA	LC4	EAR99	HMC564LC4
7 - 17	Low Noise	21	20	1.8	15	+3V @ 65mA	Chip	EAR99	HMC516
7.5 - 26.5	Low Noise	13	23	2.5	13	+3.5V @ 70mA	LC4	EAR99	HMC962LC4
9 - 18	Low Noise	20	25	2	14	+3V @ 65mA	LC5	EAR99	HMC516LC5
12 - 16	Medium Power LNA	23	34	2.5	25	+5V @ 200mA	LP5	EAR99	HMC490LP5E [1]
12 - 17	Medium Power LNA	27	35	2	26	+5V @ 200mA	Chip	EAR99	HMC490 [1]
13 - 25	Low Noise	21	13	3.5	5	+3V @ 41mA	Chip	EAR99	HMC342
13 - 25	Low Noise	22	20	3.5	9	+3V @ 43mA	LC4	EAR99	HMC342LC4
14 - 27	Low Noise	19.5	-	2.2	17	+4V @ 90mA	LC4B	5A991.h	HMC504LC4B
14 - 27	Low Noise	18	-	2.5	14	+4V @ 90mA	Chip	5A991.h	HMC-ALH216 [1]
14 - 27	Low Noise	20	-	2	14	+4V @ 90mA	Chip	5A991.h	HMC-ALH476 [1]
17 - 26	Low Noise	19	23	2.2	11	+3V @ 65mA	Chip	EAR99	HMC517
17 - 26	Low Noise	19	23	2.5	13	+3V @ 67mA	LC4	EAR99	HMC517LC4
17 - 27	Low Noise	25	25	2.2	13	+4V @ 73mA	LC4	EAR99	HMC751LC4
18 - 31	Low Noise	15	23	3.5	11	+3V @ 75mA	LC4	EAR99	HMC519LC4
18 - 32	Low Noise	15	23	2.8	12	+3V @ 65mA	Chip	3A001.b.2.d	HMC519
18 - 40	Low Noise	10	-	3.9	12	+5V @ 45mA	Chip	3A001.b.2.d	HMC-ALH445
20 - 32	Low Noise	15	23	3	12	+3V @ 65mA	Chip	3A001.b.2.d	HMC518
21 - 29	Low Noise	13	19	2.5	8	+3V @ 35mA	LC3B	EAR99	HMC341LC3B
22 - 26.5	Low Noise	25	-	3	12	+2.5V @ 52mA	Chip	5A991.h	HMC-ALH311 [1]

SMT & Chip (Die) Products

AMPLIFIERS

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
24 - 28	Low Noise	25	26	2.5	13	+3V @ 70mA	LC4	EAR99	HMC752LC4 [1]
24 - 30	Low Noise	13	16	2.5	6	+3V @ 30mA	Chip	EAR99	HMC341
24 - 32	Low Noise	21	-	2	7	+5V @ 68mA	Chip	3A001.b.2.d	HMC-ALH364
24 - 36	Low Noise	23	17	2	8	+3V @ 58mA	Chip	3A001.b.2.d	HMC263
24 - 36	Low Noise	20	18	2.2	8	+3V @ 58mA	LP4	3A001.b.2.d	HMC263LP4E
24 - 40	Low Noise	12	-	3.5	13	+4V @ 45mA	Chip	3A001.b.2.d	HMC-ALH244
24 - 40	Low Noise	22	-	2	11	+5V @ 66mA	Chip	3A001.b.2.d	HMC-ALH369
24 - 40	Low Noise	11.5	-	4	15	+4V @ 60mA	Chip	3A001.b.2.d	HMC-ALH140 [1]
27 - 33	Low Noise	20	-	3	12	+2.5V @ 52mA	Chip	3A001.b.2.d	HMC-ALH313 [1]
28 - 36	Low Noise	21	24	2.8	12	+3V @ 82mA	LP4	3A001.b.2.d	HMC566LP4E
29 - 36	Low Noise	20	23.5	2.8	12	+3V @ 80mA	Chip	3A001.b.2.d	HMC566
35 - 45	Low Noise	16	-	2	6	+4V @ 87mA	Chip	3A001.b.2.d	HMC-ALH376
37 - 42	Low Noise	22	-	3.5	12	+2.5V @ 52mA	Chip	3A001.b.2.d	HMC-ALH310 [1]
57 - 65	Low Noise	21	-	4	12	+2.5V @ 64mA	Chip	3A001.b.2.f	HMC-ALH382 [1]
71 - 86	Low Noise	13	-	5	7	+2.4V @ 30mA	Chip	3A001.b.2.f	HMC-ALH508
71 - 86	Low Noise	14	-	5	7	+2V @ 50mA	Chip	3A001.b.2.f	HMC-ALH509
***Broadband Gain Blocks** (Listed by P1dB Output Power)*									
DC - 6	SiGe Gain Block	15.5	22	3	8	+5V @ 25mA	MP86	EAR99	HMC474MP86E
DC - 6	SiGe Gain Block	15	20	3	8	+3V @ 25mA	SC70	EAR99	HMC474SC70E
DC - 6	SiGe Gain Block	20	25	2.5	12	+5V @ 35mA	MP86	EAR99	HMC476MP86E
DC - 6	SiGe Gain Block	19	24	2.5	12	+5V @ 35mA	SC70	EAR99	HMC476SC70E
DC - 10	HBT Gain Block	15	24	4.5	13	+5V @ 56mA	Chip	EAR99	HMC397
DC - 10	HBT Gain Block	15	25	4	13	+5V @ 50mA	Chip	EAR99	HMC405
DC - 6	HBT Gain Block	17	27	6.5	14	+5V @ 50mA	SOT26	EAR99	HMC313E
DC - 8	HBT Gain Block	12	30	6	14	+5V @ 56mA	Chip	EAR99	HMC396
DC - 4	HBT Gain Block	15	28	4.5	15	+5V @ 54mA	Chip	EAR99	HMC395
DC - 8	HBT Gain Block	15	30	5	15	+5V @ 54mA	SC70	EAR99	HMC311SC70E
DC - 6	HBT Gain Block	14.5	32	4.5	15.5	+5V @ 56mA	LP3	EAR99	HMC311LP3E
DC - 6	HBT Gain Block	16	31.5	4.5	15.5	+5V @ 54mA	ST89	EAR99	HMC311ST89E
DC - 4	SiGe Gain Block	24	31	2.5	17	+5V @ 62mA	SC70	EAR99	HMC478SC70E
DC - 4	SiGe Gain Block	22	32	2	18	+5V @ 62mA	MP86	EAR99	HMC478MP86E
DC - 4	SiGe Gain Block	22	33	3	18	+5V @ 62mA	ST89	EAR99	HMC478ST89E
DC - 5	SiGe Gain Block	15	34	4	18	+8V @ 72mA	MP86	EAR99	HMC479MP86E
DC - 5	SiGe Gain Block	15	34	4	18	+8V @ 75mA	ST89	EAR99	HMC479ST89E
DC - 5	SiGe Gain Block	20	33	3.5	19	+8V @ 79mA	ST89	EAR99	HMC481ST89E
DC - 10	pHEMT Gain Block	14	30	7	20	+5V @ 76mA	LP2	EAR99	HMC788LP2E
DC - 5	SiGe Gain Block	19	34	2.9	20	+8V @ 82mA	ST89	EAR99	HMC480ST89E
DC - 5	SiGe Gain Block	20	33	3.5	20	+8V @ 74mA	MP86	EAR99	HMC481MP86E
DC - 4	HBT Gain Block	21	33	4	21	+5V @ 82mA	ST89	EAR99	HMC589ST89E
0.2 - 4.0	Low Noise, High IP3, pHEMT Gain Block	13	38	2.3	22	+5V @ 110mA	ST89	EAR99	HMC639ST89E
0.2 - 4.0	Low Noise, High IP3, pHEMT Gain Block	13	40	2.2	22	+5V @ 155mA	ST89	EAR99	HMC636ST89E
DC - 1	HBT Gain Block	22	37	2.8	22	+5V @ 88mA	ST89	EAR99	HMC580ST89E
DC - 4.5	HBT Gain Block	21	35	3.5	22	+8V @ 110mA	ST89	EAR99	HMC475ST89E
DC - 5	SiGe Gain Block	19	36	4	22	+8V @ 110mA	ST89	EAR99	HMC482ST89E
DC - 5	Dual SiGe Gain Block	15	34	4	18	+8V @ 75mA	MS8G	EAR99	HMC469MS8GE
DC - 5	Dual SiGe Gain Block	20	34	3.2	20	+8V @ 80mA	MS8G	EAR99	HMC471MS8GE
CATV Amplifiers									
0.04 - 0.96	Low Noise, Dual Output	5	27	3.5	12	+5V @ 120mA	MS8G	EAR99	HMC549MS8GE
0.05 - 0.96	Low Noise, 75 Ohm	14	39	2.2	19	+5V @ 120mA	ST89	EAR99	HMC599ST89E
0.04 - 1.0	50 / 75 Ohm Differential Gain Block	16	40	2.5	23.5	+5V @ 270mA	LP4B	EAR99	HMC770LP4BE
0.05 - 3.0	HBT Gain Block	15	40	3.5	18	+5V @ 88mA	ST89	EAR99	HMC740ST89E
0.05 - 3.0	HBT Gain Block	20	42	2.5	18.5	+5V @ 96mA	ST89	EAR99	HMC741ST89E
DC - 1	HBT Gain Block, 75 Ohm	14	38	5.5	21	+5V @ 160mA	S8G	EAR99	HMC754S8GE
Driver Amplifiers									
0.7 - 2.8	HBT Driver Amplifier	18	42	3.8	25	+5V @ 125mA	ST89	EAR99	HMC789ST89E
0.8 - 3.8	Driver Amplifier	18	30	7.5	17	+5V @ 53mA	SOT26	EAR99	HMC308E
3.0 - 4.5	HBT Driver Amplifier	21	36	5	23.5	+5V @ 130mA	MS8G	EAR99	HMC326MS8GE
17.5 - 41	Driver Amplifier	21	27	-	20	+5V @ 295mA	Chip	3A001.b.2.d	HMC-AUH256
Linear & Power Amplifiers									
0.4 - 2.5	High IP3 Amp, 1/2 Watt	12.5	42	6	27	+5V @ 150mA	ST89	EAR99	HMC454ST89E
1.6 - 2.2	Medium Power Amplifier	22	40	5.5	27	+3.6V @ 270mA	QS16G	EAR99	HMC413QS16GE
5 - 6	Medium Power Amplifier	17	38	6	26	+5V @ 300mA	MS8G	EAR99	HMC406MS8GE
5 - 7	Medium Power Amplifier	15	40	5.5	25	+5V @ 230mA	MS8G	EAR99	HMC407MS8GE
5 - 18	Medium Power Amplifier	18	28	7	19.5	+5V @ 120mA	LP3	EAR99	HMC451LP3E
5 - 20	Medium Power Amplifier	22	30	6.5	20	+5V @ 127mA	Chip	EAR99	HMC451

AMPLIFIERS

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
5 - 20	Medium Power Amplifier	19	30	7	19	+5V @ 114mA	LC3	EAR99	HMC451LC3
6 - 18	Medium Power Amplifier	15.5	32	4.5	20	+5V @ 95mA	Chip	EAR99	HMC441
6 - 18	Medium Power Amplifier	17	32	4.5	20	+5V @ 95mA	LC3B	EAR99	HMC441LC3B
6.5 - 13.5	Medium Power Amplifier	14	29	4.5	18	+5V @ 95mA	LP3	EAR99	HMC441LP3E
7 - 15.5	Medium Power Amplifier	15	32	4.8	20	+5V @ 95mA	LH5 Hermetic	EAR99	HMC441LH5
7 - 15.5	Medium Power Amplifier	16	30	4.5	19	+5V @ 90mA	LM1	EAR99	HMC441LM1
9.5 - 11.5	Medium Power Amplifier	29.5	33	6	27	+5V @ 310mA	LC4	EAR99	HMC608LC4
12 - 30	Medium Power Amplifier	16	25	7	16	+5V @ 101mA	Chip	EAR99	HMC383
12 - 30	Medium Power Amplifier	15	25	7.5	16.5	+5V @ 100mA	LC4	EAR99	HMC383LC4
16 - 33	Medium Power Amplifier	17	33	-	24	+5V @ 400mA	Chip	5A991.h	HMC-APH596
17 - 24	Medium Power Amplifier	24	34	4	25	+5V @ 250mA	Chip	EAR99	HMC498
17 - 24	Medium Power Amplifier	22	36	4	25	+5V @ 250mA	LC4	EAR99	HMC498LC4
17 - 30	Medium Power Amplifier	20	31	-	22	+4.5V @ 400mA	Chip	5A991.h	HMC-APH196
17.5 - 24	Medium Power Amplifier	14	28	6.5	21.5	+5V @ 85mA	LM1	EAR99	HMC442LM1
17.5 - 25.5	Medium Power Amplifier	15	28	5.5	22	+5V @ 85mA	Chip	EAR99	HMC442 [1]
17.5 - 25.5	Medium Power Amplifier	13	27	8	22	+5V @ 84mA	LC3B	EAR99	HMC442LC3B [1]
21 - 32	Medium Power Amplifier	16	33	5	24	+5V @ 200mA	Chip	3A001.b.2.b	HMC499 [1]
21 - 32	Medium Power Amplifier	17	34	5	23	+5V @ 200mA	LC4	3A001.b.2.d	HMC499LC4 [1]
34 - 42	Medium Power Amplifier	18.5	29	6.5	18	+5V @ 120mA	Chip	3A001.b.2.d	HMC-ABH264 [1]
37 - 40	Medium Power Amplifier	20	35	-	26	+5V @ 640mA	Chip	3A001.b.2.d	HMC-APH510
37 - 45	Medium Power Amplifier	21	32	-	23	+5V @ 475mA	Chip	3A001.b.2.d	HMC-APH403
50 - 66	Medium Power Amplifier	24	25	-	17	+5V @ 220mA	Chip	3A001.b.2.f	HMC-ABH241
55 - 65	Medium Power Amplifier	13	25	-	16	+5V @ 80mA	Chip	3A001.b.2.f	HMC-ABH209 [1]
71 - 76	Medium Power Amplifier	24	-	-	17.5	+4V @ 130mA	Chip	3A001.b.2.f	HMC-AUH318 [1]
71 - 76	Medium Power Amplifier	13	-	-	20	+4V @ 240mA	Chip	3A001.b.2.f	HMC-APH633
71 - 86	Medium Power Amplifier	15	-	-	15	+4V @ 130mA	Chip	3A001.b.2.f	HMC-AUH320 [1]
81 - 86	Medium Power Amplifier	22	-	-	17.5	+4V @ 160mA	Chip	3A001.b.2.f	HMC-AUH317 [1]
81 - 86	Medium Power Amplifier	12	-	-	19	+4V @ 240mA	Chip	3A001.b.2.f	HMC-APH634
0.4 - 2.2	Power Amplifier, 1 Watt	21	49	6.5	30	+5V @ 510mA	ST89	EAR99	HMC452ST89E
0.4 - 2.2	Power Amplifier, 1.6 Watt	20.5	49	6.5	32	+5V @ 725mA	ST89	EAR99	HMC453ST89E
0.4 - 2.7	Power Amplifier, 2 Watt	16	48	8.5	33	+5V @ 700mA	LP4	EAR99	HMC921LP4E
0.45 - 2.2	Power Amplifier, 1 Watt	22.5	48	7	30	+5V @ 485mA	QS16G	EAR99	HMC452QS16GE
0.45 - 2.2	Power Amplifier, 1.6 Watt	21.5	51	6.5	33	+5V @ 725mA	QS16G	EAR99	HMC453QS16GE
1.7 - 2.2	Power Amplifier, 1 Watt	27	46	5	30.5	+5V @ 500mA	QS16G	EAR99	HMC457QS16GE
2.3 - 2.8	Power Amplifier, 1 Watt	31	45	5	32.5	+5V @ 430mA	LP4	EAR99	HMC755LP4E
3 - 4	Power Amplifier, 1/2 Watt	21	40	5	27	+5V @ 250mA	MS8G	EAR99	HMC327MS8GE
3.3 - 3.8	Power Amplifier, 1 Watt	31	45.5	5.8	30.5	+5V @ 615mA	LP4	EAR99	HMC409LP4E
5.1 - 5.9	Power Amplifier, 1 Watt	20	43	6	30	+5V @ 750mA	LP3	EAR99	HMC408LP3E
6 - 9.5	Power Amplifier, 1 Watt	21	40	-	30.5	+7V @ 820mA	LP5	3A001.b.2.d	HMC590LP5E
6 - 9.5	Power Amplifier, 2 Watt	18	41	-	33	+7V @ 1340mA	LP5	3A001.b.2.d	HMC591LP5E
6 - 10	Power Amplifier, 1 Watt	25	41	-	31.5	+7V @ 820mA	Chip	3A001.b.2.d	HMC590
6 - 10	Power Amplifier, 2 Watt	23	43	-	33.5	+7V @ 1340mA	Chip	3A001.b.2.d	HMC591
7 - 9	Power Amplifier, 2 Watt	26	40	6.5	33.5	+7V @ 1.3A	Chip	3A001.b.2.b	HMC486
7 - 9	Power Amplifier, 2 Watt	22	40	7	32	+7V @ 1.3A	LP5	3A001.b.2.b	HMC486LP5E
9 - 12	Power Amplifier, 2 Watt	20	36	8	32	+7V @ 1.3A	LP5	3A001.b.2.b	HMC487LP5E
10 - 13	Power Amplifier, 1 Watt	19	38	-	31	+7V @ 750mA	Chip	3A001.b.2.b	HMC592
12 - 16	Power Amplifier, 1 Watt	13	34	9	31	+7V @ 1.3A	LP5	3A001.b.2.b	HMC489LP5E
12.5 - 15.5	Power Amplifier, 2 Watt	30	42	-	34.5	+7V @ 1200mA	Chip	3A001.b.2.b	HMC949
12.5 - 15.5	Power Amplifier, 4 Watt	28	44	-	36	+7V @ 1200mA	Chip	3A001.b.2.b	HMC950
12.5 - 15.5	Power Amplifier, 2 Watt	27	40	-	32	+6V @ 1200mA	LP5	3A001.b.2.b	HMC965LP5E
NEW! 12.5 - 15.5	Power Amplifier, 2 Watt	26	41	-	34	+7V @ 1200mA	LP5G	3A001.b.2.b	HMC995LP5GE
15 - 27	Power Amplifier, 1 Watt	17	37	-	29	+5V @ 1.44A	Chip	3A001.b.2.c	HMC-APH462
16 - 24	Power Amplifier, 1 Watt	23	41	-	31	+7V @ 790mA	Chip	3A001.b.2.c	HMC756
16 - 24	Power Amplifier, 1/2 Watt	22	37	-	29	+7V @ 395mA	Chip	3A001.b.2.c	HMC757
16 - 24	Power Amplifier, 1/2 Watt	20.5	34.5	-	26.5	+5V @ 400mA	LP4	3A001.b.2.c	HMC757LP4E
18 - 20	Power Amplifier, 1 Watt	17.5	38.5	-	30	+5V @ 900mA	Chip	3A001.b.2.c	HMC-APH478
21 - 24	Power Amplifier, 1 Watt	17	39	-	30.5	+5V @ 950mA	Chip	3A001.b.2.c	HMC-APH518
22 - 26.5	Power Amplifier, 1/2 Watt	20	33	7	26.5	+5V @ 400mA	LP4	EAR99	HMC863LP4E
22.5 - 26.5	Power Amplifier, 1 Watt	17	40	-	30	+5V @ 950mA	Chip	3A001.b.2.c	HMC-APH608
24 - 29.5	Power Amplifier, 1/2 Watt	22	-	-	26.5	+6V @ 360mA	Chip	EAR99	HMC863
24 - 29.5	Power Amplifier, 1 Watt	27	40	-	29	+6V @ 750mA	Chip	3A001.b.2.c	HMC864
24 - 31.5	Power Amplifier, 1.5 Watt	22	43	-	34	+5.5V @ 1200mA	LP5	3A001.b.2.c	HMC943LP5E
27 - 31.5	Power Amplifier, 1/2 Watt	14	37	-	28	+5V @ 900mA	Chip	3A001.b.2.c	HMC-APH460
27 - 34	Power Amplifier, 1 Watt	17.5	37	-	29	+5V @ 800mA	Chip	3A001.b.2.d	HMC693
27.3 - 33.5	Power Amplifier, 2 Watt	23	43	-	33	+6V @ 1200mA	Chip	3A001.b.2.d	HMC906

SMT & Chip (Die) Products

AMPLIFIERS

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
37 - 40	Power Amplifier, 1 Watt	15	37	-	28	+5V @ 1.08A	Chip	3A001.b.2.d	HMC-APH473
37 - 40	Power Amplifier, 1 Watt	21	38	-	30.5	+6V @ 900mA	Chip	3A001.b.2.d	HMC968
40 - 43.5	Power Amplifier, 1 Watt	22	38	-	29	+6V @ 900mA	Chip	EAR99	HMC969
Wideband (Distributed) Amplifiers									
DC - 20	Wideband LNA	14	28	2.5	16	+8V @ 60mA	Chip	EAR99	HMC460 [1]
DC - 20	Wideband LNA	14	29.5	2.5	17	+8V @ 75mA	LC5	EAR99	HMC460LC5 [1]
2 - 20	Wideband LNA	15	26.5	2.5	15	+5V @ 63mA	Chip	EAR99	HMC462
2 - 20	Wideband LNA	13	25	2.5	14	+5V @ 66mA	LP5	EAR99	HMC462LP5E
2 - 20	Wideband LNA with AGC	14	28	2.5	19	+5V @ 60mA	Chip	EAR99	HMC463 [1]
2 - 20	Wideband LNA with AGC	13	26	3	18	+5V @ 60mA	LP5	EAR99	HMC463LP5E [1]
2 - 20	Wideband LNA with AGC	14	28	2.5	18	+5V @ 60mA	LH250	EAR99	HMC463LH250
2 - 20	Wideband LNA	10	-	3.5	10	+2V @ 55mA	Chip	EAR99	HMC-ALH102
2 - 22	Wideband LNA	16	-	1.7	14	+4V @ 45mA	Chip	EAR99	HMC-ALH482
DC - 20	Wideband Driver	17	30	2.5	22	+8V @ 160mA	Chip	EAR99	HMC465 [1]
DC - 20	Wideband Driver	15	28	3	23	+8V @ 160mA	LP5	EAR99	HMC465LP5E [1]
DC - 35	Wideband Driver	15	-	-	21	+5V @ 200mA	Chip	3A001.b.2.d	HMC-AUH249
DC - 43	Wideband Driver	14	-	5.4	16.5	+5V @ 180mA	Chip	3A001.b.2.d	HMC-AUH232
0.5 - 65	Wideband Driver	10	-	-	-	+8V @ 60mA	Chip	3A001.b.2.d	HMC-AUH312
2 - 35	Wideband Driver	12.5	27	3	18	+8V @ 80mA	Chip	3A001.b.2.d	HMC562 [1]
5 - 17	Wideband Driver	31	30	8	23	+5V @ 180mA	Chip	EAR99	HMC633 [1]
5 - 20	Wideband Driver	22	31	7.5	23	+5V @ 180mA	Chip	EAR99	HMC634 [1]
5 - 20	Wideband Driver	21	29	7.5	22	+5V @ 180mA	LC4	EAR99	HMC634LC4 [1]
5.5 - 17	Wideband Driver	30	30	8	23	+5V @ 180mA	LC4	EAR99	HMC633LC4 [1]
18 - 40	Wideband Driver	19.5	29	8	23	+5V @ 280mA	Chip	3A001.b.2.e	HMC635
18 - 40	Wideband Driver	18.5	27	7	22	+5V @ 280mA	LC4	3A001.b.2.f	HMC635LC4
DC - 6	Wideband Power Amplifier	14	45	5	29	+12V @ 400mA	Chip	EAR99	HMC637
DC - 6	Wideband Power Amplifier	13	40	5	29	+12V @ 400mA	LP5	EAR99	HMC637LP5E
DC - 10	Wideband Power Amplifier	12	41	6	28.5	+12V @ 300mA	Chip	EAR99	HMC619
DC - 10	Wideband Power Amplifier	12	41	6	28	+12V @ 300mA	LP5	EAR99	HMC619LP5E
DC - 15	Wideband Power Amplifier	19	35	2	26.5	+8V @ 300mA	Chip	EAR99	HMC659
DC - 15	Wideband Power Amplifier	19	35	2.5	27.5	+8V @ 300mA	LC5	EAR99	HMC659LC5
DC - 18	Wideband Power Amplifier	17	32	3	25	+8V @ 290mA	Chip	EAR99	HMC459
DC - 20	Wideband Power Amplifier	14	36	4	28	+10V @ 400mA	Chip	3A001.b.2.c	HMC559
DC - 22	Wideband Power Amplifier	14	40	2.5	28	+11V @ 400mA	Chip	3A001.b.2.c	HMC797
DC - 22	Wideband Power Amplifier	13.5	39	4	28	+10V @ 400mA	LP5	3A001.b.2.c	HMC797LP5E
DC - 40	Wideband Power Amplifier	13	33.5	5	22	+10V @ 175mA	Chip	3A001.b.2.f	HMC930 [1]
0.2 - 22	Wideband Power Amplifier	13	38	3	27	+11V @ 365mA	Chip	3A001.b.2.c	HMC907
0.2 - 22	Wideband Power Amplifier	12	36	3.5	26	+10V @ 350mA	LP5	3A001.b.2.c	HMC907LP5E
2 - 20	Wideband Power Amplifier	16	30	4	26	+8V @ 290mA	Chip	EAR99	HMC464
2 - 20	Wideband Power Amplifier	14	30	4	26	+8V @ 290mA	LP5	EAR99	HMC464LP5E

[1] Amplifiers that benefit from Hittite Active Bias Controllers

AMPLIFIERS - Low Phase Noise

Frequency (GHz)	Function	Gain / NF (dB)	OIP3 (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	P1dB / Psat (dBm)	Bias Supply	Package	ECCN Code	Part Number
2 - 18	Wideband, Low Phase Noise	14 / 4.5	27	-160	15 / 18	+5V @ 64mA	Chip	EAR99	HMC606
2 - 18	Wideband, Low Phase Noise	13.5 / 5	27	-160	15 / 17	+5V @ 64mA	LC5	EAR99	HMC606LC5

AMPLIFIERS - Microwave & Optical Modulator Drivers

Frequency (GHz)	Function	Gain (dB)	Group Variation Delay (ps)	Additive Jitter (ps)	P1dB (dBm)	Output Voltage Level (Vp-p)	Package	ECCN Code	Part Number
DC - 20	MZ Optical Modulator Driver	18	±15	0.3	22	2.5 - 8	LC5	EAR99	HMC870LC5 [1]
DC - 20	EA Optical Modulator Driver	15	±15	0.3	16.5	2.5 - 4	LC5	EAR99	HMC871LC5 [1]

[1] Amplifiers that benefit from Hittite Active Bias Controllers

ATTENUATORS

Frequency (GHz)	Function	Insertion Loss (dB)	Attenuation Range (dB)	IIP3 (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
Attenuators - Analog								
0.45 - 2.2	Analog VVA	1.9	0 to 48	20	0 to +3V	MS8	EAR99	HMC473MS8E
0.5 - 6.0	Analog VVA	2.5	0 to 26	35	0 to +5V	LP3	EAR99	HMC973LP3E
DC - 8	Analog VVA	1.5	0 to 32	10	0 to -3V	MS8G	EAR99	HMC346MS8GE
DC - 8	Analog VVA	2	0 to 30	10	0 to -3V	C8	EAR99	HMC346C8
DC - 8	Analog VVA	2	0 to 30	10	0 to -3V	G8 Hermetic	EAR99	HMC346G8
DC - 14	Analog VVA	2	0 to 30	10	0 to -3V	LP3	EAR99	HMC346LP3E
DC - 18	Analog VVA	1.5	0 to 30	10	0 to -3V	LC3B	EAR99	HMC346LC3B
DC - 20	Analog VVA	2.2	0 to 25	10	0 to -3V	Chip	EAR99	HMC346

ATTENUATORS

	Frequency (GHz)	Function	Insertion Loss (dB)	Attenuation Range (dB)	IIP3 (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
	5 - 26.5	Analog VVA	3.5	0 to 28	32	0 to -3V	LP3C	EAR99	HMC712LP3CE
	5 - 30	Analog VVA	2.5	0 to 30	32	0 to -3V	Chip	EAR99	HMC712
	5 - 30	Analog VVA	2	0 to 28	28	0 to -3V	LC4	EAR99	HMC812LC4
	17 - 27	Analog VVA	1.5	0 to 22	17	-4 to +4V	Chip	5A991.h	HMC-VVD102
NEW!	20 - 50	Analog VVA	3	0 to 35	33	0 to +3V	Chip	EAR99	HMC985
	36 - 50	Analog VVA	1.5	0 to 22	17	0 to +4V	Chip	5A991.h	HMC-VVD106
	70 - 86	Analog VVA	2	0 to 14	-	-5 to +5V	Chip	5A991.h	HMC-VVD104
	Attenuators - Digital								
	DC - 5	1-Bit Digital	1	10	50	TTL/CMOS	LP3	EAR99	HMC541LP3E
	DC - 10	1-Bit Digital	2	10	54	0 / +3 to +5V	LP3	EAR99	HMC800LP3E
	DC - 10	1-Bit Digital	1.5	15	53	0 / +3 to +5V	LP3	EAR99	HMC801LP3E
	DC - 10	1-Bit Digital	2.5	20	53	0 / +3 to +5V	LP3	EAR99	HMC802LP3E
	0.7 - 4.0	2-Bit Digital	0.5	2 to 6	52	0 / +3V	SOT26	EAR99	HMC290E
	0.7 - 4.0	2-Bit Digital	0.9	4 to 12	54	0 / +3V	SOT26	EAR99	HMC291E
	DC - 6	2-Bit Digital	0.5	2 to 6	50	TTL/CMOS	LP3	EAR99	HMC467LP3E
	0.75 - 2.0	3-Bit Digital	1.8	4 to 28	45	0 / +3V	MS8	EAR99	HMC230MS8E
	0.7 - 3.7	3-Bit Digital	1.3	2 to 14	51	0 / +3V	MS8	EAR99	HMC288MS8E
	DC - 6	3-Bit Digital	0.7	1 to 7	50	TTL/CMOS	LP3	EAR99	HMC468LP3E
	DC - 5.5	4-Bit Digital	0.8	1 to 15	50	TTL/CMOS	LP3	EAR99	HMC540LP3E
	DC - 6	4-Bit Digital, Serial & Parallel Control	2.5	3 to 45	50	0 / +5V	LP4	EAR99	HMC629LP4E
	0.1 - 30	5-Bit Digital	2.5	0.5 to 15.5	43	0 / +5V	Chip	EAR99	HMC941
	0.1 - 40	5-Bit Digital	3.5	1 to 31	45	0 / +5V	Chip	EAR99	HMC939
	0.7 - 2.7	5-Bit Digital	2.3	1 to 31	54	0 / +3V	QS16	EAR99	HMC274QS16E
	0.7 - 3.7	5-Bit Digital, Serial Control	2.1	1 to 31	48	Serial/CMOS	LP4	EAR99	HMC271ALP4E
	0.7 - 3.8	5-Bit Digital	2.1	1 to 31	48	0 / +3V	MS10G	EAR99	HMC273MS10GE
	0.7 - 3.8	5-Bit Digital, Serial Control	1.5	0.5 to 15.5	52	Serial/CMOS	LP4	EAR99	HMC305ALP4E
	0.7 - 3.8	5-Bit Digital	1.5	0.5 to 15.5	52	0 / +3V	MS10	EAR99	HMC306MS10E
	0.7 - 3.8	5-Bit Digital	1.3	0.5 to 15.5	48	0 / +3V	MS10	EAR99	HMC603MS10E
	0.7 - 3.8	5-Bit Digital	1.3	0.5 to 15.5	48	0 / +3V	QS16	EAR99	HMC603QS16E
	DC - 3	5-Bit Digital	2.0	1 to 31	44	0 / -5V	G16 Hermetic	EAR99	HMC335G16
	DC - 3	5-Bit Digital	1.3	1 to 31	45	TTL/CMOS	LP3	EAR99	HMC470LP3E
	DC - 4	5-Bit Digital	1.9	1 to 31	44	0 / -5V	QS16G	EAR99	HMC307QS16GE
	DC - 4	5-Bit Digital	0.7	0.25 to 7.75	50	TTL/CMOS	LP3	EAR99	HMC539LP3E
	DC - 3.8	6-Bit Digital	1.5	0.5 to 31.5	45	TTL/CMOS	LP4	EAR99	HMC472LP4E
	DC - 3	6-Bit Digital	3.0	0.5 to 31.5	32	0 / -5V	G16 Hermetic	EAR99	HMC424G16
	DC - 4	6-Bit Digital, Serial Control	1.2	0.5 to 31.5	45	Serial/CMOS	LP4	EAR99	HMC542ALP4E
	DC - 6	6-Bit Digital, Serial & Parallel Control	1.8	0.25 to 31.5	55	0 / +5V	LP4	EAR99	HMC624LP4E
	DC - 6	6-Bit Digital, Serial & Parallel Control	1.8	0.25 to 15.75	55	TTL/CMOS	LP4	EAR99	HMC792LP4E
	DC - 13	6-Bit Digital	4.0	0.5 to 31.5	32	0 / -5V	Chip	EAR99	HMC424
	DC - 13	6-Bit Digital	3.2	0.5 to 31.5	32	0 / -5V	LH5 Hermetic	EAR99	HMC424LH5
	DC - 13	6-Bit Digital	4.0	0.5 to 31.5	32	0 / -5V	LP3	EAR99	HMC424LP3E
	2.4 - 8.0	6-Bit Digital	3.5	0.5 to 31.5	40	0 / +5V	Chip	EAR99	HMC425
	2.2 - 8.0	6-Bit Digital	3.2	0.5 to 31.5	40	0 / +5V	LP3	EAR99	HMC425LP3E
	0.01 - 0.3	7-Bit Digital	3.3	0.25 to 31.75	40	TTL/CMOS	LP3	EAR99	HMC759LP3E

FILTERS - *Tunable (Band Pass & Low Pass)*

RF Band Pass

	Frequency Range (GHz)	Function	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	Package	ECCN Code	Part Number
	1 - 2	Band Pass	10	11	0.8 x Fcenter	1.2 x Fcenter	200	LP5	EAR99	HMC890LP5E
	2 - 3.9	Band Pass	10	9	0.9 x Fcenter	1.15 x Fcenter	200	LP5	EAR99	HMC891LP5E
	4 - 7.7	Band Pass	15	9	0.9 x Fcenter	1.13 x Fcenter	200	LP5	EAR99	HMC892LP5E
	4.8 - 9.5	Band Pass	7	6.5	0.9 x Fcenter	1.1 x Fcenter	200	LP5	EAR99	HMC893LP5E
NEW!	5.9 - 11.2	Band Pass	7.5	6	0.92 x Fcenter	1.08 x Fcenter	200	LP5	EAR99	HMC894LP5E
	9 - 19	Band Pass	9.5	18	0.81 x Fcenter	1.17 x Fcenter	200	LP4	EAR99	HMC897LP4E
NEW!	18.5 - 37.0	Band Pass	10	18	0.81 x Fcenter	1.20 x Fcenter	200	LP4	EAR99	HMC899LP4E

RF Low Pass

Frequency Range (GHz)	Function	Return Loss (dB)	Cutoff Frequency Range (GHz)	Stopband Frequency (Rej. >20 dB)	Tuning Response (ns)	Package	ECCN Code	Part Number
DC - 4.0	Low Pass	10	2.2 - 4.0	1.25 x Fcutoff	150	LP5	EAR99	HMC881LP5E
DC - 7.6	Low Pass	10	4.5 - 7.6	1.23 x Fcutoff	150	LP5	EAR99	HMC882LP5E

IF / BASEBAND PROCESSING - Dual Baseband Low Pass Filter & Dual Baseband Digital VGA

Dual Baseband Low Pass Filter

3 dB Bandwidth Setting (MHz)	Function	3 dB Bandwidth Accuracy (%)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package	ECCN Code	Part Number
3.5 - 50	Dual Low Pass with ADC Driver	± 2.5	0 / 10	12	30	LP5	EAR99	HMC900LP5E

Please Note: 400 Ohm Reference Impedance Are Shown

Dual Baseband Digital VGA

Frequency (MHz)	Function	NF (dB)	Variable Gain (dB)	OIP3 (dBm)	OIP2 (dBm)	Sideband Supp. (dB)	Magnitude (dB) / Phase (deg) Balance	Bias Supply	Package	ECCN Code	Part Number
DC - 100	Digital, Serial & Parallel Control	6	0 to 40	+30	+65	55	±0.1 / ±1	+5V @ 70mA	LP4	EAR99	HMC960LP4E

Please Note: 100 Ohm Reference Impedance Are Shown

I/Q MIXERS / IRMs

RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Image Rejection (dB)	IIP3 (dBm)	Package	ECCN Code	Part Number
I/Q Mixers / IRMs								
3 - 7	I/Q Mixer / IRM	DC - 3.5	-7.5	33	23	Chip	EAR99	HMC620
3 - 7	I/Q Mixer / IRM	DC - 3.5	-7.5	32	22	LC4	EAR99	HMC620LC4
4 - 8.5	I/Q Mixer / IRM	DC - 3.5	-7.5	40	23	Chip	EAR99	HMC525
4 - 8.5	I/Q Mixer / IRM	DC - 3.5	-7.5	40	23	LC4	EAR99	HMC525LC4
5.9 - 12.0	I/Q Mixer / IRM	DC - 1.5	-8	30	18	Chip	EAR99	HMC256
6 - 10	I/Q Mixer / IRM	DC - 3.5	-7	40	22	Chip	EAR99	HMC520
6 - 10	I/Q Mixer / IRM	DC - 3.5	-7	40	23	LC4	EAR99	HMC520LC4
6 - 10	I/Q Mixer / IRM	DC - 3.5	-7.5	40	28	Chip	EAR99	HMC526
6 - 10	I/Q Mixer / IRM	DC - 3.5	-7.5	40	28	LC4	EAR99	HMC526LC4
8.5 - 13.5	I/Q Mixer / IRM	DC - 3.5	-7.5	40	24	Chip	EAR99	HMC521
8.5 - 13.5	I/Q Mixer / IRM	DC - 3.5	-7.5	38	24	LC4	EAR99	HMC521LC4
8.5 - 13.5	I/Q Mixer / IRM	DC - 2	-7.5	35	28	Chip	EAR99	HMC527
8.5 - 13.5	I/Q Mixer / IRM	DC - 2	-7.5	34	28	LC4	EAR99	HMC527LC4
10 - 16	I/Q Mixer / IRM	DC - 3.5	-8	25	25	LC5	EAR99	HMC775LC5
11 - 16	I/Q Mixer / IRM	DC - 3.5	-7.5	35	24	Chip	EAR99	HMC522
11 - 16	I/Q Mixer / IRM	DC - 3.5	-7.5	35	24	LC4	EAR99	HMC522LC4
11 - 16	I/Q Mixer / IRM	DC - 3.5	-8	35	27	Chip	EAR99	HMC528
11 - 16	I/Q Mixer / IRM	DC - 3.5	-8	35	26	LC4	EAR99	HMC528LC4
15 - 23	I/Q Mixer / IRM	DC - 3.5	-8	25	25	LC4	EAR99	HMC523LC4
15 - 23.6	I/Q Mixer / IRM	DC - 3.5	-8	27	25	Chip	EAR99	HMC523
19 - 33	I/Q Mixer / IRM	DC - 5	-8	25	17	Chip	5A001.h	HMC-MDB172
22 - 32	I/Q Mixer / IRM	DC - 3.5	-10	23	20	Chip	EAR99	HMC524
22 - 32	I/Q Mixer / IRM	DC - 4.5	-10	20	20	LC3B	EAR99	HMC524LC3B
31 - 38	I/Q Mixer / IRM	DC - 3.5	-10.5	17	21	Chip	EAR99	HMC555
35 - 45	I/Q Mixer / IRM	DC - 5	-8	25	17	Chip	5A991.h	HMC-MDB171
36 - 41	I/Q Mixer / IRM	DC - 3.5	-11	18	23	Chip	EAR99	HMC556
55 - 64	I/Q Mixer / IRM	DC - 3	-9	30	16	Chip	5A991.h	HMC-MDB207
26 - 33 RF	Sub-Harmonic, I/Q Mixer / IRM	DC - 3	-11	22	16	Chip	EAR99	HMC404
54 - 64 RF	Sub-Harmonic, I/Q Mixer / IRM	DC - 3	-12.5	30	7	Chip	5A991.h	HMC-MDB218

I/Q DOWNCONVERTER / RECEIVERS

	RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Noise Figure (dB)	Image Rejection (dB)	IIP3 (dBm)	Package	ECCN Code	Part Number
	5.6 - 8.6	I/Q Downconverter / Receiver	DC - 3	12	2.2	20	2	LP4	EAR99	HMC951LP4E
	7 - 9	I/Q Downconverter / Receiver	DC - 3.5	10	2.5	35	1.5	LC5	EAR99	HMC567LC5
	9 - 12	I/Q Downconverter / Receiver	DC - 3.5	11	2.2	25	2	LC5	EAR99	HMC908LC5
	12 - 16	I/Q Downconverter / Receiver	DC - 3.5	14	2.8	32	-1	LC5	EAR99	HMC869LC5
	17 - 20	I/Q Downconverter / Receiver	DC - 3.5	14	2.5	40	0	LP4	EAR99	HMC966LP4E
	17 - 21	I/Q Downconverter / Receiver	DC - 3.5	10	3	17	3	Chip	EAR99	HMC570
	17 - 21	I/Q Downconverter / Receiver	DC - 3.5	10	3	18	2	LC5	EAR99	HMC570LC5
	17 - 24	I/Q Downconverter / Receiver	DC - 3.3	11	2.2	21	2	LC5	EAR99	HMC904LC5
	17 - 24	I/Q Downconverter / Receiver	DC - 3.5	15	2.5	25	1	LP4	EAR99	HMC967LP4E
NEW!	20 - 28	I/Q Downconverter / Receiver	DC - 3.5	14	2.5	21	1	LP4	EAR99	HMC977LP4E
	21 - 25	I/Q Downconverter / Receiver	DC - 3.5	11	3	24	5	Chip	EAR99	HMC571
	21 - 25	I/Q Downconverter / Receiver	DC - 3.5	10	2	20	5	LC5	EAR99	HMC571LC5
	24 - 28	I/Q Downconverter / Receiver	DC - 3.5	8	3.5	20	5	Chip	EAR99	HMC572
	24 - 28	I/Q Downconverter / Receiver	DC - 3.5	8	3.5	18	5	LC5	EAR99	HMC572LC5

I/Q UPCONVERTER / TRANSMITTERS

RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Sideband Rejection (dBc)	OIP3 (dBm)	Package	ECCN Code	Part Number
5.5 - 8.6	I/Q Upconverter / Transmitter w/ VGA	DC - 3	16.5	-30	29	LC5	EAR99	HMC925LC5
10 - 16	I/Q Upconverter / Transmitter w/ VGA	DC - 3	17	-30	14	LC5	EAR99	HMC924LC5
11 - 17	I/Q Upconverter / Transmitter	DC - 2	13	-20	26	LC5	EAR99	HMC709LC5
16 - 21	I/Q Upconverter / Transmitter	DC - 3.5	12	-20	30	LC5	EAR99	HMC710LC5
17.7 - 23.6	I/Q Upconverter / Transmitter	DC - 3.5	15	-35	35	LC5	EAR99	HMC819LC5
21 - 27	I/Q Upconverter / Transmitter	DC - 3.75	12	-20	27	LC5	EAR99	HMC815LC5

MIXERS

RF Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Package	ECCN Code	Part Number
High IP3 Mixers								
0.4 - 0.65	High IP3, 0 LO	DC - 0.25	-9	7	33	MS8G	EAR99	HMC585MS8GE
0.45 - 0.5	High IP3, SGL-END	DC - 0.15	-9.5	20	32	MS8	EAR99	HMC387MS8E
0.5 - 2.7	High IP3, DBL-BAL, +2 LO	DC - 1	-8	28	28	LP4	EAR99	HMC915LP4E
0.7 - 1.0	High IP3, SGL-END	DC - 0.25	-8.5	24	35	MS8	EAR99	HMC399MS8E
0.7 - 1.0	High IP3, DBL-BAL, 0 LO	DC - 0.45	-7	23	32	LP4	EAR99	HMC684LP4E
0.7 - 1.1	High IP3, DBL-BAL, 0 LO	0.05 - 0.25	-7.5	24	40	LP4	EAR99	HMC786LP4
0.7 - 1.2	High IP3, DBL-BAL	DC - 0.3	-9	42	25	S8	EAR99	HMC351S8E
0.7 - 1.5	High IP3, 0 LO	DC - 0.35	-9	20	33	MS8G	EAR99	HMC483MS8GE
0.7 - 1.5	High IP3, DBL-BAL, 0 LO	DC - 0.5	-7.5	24	34	LP4	EAR99	HMC686LP4E
0.8 - 1.2	High IP3, DBL-BAL, 0 LO	DC - 0.3	-8	27	27	LP4	EAR99	HMC551LP4E
1.5 - 3.5	High IP3, DBL-BAL	DC - 1	-8	38	25	MS8	EAR99	HMC316MS8E
1.6 - 3.0	High IP3, DBL-BAL, 0 LO	DC - 1	-8	30	25	LP4	EAR99	HMC552LP4E
1.7 - 2.2	High IP3, SGL-END	DC - 0.3	-8.8	30	36	MS8	EAR99	HMC400MS8E
1.7 - 2.2	High IP3, DBL-BAL, 0 LO	DC - 0.5	-8	30	35	LP4	EAR99	HMC685LP4E
1.7 - 2.2	High IP3, DBL-BAL, 0 LO	DC - 0.5	-8	31	34	LP4	EAR99	HMC687LP4E
1.7 - 2.2	High IP3, DBL-BAL, 0 LO	0.05 - 0.30	-8	30	38	LP4	EAR99	HMC785LP4E
1.7 - 2.4	High IP3, SGL-END	0.05 - 0.3	-9.2	10	34	MS8G	EAR99	HMC485MS8GE
1.7 - 3.0	High IP3, SGL-BAL	DC - 0.8	-9	30	30	MS8	EAR99	HMC304MS8E
1.7 - 4.0	High IP3, DBL-BAL, +4 LO	DC - 1.0	-8	32	25	LP4	EAR99	HMC215LP4E
1.8 - 2.2	High IP3, SGL-END	DC - 0.5	-8.5	25	31	MS8	EAR99	HMC402MS8E
2.0 - 2.7	High IP3, DBL-BAL, 0 LO	DC - 0.45	-7.5	25	31	LP4	EAR99	HMC688LP4E
2.0 - 2.7	High IP3, DBL-BAL, 0 LO	DC - 0.45	-7.5	26	31	LP4	EAR99	HMC689LP4E
2.3 - 4.0	High IP3, +4 LO	DC - 1	-10	15	35	LP4	EAR99	HMC615LP4E
2.4 - 4.0	High IP3, SGL-END	DC - 1	-10	30	34	MS8	EAR99	HMC214MS8E
3.1 - 3.9	High IP3, DBL-BAL, 0 LO	DC - 0.6	-8.5	28	30	LP4	EAR99	HMC666LP4E
6 - 12	High IP3, DBL-BAL	DC - 4	-8	40	30	LC3	EAR99	HMC663LC3
9 - 15	High IP3, DBL-BAL	DC - 2.5	-7.5	40	24	MS8G	EAR99	HMC410AMS8GE
Downconverter RFICs								
0.7 - 1.0	Downconverter	0.05 - 0.25	12.5	25	15	QS16	EAR99	HMC420QS16E
0.7 - 1.0	High IP3, Dual Downconverter	0.06 - 0.5	7.5	16	23	LP6C	EAR99	HMC683LP6CE
0.8 - 0.96	High IP3 Dual Downconverter	0.05 - 0.3	9	4	26	LP6	EAR99	HMC581LP6E
0.8 - 1.0	High IP3 Downconverter	0.05 - 0.25	13.8	28	15	QS16G	EAR99	HMC377QS16GE
0.8 - 2.7	Hi-IP3 Wideband Downconverter	0.001 - 0.6	-1	48	26	LP4	EAR99	HMC334LP4E
0.9 - 1.6	Hi-IP3 Downconverter with RF Amplifier	0.05 - 0.5	30	45	6	LP4	EAR99	HMC621LP4E
1.4 - 2.3	High IP3 Downconverter	0.05 - 0.3	9	33	19	QS16G	EAR99	HMC421QS16E
1.7 - 2.2	High IP3 Downconverter	0.05 - 0.3	11	25	19	QS16G	EAR99	HMC380QS16GE
1.7 - 2.2	High IP3, Dual Downconverter	50 - 300	9	10	27	LP6	EAR99	HMC381LP6E
1.7 - 2.2	High IP3, Dual Downconverter	0.06 - 0.4	6	25	25	LP6C	EAR99	HMC682LP6CE
1.8 - 2.7	High IP3 Downconverter with RF Amplifier	0.05 - 0.65	33	45	11	LP4	EAR99	HMC623LP4E
0 to +7 dBm LO Double & Single Balanced Mixers								
0.6 - 1.3	Low LO, DBL-BAL	DC - 0.4	-8	35	15	MS8	EAR99	HMC423MS8E
0.7 - 1.2	0 LO, DBL-BAL	0.25 - 0.45	10	36	23	LP4	EAR99	HMC665LP4E
1.2 - 2.6	Low LO, DBL-BAL	DC - 1	-8	30	15	MS8	EAR99	HMC422MS8E
1.8 - 3.9	+3 LO, DBL-BAL	0.2 - 0.55	9	33	23	LP4	EAR99	HMC622LP4E
3 - 3.8	Low LO, SGL-BAL	DC - 1	-8.5	15	10	SOT26	EAR99	HMC333E
4 - 7	0 LO, DBL-BAL	DC - 2.5	-7	32	15	MS8G	EAR99	HMC488MS8GE
4.5 - 6.0	+7 LO, DBL-BAL	DC - 1.6	-7	30	18	MS8	EAR99	HMC218MS8E
+10 dBm LO Double & Single Balanced Mixers								
0.7 - 2.0	+10 LO, DBL-BAL	DC - 0.3	-9	45	17	S8	EAR99	HMC207S8E
0.7 - 2.0	+10 LO, DBL-BAL	DC - 0.5	-9	24	17	MS8	EAR99	HMC208MS8E
1.5 - 4.5	+10 LO, DBL-BAL	DC - 1.5	-8.5	40	19	MS8	EAR99	HMC213AMS8E
1.7 - 3.0	+10 LO, SGL-BAL	DC - 0.8	-9	30	21	MS8	EAR99	HMC272MS8E
1.7 - 3.5	+10 LO, SGL-BAL	DC - 0.9	-9	30	21	SOT26	EAR99	HMC285E
4.5 - 8.0	+10 LO, DBL-BAL	DC - 2	-8.2	35	16	C8	EAR99	HMC168C8
5 - 12	+10 LO, DBL-BAL	DC - 4	-7.5	25	17	MS8	EAR99	HMC220MS8E

SMT & Chip (Die) Products

MIXERS

RF Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Package	ECCN Code	Part Number
7 - 10	+10 LO, DBL-BAL	DC - 2	-9	32	16	C8	EAR99	HMC171C8
+13 to +14 dBm LO Double & Single Balanced Mixers								
0.7 - 1.2	+13 LO, SGL-BAL	DC - 0.3	-9	26	21	MS8	EAR99	HMC277MS8E
1.7 - 4.5	+13 LO, DBL-BAL	DC - 1	-8	30	20	MS8	EAR99	HMC175MS8E
1.7 - 4.5	+13 LO, Dual Channel	DC - 1.5	-8	-	23	LP5	EAR99	HMC340ALP5E
2.5 - 4.0	+13 LO, DBL-BAL	DC - 2	-9	45	18	C8	EAR99	HMC170C8
4.5 - 9.0	+13 LO, DBL-BAL	DC - 2.5	-8.5	25	21	MS8	EAR99	HMC219AMS8E
6 - 26	+13 LO, DBL-BAL	DC - 10	-9	32	20	Chip	EAR99	HMC773
6 - 26	+13 LO, DBL-BAL	DC - 8	-9	38	22	LC3B	EAR99	HMC773LC3B
7 - 14	+13 LO, DBL-BAL	DC - 5	-7	48	22	Chip	EAR99	HMC553
7 - 14	+13 LO, DBL-BAL	DC - 5	-7	50	22	LC3B	EAR99	HMC553LC3B
7 - 34	+13 LO, DBL-BAL	DC - 8	-11	35	22	LC3B	EAR99	HMC774LC3B
7 - 43	+13 LO, DBL-BAL	DC - 10	-9	35	22	Chip	EAR99	HMC774
9 - 15	+13 LO, DBL-BAL	DC - 2.5	-7.5	40 - 50	17	MS8G	EAR99	HMC412AMS8GE
10 - 15	+13 LO, SGL-BAL	DC - 3	-9	27	16	MS8G	EAR99	HMC411MS8GE
11 - 20	+13 LO, DBL-BAL	DC - 6	-7	46	18	Chip	EAR99	HMC554
11 - 20	+13 LO, DBL-BAL	DC - 6	-7	46	18	LC3B	EAR99	HMC554LC3B
14 - 26	+13 LO, DBL-BAL	DC - 8	-7.5	39	20	Chip	EAR99	HMC260
14 - 26	+13 LO, DBL-BAL	DC - 8	-7.5	38	20	LC3B	EAR99	HMC260LC3B
16 - 30	+13 LO, DBL-BAL	DC - 8	-8	40	21	LC3B	EAR99	HMC292LC3B
17 - 31	+13 LO, DBL-BAL	DC - 6	-8	32	19	LM3C	EAR99	HMC292LM3C
18 - 32	+13 LO, DBL-BAL	DC - 8	-7.5	38	19	Chip	EAR99	HMC292
24 - 32	+13 LO, DBL-BAL	DC - 8	-10	38	19	LC3B	EAR99	HMC329LC3B
24 - 40	+13 LO, DBL-BAL	DC - 18	-8	35	21	Chip	EAR99	HMC560
24 - 40	+13 LO, DBL-BAL	DC - 17	-10	35	21	LM3	EAR99	HMC560LM3
25 - 40	+13 LO, DBL-BAL	DC - 8	-9.5	42	19	Chip	EAR99	HMC329
26 - 40	+13 LO, DBL-BAL	DC - 8	-8	37	19	LM3	EAR99	HMC329LM3
54 - 64	+13 LO, DBL-BAL	DC - 5	-8	30	13	Chip	5A991.h	HMC-MDB169
70 - 90	+14 LO, DBL-BAL	DC - 18	-12	-	-	Chip	5A991.h	HMC-MDB277
+15 to +20 dBm LO Double & Single Balanced Mixers								
1.8 - 5.0	+15 LO, DBL-BAL	DC - 3	-7	42	18	Chip	EAR99	HMC128
1.8 - 5.0	+15 LO, DBL-BAL	DC - 2	-10	40	18	G8 Hermetic	EAR99	HMC128G8
2.5 - 7	+15 LO, DBL-BAL	DC - 3	-7	48	22	Chip	EAR99	HMC557
2.5 - 7	+15 LO, DBL-BAL	DC - 3	-7	48	22	LC4	EAR99	HMC557LC4
4 - 8	+15 LO, DBL-BAL	DC - 3	-7	40	17	Chip	EAR99	HMC129
4 - 8	+15 LO, DBL-BAL	DC - 3	-8	30	18	G8 Hermetic	EAR99	HMC129G8
4 - 8	+15 LO, DBL-BAL	DC - 3	-7	40	17	LC4	EAR99	HMC129LC4
5.5 - 14	+15 LO, DBL-BAL	DC - 6	-7	45	24	Chip	EAR99	HMC558
5.5 - 14	+15 LO, DBL-BAL	DC - 6	-7	45	24	LC3B	EAR99	HMC558LC3B
6 - 11	+15 LO, DBL-BAL	DC - 2	-7	40	17	Chip	EAR99	HMC130
6 - 15	+15 LO, DBL-BAL	DC - 2	-8.5	35	20	C8	EAR99	HMC141C8 / 142C8
6 - 18	+15 LO, DBL-BAL	DC - 6	-10	25	21	Chip	EAR99	HMC141 / 142
7 - 14	+15 LO, DBL-BAL	DC - 2	-10	35	20	LH5 Hermetic	EAR99	HMC141LH5
14 - 23	+15 LO, DBL-BAL	DC - 2	-10.5	38	18	Chip	EAR99	HMC203
3 - 10	+17 LO, DBL-BAL	DC - 4	-9	55	23	LC3B	EAR99	HMC787LC3B
5 - 20	+20 LO, DBL-BAL	DC - 3	-10	30	25	Chip	EAR99	HMC143 / 144
6 - 20	+20 LO, DBL-BAL	DC - 3	-10	35	23	LC4	EAR99	HMC144LC4
6 - 20	+20 LO, DBL-BAL	DC - 3	-10	35	24	LH5 Hermetic	EAR99	HMC144LH5
Sub-Harmonic Mixers								
14 - 20	Sub-Harmonic	DC - 3	-10	40	7	LM3	EAR99	HMC258LM3
14 - 21	Sub-Harmonic	DC - 3	-10	40	7	Chip	EAR99	HMC258
14.5 - 19.5	Sub-Harmonic	DC - 3.5	-10	45	5	LC3B	EAR99	HMC258LC3B
17 - 25	Sub-Harmonic	DC - 3	-9	27	10	Chip	EAR99	HMC337
17.7 - 23.6	Sub-Harmonic, Upconverter	DC - 3.5	15	40	13	LC5	EAR99	HMC711LC5
20 - 30	Sub-Harmonic	DC - 4	-9	30	10	LM3	EAR99	HMC264LM3
20 - 31	Sub-Harmonic, Downconverter	0.7 - 3.0	3	28	8	LM3	EAR99	HMC265LM3
20 - 32	Sub-Harmonic	DC - 6	-10	40	13	Chip	EAR99	HMC264
20 - 32	Sub-Harmonic, Downconverter	0.7 - 3.0	3	30	10	Chip	EAR99	HMC265
20 - 40	Sub-Harmonic	1 - 3	-12	24	13	Chip	EAR99	HMC266
21 - 31	Sub-Harmonic	DC - 6	-9	40	13	LC3B	EAR99	HMC264LC3B
24 - 34	Sub-Harmonic	DC - 3	-11	33	13	LC3B	5A991.b	HMC338LC3B
24 - 34	Sub-Harmonic	DC - 4	-10	30	22	LC4	EAR99	HMC798LC4
26 - 33	Sub-Harmonic	DC - 2.5	-9	33	11	Chip	5A991.b	HMC338
33 - 42	Sub-Harmonic	DC - 3	-10	37	10	Chip	EAR99	HMC339

DEMODULATORS - *I/Q Demodulator*

Input Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Noise Figure (dB)	IIP3 / IIP2 (dBm)	Package	ECCN Code	Part Number
0.1 - 4.0	I/Q Demodulator	DC - 0.6	-3.5	15	+25 / +60	LP4	EAR99	HMC597LP4E

MODULATORS - *Bi-Phase Modulator*

Input Frequency (GHz)	Function	Loss (dB)	Amp / Phase Balance (dB/Deg)	Carrier Suppression (dBc)	Bias Control (mA)	Package	ECCN Code	Part Number
1.8 - 5.2	Bi-Phase	8	0.2 / 2.5	30	+/- 5	Chip	EAR99	HMC135
4 - 8	Bi-Phase	8	0.1 / 4.0	30	+/- 5	Chip	EAR99	HMC136
6 - 11	Bi-Phase	9	0.25 / 10.0	20	+/- 5	Chip	EAR99	HMC137

MODULATORS - *Direct Quadrature Modulator*

Input Freq. (GHz)	Function	OIP3 (dBm) / Carrier Suppression (dBc)	Modulation Bandwidth (MHz)	Output Noise Floor (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
0.02 - 2.7	Direct Quadrature	23 / 42	DC - 700	-162	+5V @ 160mA	LP4	EAR99	HMC696LP4E
0.05 - 2.7	Direct Quadrature with VGA	25 / 50	DC - 440	-159	+5V @ 120mA	LP5	3A001.a.11.b	HMC795LP5E
0.1 - 4	Direct Quadrature	23 / 42	DC - 700	-159	+5V @ 170mA	LP4	EAR99	HMC497LP4E
0.25 - 3.8	Direct Quadrature	14 / 38	DC - 250	-158	+3.3V @ 108mA	LP3	EAR99	HMC495LP3E
0.45 - 4.0	Direct Quadrature	22 / 43	DC - 700	-165	+5V @ 168mA	LP4	EAR99	HMC697LP4E
4 - 7	Direct Quadrature	17 / 34	DC - 250	-157	+3V @ 93mA	LP3	EAR99	HMC496LP3E

MODULATORS - *Vector Modulators*

Frequency (GHz)	Function	Gain Range (dB)	Continuous Phase Control (deg)	IP3 / Noise Floor (Ratio)	IIP3 @ Max. Gain (dBm)	Package	ECCN Code	Part Number
0.7 - 1.0	Vector	-50 to -10	360	186.5	34	LP3	EAR99	HMC630LP3E
1.8 - 2.7	Vector	-50 to -10	360	186	35	LP3	EAR99	HMC631LP3E
1.8 - 2.2	Vector	-50 to -10	360	185	33	LP3	EAR99	HMC500LP3E

PASSIVES - *Fixed Attenuators*

Frequency (GHz)	Function	Attenuation Accuracy (dB)	Nominal Attenuation (dB)	Maximum Input Power (dBm)	Chip Size (Mils)	Package	ECCN Code	Part Number
DC - 50	Thru Line	±0.2	0.15	-	17 x 18	Chip	EAR99	HMC650
DC - 50	Thru Line	±0.3	0.15	-	23 x 18	Chip	EAR99	HMC651
DC - 50	Passive	±0.2	2	27	17 x 18	Chip	EAR99	HMC652
DC - 25	Passive	±0.5	2	27	-	LP2	EAR99	HMC652LP2E
DC - 50	Passive	±0.2	3	26	17 x 18	Chip	EAR99	HMC653
DC - 25	Passive	±0.5	3	26	-	LP2	EAR99	HMC653LP2E
DC - 50	Passive	±0.2	4	25	17 x 18	Chip	EAR99	HMC654
DC - 25	Passive	±0.5	4	25	-	LP2	EAR99	HMC654LP2E
DC - 50	Passive	±0.2	6	26	17 x 18	Chip	EAR99	HMC655
DC - 25	Passive	±0.5	6	26	-	LP2	EAR99	HMC655LP2E
DC - 50	Passive	±0.1	10	25	17 x 18	Chip	EAR99	HMC656
DC - 25	Passive	±1.5	10	25	N/A	LP2	EAR99	HMC656LP2E
DC - 50	Passive	±0.4	15	25	17 x 18	Chip	EAR99	HMC657
DC - 25	Passive	±2	15	25	N/A	LP2	EAR99	HMC657LP2E
DC - 50	Passive	±0.5	20	25	23 x 18	Chip	EAR99	HMC658
DC - 25	Passive	±2	20	25	N/A	LP2	EAR99	HMC658LP2E

PHASE SHIFTERS - *Analog*

	Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	2nd Harmonic Pin = -10 dBm (dBc)	Control Voltage Range (Vdc)	Package	ECCN Code	Part Number
	2 - 4	Analog	3.5	480° @ 2 GHz 450° @ 4 GHz	-40	0V to +13V	LP5	EAR99	HMC928LP5E
NEW!	2 - 20	Analog	4	270° @ 2 GHz 180° @ 20 GHz	-45	0.5 to +11V	LP5	EAR99	HMC935LP5E
	4 - 8	Analog	4	450° @ 4 GHz 430° @ 8 GHz	-40	0V to +13V	LP4	EAR99	HMC929LP4E
	5 - 18	Analog	4	500° @ 5 GHz 100° @ 18 GHz	-80	0V to +10V	Chip	EAR99	HMC247
	6 - 15	Analog	7	750° @ 6 GHz 500° @ 15 GHz	-40	0V to +5V	LP4	EAR99	HMC538LP4E
	8 - 12	Analog	3.5	425° @ 8 GHz 405° @ 12 GHz	-35	0 to +13V	LP4	EAR99	HMC931LP4E
	12 - 18	Analog	4	405° @ 12 GHz 385° @ 18 GHz	-40	0 to +13V	LP4	EAR99	HMC932LP4E
	18 - 24	Analog	4.5	495° @ 18 GHz 460° @ 24 GHz	-37	0 to +13V	LP4	EAR99	HMC933LP4E

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SMT & Chip (Die) Products

PHASE SHIFTERS - Digital

Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	IIP3 (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
8 - 12	-Bit Digital	5	22.5 to 360	40	0 / -3V	Chip	EAR99	HMC543
8 - 12	4-Bit Digital	6.5	22.5 to 360	37	0 / -3V	LC4B	EAR99	HMC543LC4B
15 - 18.5	5-Bit Digital	7	11.25 to 360	40	0 / -3	Chip	EAR99	HMC644
15 - 18.5	5-Bit Digital	7	11.25 to 360	40	0 / -3	LC5	EAR99	HMC644LC5
1.2 - 1.4	6-Bit Digital	4	5.625 to 360	45	0 / +5V	LP6	EAR99	HMC936LP6E
2.5 - 3.1	6-Bit Digital	4	5.625 to 360	54	0 / +5	Chip	EAR99	HMC647
2.5 - 3.1	6-Bit Digital	4	5.625 to 360	54	0 / +5	LP6	EAR99	HMC647LP6E
2.9 - 3.9	6-Bit Digital	4	5.625 to 360	45	0 / +5	Chip	EAR99	HMC648
2.9 - 3.9	6-Bit Digital	5	5.625 to 360	45	0 / +5	LP6	EAR99	HMC648LP6E
3 - 6	6-Bit Digital	6.5	5.625 to 360	44	0 / +5	Chip	EAR99	HMC649
3 - 6	6-Bit Digital	8	5.625 to 360	44	0 / +5	LP6	EAR99	HMC649LP6E
9 - 12	6-Bit Digital	6.5	5.625 to 360	38	0 / -3	Chip	EAR99	HMC643
9 - 12	6-Bit Digital	7	5.625 to 360	38	0 / -3	LC5	EAR99	HMC643LC5
9 - 12.5	6-Bit Digital	6.5	5.625 to 360	41	0 / +5	Chip	EAR99	HMC642
9 - 12.5	6-Bit Digital	7	5.625 to 360	41	0 / +5	LC5	EAR99	HMC642LC5

POWER DETECTORS - Log Detector/Controllers & RMS Detectors

	Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV/dB)	RF Threshold Level (dBm)	Bias Supply	Package	ECCN Code	Part Number
	50 Hz - 3.0	Log Detector / Controller	74 ±3	19	-66	+3.3V @ 29mA	LP4	EAR99	HMC612LP4E
	0.001 - 8.0	Log Detector / Controller	70 ±3	-25	-61	+5V @ 113mA	LP4	EAR99	HMC602LP4E
	0.001 - 10.0	Log Detector / Controller	73 ±3	-25	-65	+5V @ 103mA	Chip	EAR99	HMC611
	0.001 - 10.0	Log Detector / Controller	70 ±3	-25	-65	+5V @ 106mA	LP4	EAR99	HMC611LP4E
	0.01 - 4.0	Log Detector / Controller	70 ±3	19	-68	+3.3V @ 30mA	LP4	EAR99	HMC601LP4E
	0.05 - 4.0	Log Detector / Controller	70 ±3	19	-69	+3.3V @ 29mA	LP4	EAR99	HMC600LP4E
	0.05 - 8.0	Log Detector / Controller	54 ±1	17.5	-55	+5V @ 17mA	LP3	EAR99	HMC713LP3E
	0.1 - 2.7	Log Detector / Controller	54 ±1	17.5	-52	+5V @ 17mA	MS8	EAR99	HMC713MS8E
	8 - 30	Log Detector	54 ±3	13.3	-55	+3.3V @ 88mA	LP3	EAR99	HMC662LP3E
	1 - 23	mmW Power Detector	56 ±3	14.2	-52	+3.3V @ 91mA	LP3	3A001.b.2.c	HMC948LP3E
	DC - 3.9	RMS Power Detector	60 ±1	37	-69	+5V @ 50mA	LP4	EAR99	HMC1010LP4E
	DC - 3.9	RMS, Single-Ended	72 ±1	35	-68	+5V @ 55 mA	LP4	EAR99	HMC1020LP4E
	DC - 3.9	RMS, Single-Ended with Envelope Tracker	70 ±1	35	-68	+5V @ 75 mA	LP4	EAR99	HMC1021LP4E
NEW!	DC - 3.9	Dual RMS, Single-Ended	70 ±1	38.5	-66	+5V @ 143mA	LP5	EAR99	HMC1030LP5E
	DC - 5.8	RMS Power Detector	40 ±1	37	-69	+5V @ 42mA	LP4	EAR99	HMC909LP4E

SDLVAs - Successive Detection Log Video Amplifiers

Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV/dB)	RF Threshold Level (dBm)	Bias Supply	Package	ECCN Code	Part Number
0.1 - 20	SDLVA	59	14	-54	+3.3V @ 83mA	LC4B	EAR99	HMC613LC4B
0.6 - 20	SDLVA	59	14	-54	+3.3V @ 80mA	Chip	EAR99	HMC913
0.6 - 20	SDLVA	59	14	-54	+3.3V @ 80mA	LC4B	EAR99	HMC913LC4B
1 - 20	SDLVA with Limited RF Output	55	15	-53	+3.3V @ 153mA	LC4B	EAR99	HMC813LC4B
1 - 26	SDLVA with Limited RF Output	55	14.5	-53	+3.3V @ 150mA	Chip	EAR99	HMC813

SWITCHES

Frequency (GHz)	Function	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
SPST & SPDT Switches								
DC - 6	SPST, Failsafe	0.7	25	27	0 / +2.2 to +5V	SOT26	EAR99	HMC550E
DC - 6	SPST, High Isolation	1.4	52	27	0 / -5V	G7 Hermetic	EAR99	HMC231G7
DC - 3	SPDT, Reflective	0.4	27	30	0 / +3V	MS8	EAR99	HMC190AMS8E
DC - 3	SPDT, High Isolation	0.7	50	23	0 / +5V	MS8	EAR99	HMC194MS8E
DC - 3	SPDT, Reflective	0.4	28	30	0 / +3V	SOT26	EAR99	HMC197AE
DC - 3	SPDT, Reflective	0.4	28	30	0 / +3V	SOT26	EAR99	HMC221AE
DC - 3	SPDT, Reflective	0.3	31	34	0 / +3 to +8V	SOT26	EAR99	HMC545E
DC - 3.5	SPDT, High Isolation	0.5	45	25	0 / +5V	MS8G	EAR99	HMC284MS8GE
DC - 4	SPDT, High Isolation	0.9	65	31	0 / +5V	LP4C	EAR99	HMC349LP4CE
DC - 4	SPDT, High Isolation	0.9	57	31	0 / +5V	MS8G	EAR99	HMC349MS8GE
DC - 4	SPDT, High Isolation	1.1	47	31	0 / +5V	MS8G	EAR99	HMC435MS8GE
DC - 4	SPDT, Differential	0.8	45	35	0 / +3V to	LP4	EAR99	HMC922LP4E
DC - 6	SPDT, High Isolation	1.4	50	26	0 / -5V	G7 Hermetic	EAR99	HMC232G7
DC - 6	SPDT, High Isolation	1.4	43	26	0 / -5V	G8 Hermetic	EAR99	HMC232G8
DC - 6	SPDT, High Isolation	1.4	43	26	0 / -5V	G8 Hermetic	EAR99	HMC233G8
DC - 6	SPDT, High Isolation	1.6	42	25	0 / +5V	MS8G	EAR99	HMC336MS8GE
DC - 6	SPDT, High Isolation	1.4	46	27	0 / -5V	G7 Hermetic	EAR99	HMC607G7
DC - 6	SPDT, High Isolation	0.8	60	35	0 / +3 to +5V	LP4C	EAR99	HMC849LP4CE

SWITCHES

Frequency (GHz)	Function	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Control Input (Vdc)	Package	ECCN Code	Part Number
DC - 8	SPDT, High Isolation	1.4	50	26	0 / -5V	C8	EAR99	HMC232C8
DC - 8	SPDT, High Isolation	1.5	45	26	0 / -5V	C8	EAR99	HMC234C8
DC - 8	SPDT, High Isolation	1.2	48	23	0 / -5V	MS8G	EAR99	HMC270MS8GE
DC - 8	SPDT, High Isolation	2.0	44	23	0 / -5V	C8	EAR99	HMC347C8
DC - 8	SPDT, High Isolation	2.2	35	23	0 / -5V	G8 Hermetic	EAR99	HMC347G8
DC - 12	SPDT, High Isolation	1.5	55	27	0 / -5V	LP4	EAR99	HMC232LP4E
DC - 14	SPDT, High Isolation	1.7	44	23	0 / -5V	LP3	EAR99	HMC347LP3E
DC - 15	SPDT, High Isolation	1.4	50	26	0 / -5V	Chip	EAR99	HMC232
DC - 15	SPDT, High Isolation	1.7	60	26	0 / -5V	Chip	EAR99	HMC607
DC - 20	SPDT, High Isolation	1.7	45	23	0 / -5V	Chip	EAR99	HMC347
DC - 20	SPDT, High Isolation	1.8	47	23	0 / -5V	LP3	EAR99	HMC547LP3E
55 - 86	SPDT, PIN MMIC	2	30	-	-5 / +5	Chip	5A991.h	HMC-SDD112
0.1 - 2.1	SPDT, 40W, Failsafe	0.4	22	46	0 / +3V to +8V	LP2	EAR99	HMC646LP2E
0.2 - 2.2	SPDT, 10W, Failsafe	0.4	40	> 40	0 / +3 to +8V	MS8G	EAR99	HMC546MS8GE
0.2 - 2.7	SPDT, 10W, Failsafe	0.4	35	43	0 / +3 to +8V	LP2	EAR99	HMC546LP2E
0.824 - 0.894	SPDT, 10W, T/R	0.6	22	> 40	0 / +5V	SOT26	EAR99	HMC446E
DC - 2.5	SPDT, CATV	0.6	58	28	0 / +5V	LP3	EAR99	HMC348LP3E
DC - 3	SPDT T/R	0.5	25	39	TTL/CMOS	MS8	EAR99	HMC174MS8E
DC - 3	SPDT, 5W, T/R	0.3	30	39	0 / +3 to +10V	MS8	EAR99	HMC574MS8E
DC - 3	SPDT, 3W, T/R	0.3	30	37	0 / +3 to +10V	SOT26	EAR99	HMC595E
DC - 4	SPDT T/R	0.25	23	39	0 / +3 to +5V	SOT26	EAR99	HMC544E
DC - 4	SPDT, 10W, T/R	0.4	30	40	0 / +3 to +8V	MS8G	EAR99	HMC784MS8GE
DC - 6	SPDT T/R	0.5	27	37	0 / +3 to +5V	MS8G	EAR99	HMC536MS8GE
DC - 6	SPDT T/R	0.6	27	37	0 / +3 to +5V	LP2	EAR99	HMC536LP2E
5 - 6	SPDT T/R	1.2	31	33	TTL/CMOS	MS8	EAR99	HMC224MS8E
Multi-Throw Switches								
DC - 3.5	SP3T	0.5	44	26	TTL/CMOS	QS16	EAR99	HMC245QS16E
DC - 2	SP4T	0.8	32	24	0 / -5V	S14	EAR99	HMC182S14E
DC - 3.5	SP4T	0.5	45	25	TTL/CMOS	QS16	EAR99	HMC241QS16E
DC - 4	SP4T	0.6	47	26	TTL/CMOS	LP3	EAR99	HMC241LP3E
DC - 4	SP4T	0.7	40	25	TTL/CMOS	G16 Hermetic	EAR99	HMC244G16
DC - 8	SP4T	1.8	42	21	0 / -5V	Chip	EAR99	HMC344
DC - 8	SP4T	2.0	45	26	0 / -5V	LC3	EAR99	HMC344LC3
DC - 8	SP4T	1.8	40	21	0 / -5V	LP3	EAR99	HMC344LP3E
DC - 8	SP4T	2.2	32	21	0 / 5V	LP3	EAR99	HMC345LP3E
DC - 12	SP4T	1.8	42	27	0 / -5V	LH5 Hermetic	EAR99	HMC344LH5
DC - 18	SP4T	2.1	42	24	0 / -5V	Chip	EAR99	HMC641
DC - 20	SP4T	2.1	42	23	0 / -5V	LC4	EAR99	HMC641LC4
DC - 20	SP4T	2.3	45	22	0 / -5V	LP4	EAR99	HMC641LP4E
23 - 30	SP4T	2.8	35	25	0 / -3V	LC4	EAR99	HMC944LC4
DC - 3	SP6T	0.8	41	24	TTL/CMOS	QS24	EAR99	HMC252QS24E
DC - 2	SP8T	1.3	30	20	0 / -5V	QS24	EAR99	HMC183QS24E
DC - 2.5	SP8T	1.1	36	23	TTL/CMOS	QS24	EAR99	HMC253QS24E
DC - 3.5	SP8T	1.2	36	24	TTL/CMOS	LC4	EAR99	HMC253LC4
DC - 8	SP8T	2.3	40	23	0 / 5V	LP4	EAR99	HMC321LP4E
DC - 8	SP8T	2.5	25	23	0 / -5V	LP4	EAR99	HMC322LP4E
DC - 10	SP8T	2	38	23	0 / -5V	Chip	EAR99	HMC322
Bypass, Diversity, Matrix & Transfer Switches								
DC - 2.5	Bypass DPDT	0.3	25	23	0 / +5V	MS8	EAR99	HMC199MS8E
5 - 6	DPDT, Diversity	1.2	20	30	0 / +5V	MS8G	EAR99	HMC393MS8GE
0.2 - 3.0	4x2 Matrix	6	44	26	0 / +5V	LP4	EAR99	HMC276LP4E
0.2 - 3.0	4x2 Matrix	6.5	43	22	0 / +3 to +5V	LP4	EAR99	HMC596LP4E
0.7 - 3.0	4x2 Matrix	5.8	33	26	0 / +5V	QS24	EAR99	HMC276QS24E
DC - 8	Transfer	1.2	42	26	0 / +5V	LP3	EAR99	HMC427LP3E

Hittite MICROWAVE CORPORATION

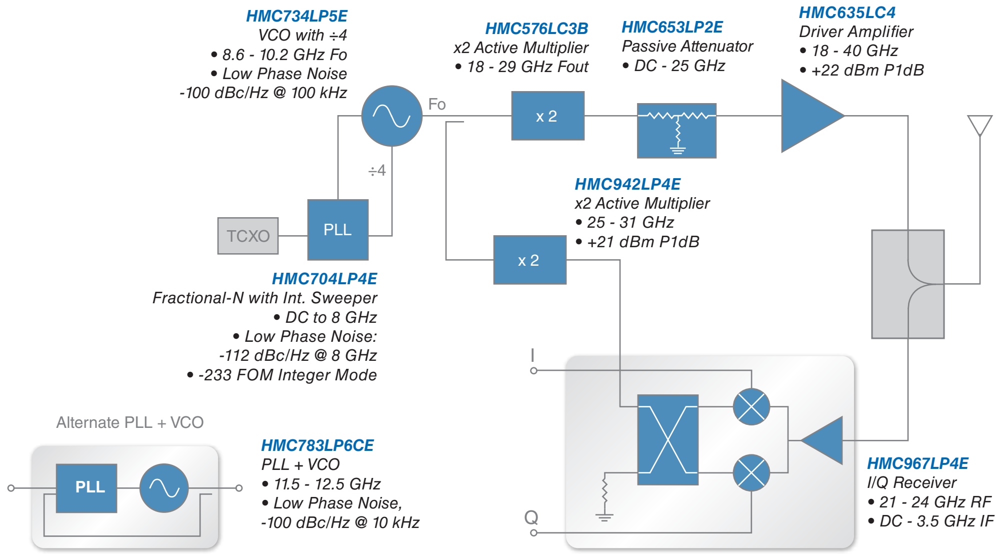
SMT & Chip (Die) Products

VARIABLE GAIN AMPLIFIERS

	Frequency (GHz)	Function	Gain Control Range (dB)	NF * (dB)	OIP3 * (dBm)	P1dB (dBm)	Bias Supply	Package	ECCN Code	Part Number
	0.5 - 6.0	Analog	-35 to 15	7.5	28	21	+5V @ 90mA	LP5	EAR99	HMC972LP5E
	2.3 - 2.5	Analog	-8 to 22	2.5	7	3	+3V @ 9mA	MS8	EAR99	HMC287MS8E
	6 - 17	Analog	0 to 23	5	30	22	+5V @ 170mA	Chip	EAR99	HMC694
	6 - 17	Analog	0 to 23	6	30	22	+5V @ 175mA	LP4	EAR99	HMC694LP4E
	0.03 - 0.4	5-Bit digital, Differential Outputs	-4 to 19	5	40	25	+5V @ 240mA	LP4	EAR99	HMC680LP4E
	0.05 - 0.8	5-Bit Digital	-8 to 15	5	35	18	+5V @ 65mA	LP4	EAR99	HMC628LP4E
	0.07 - 4.0	6-Bit Digital, Serial & Parallel Control	-19.5 to 12	4	39	23	+5V @ 150mA	LP5	EAR99	HMC742LP5E
NEW!	0.5 - 4.0	6-Bit Digital, Serial & Parallel Control or Latched Parallel Control	-19 to 12.5	4	39	21.5	+5V @ 150mA	LP5	EAR99	HMC742HFLP5E
	0.7 - 1.2	6-Bit Digital, Serial & Parallel Control	-2.5 to 29	0.8	38.5	21	+5V @ 236mA	LP5	EAR99	HMC707LP5E
	0.7 - 2.7	6-Bit Digital	6.5 to 38	4.4	45	25	+5V @ 218mA	LP5	EAR99	HMC926LP5E
	DC - 1	6-Bit Digital, Serial & Parallel Control	-11.5 to 20	4.3	36	20	+5V @ 90mA	LP5	EAR99	HMC627LP5E
	DC - 1	6-Bit Digital, Parallel Control	8.5 to 40	2.8	36	20	+5V @ 176mA	LP5	EAR99	HMC626LP5E
	DC - 1	6-Bit Digital, Serial Control	13.5 to 45	2.7	36	20	+5V @ 176mA	LP5	EAR99	HMC681LP5E
	DC - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to 18	6	33	19	+5V @ 88mA	LP5	EAR99	HMC625LP5E
NEW!	0.5 - 6.0	6-Bit Digital, Serial & Parallel Control	-13.5 to 18	6	33	19	+5V @ 88mA	LP5	EAR99	HMC625HFLP5E
	1.7 - 2.2	6-Bit Digital, Serial & Parallel Control	-2.5 to 29	1.0	37.5	21.5	+5V @ 252mA	LP5	EAR99	HMC708LP5E
	DC - 4	12-Bit Digital, Serial Control	-45 to 18	6	33	18	+5V @ 82mA	LP6C	EAR99	HMC743LP6CE

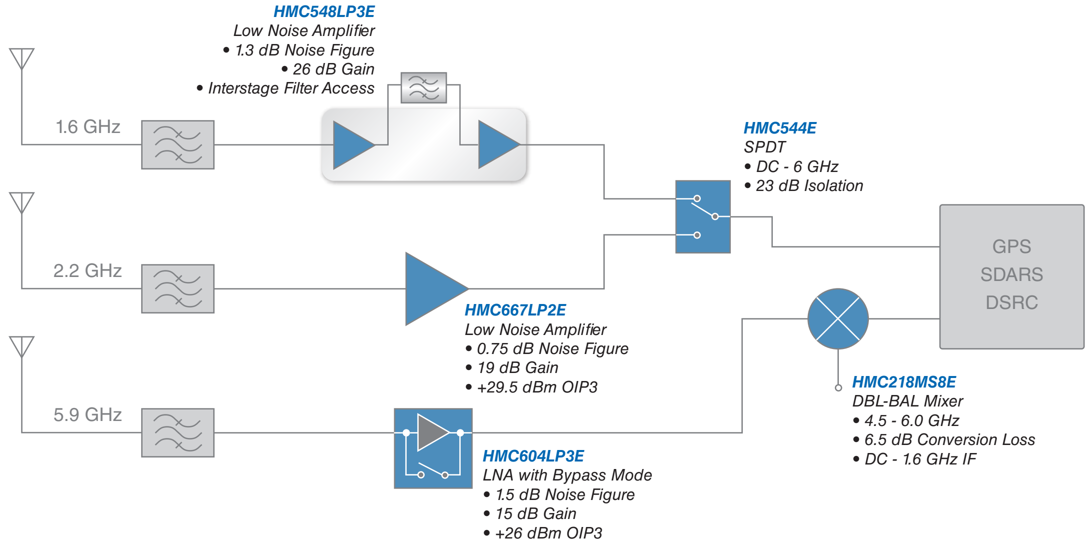
** Maximum Gain State*

24 GHz FMCW Automotive Sensor



Typical Automotive application is illustrated.
See the full product listing for alternatives to the HMC products shown in each functional block.

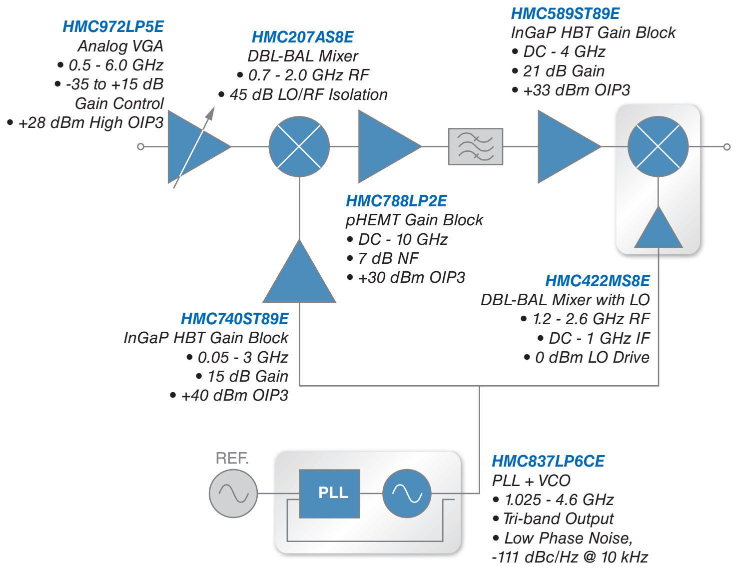
GPS, SDARS & DSRC RF Front-End for Telematics



Typical Automotive application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

CABLE MODEM, CATV, DBS & VoIP SOLUTIONS, 5 - 2150 MHz

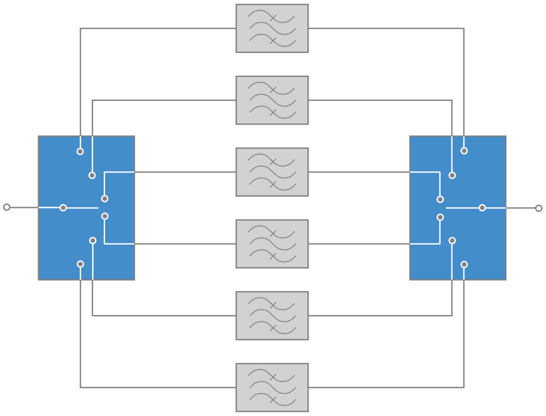
Cable Modem Termination System (CMTS)



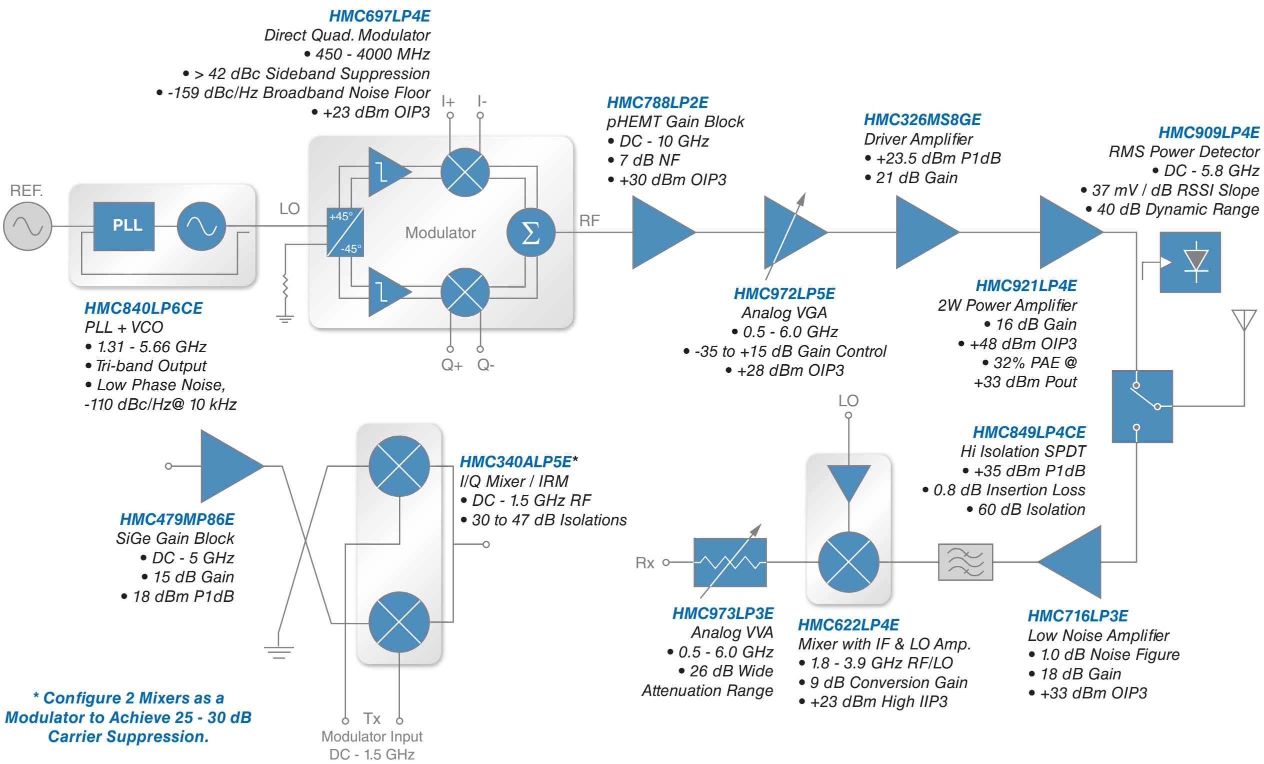
Typical Broadband applications are illustrated. See the full product listing for alternatives to the select HMC products shown in each functional block.

A Selection of SPNT Switches for CATV Filter & Signal Routing

Part Number	Frequency (GHz)	Function	1 GHz Loss / Isolation (dB)
HMC348LP3E	DC - 2.5	SPDT, 75 Ω	0.6 / 58
HMC349LP4CE	DC - 4	SPDT	0.9 / 65
HMC347LP3E	DC - 14	SPDT	1.7 / 44
HMC245QS16E	DC - 3.5	SP3T	0.5 / 44
HMC345LP3E	DC - 8	SP4T	2.2 / 32
HMC252QS24E	DC - 3	SP6T	2.0 / >45
HMC321LP4E	DC - 8	SP8T	2.0 / >45

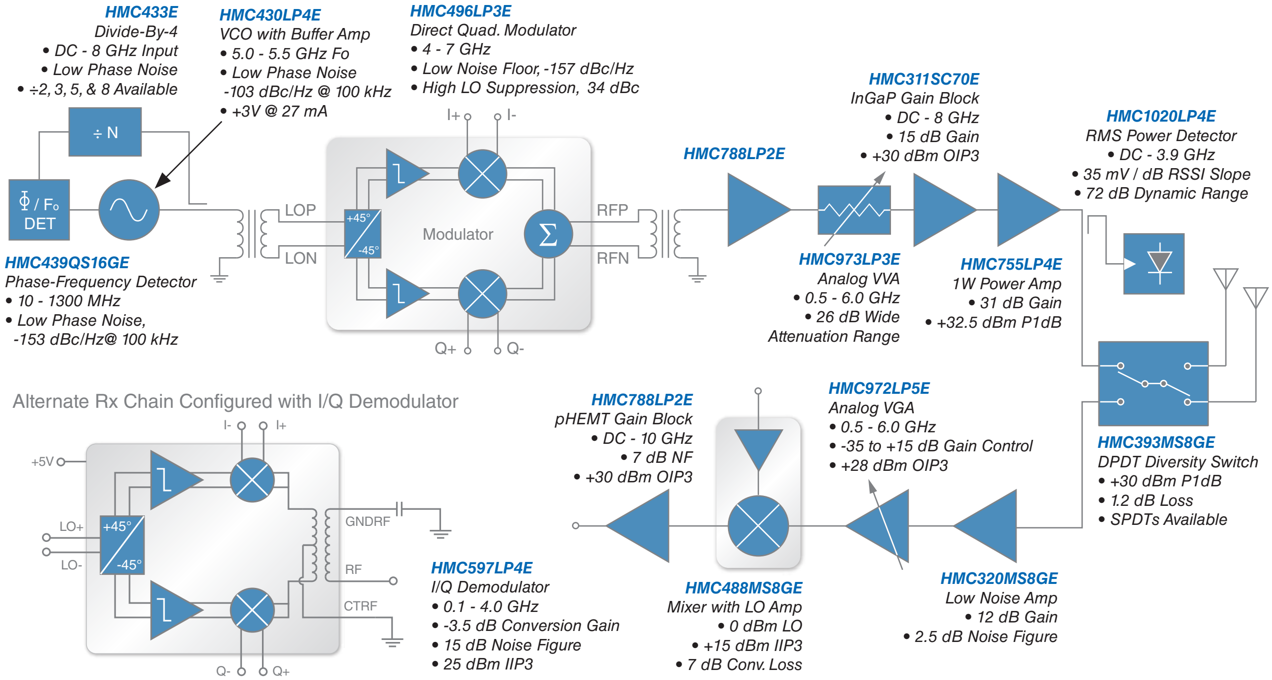


WiMAX & FIXED WIRELESS, 2 - 6 GHz



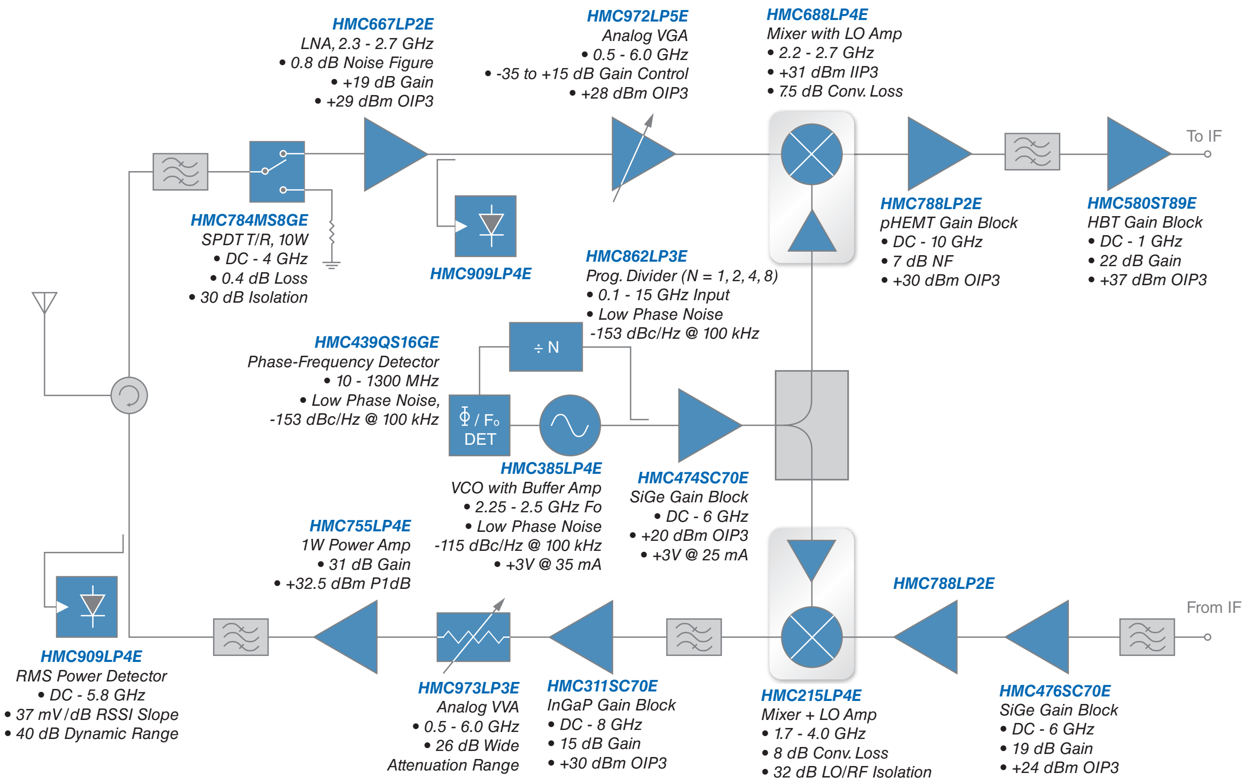
Typical WiMAX / FWA Transceiver is illustrated. See the full product listing for alternatives to the select HMC products shown in each functional block.

WirelessLAN, UWB, UNII & ISM Solutions, 2.4, 4.9, 5.4, 5.8 & 3 - 11 GHz



Typical 4.9 - 5.9 GHz Wi-Fi Access Point application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

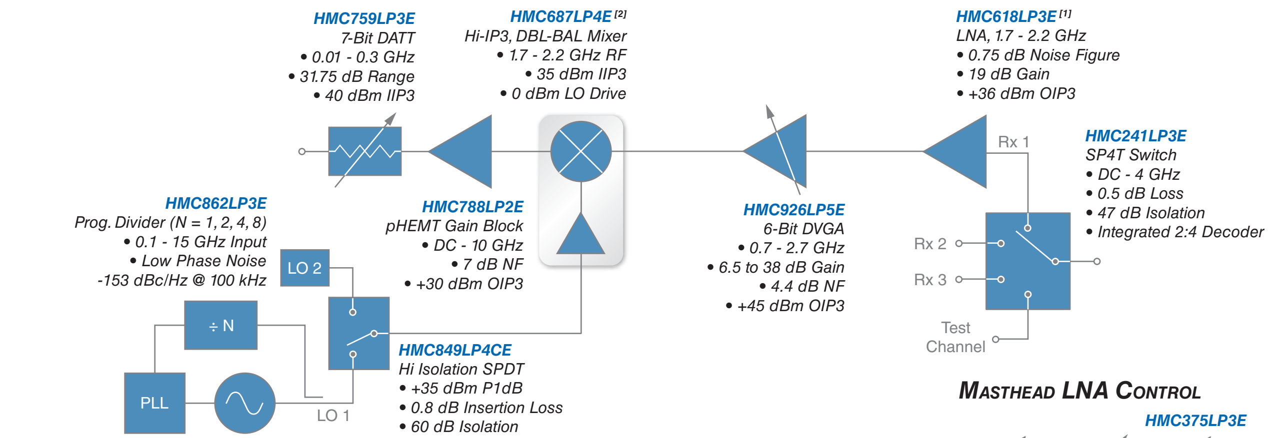
WiBro "Wireless Broadband", 1.82 - 1.87, 2.3 - 2.5 & 3.48 - 3.52 GHz



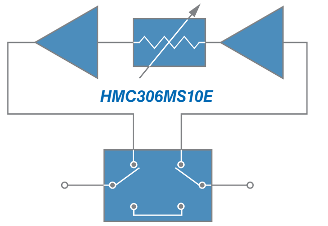
Typical WiBro application is illustrated. See the full product listing for alternatives to the select HMC products shown in each functional block.

Cellular Infrastructure, 380 - 2690 MHz

BTS Receiver Solutions Featuring High IP3 Mixer



Masthead LNA Control



HMC199MS8E
Bypass SPDT Switch
• DC - 2.5 GHz
• 0.3 dB Insertion Loss
• Integrated "Thru-Line"

[1] For 700 - 1000 MHz Systems Use:

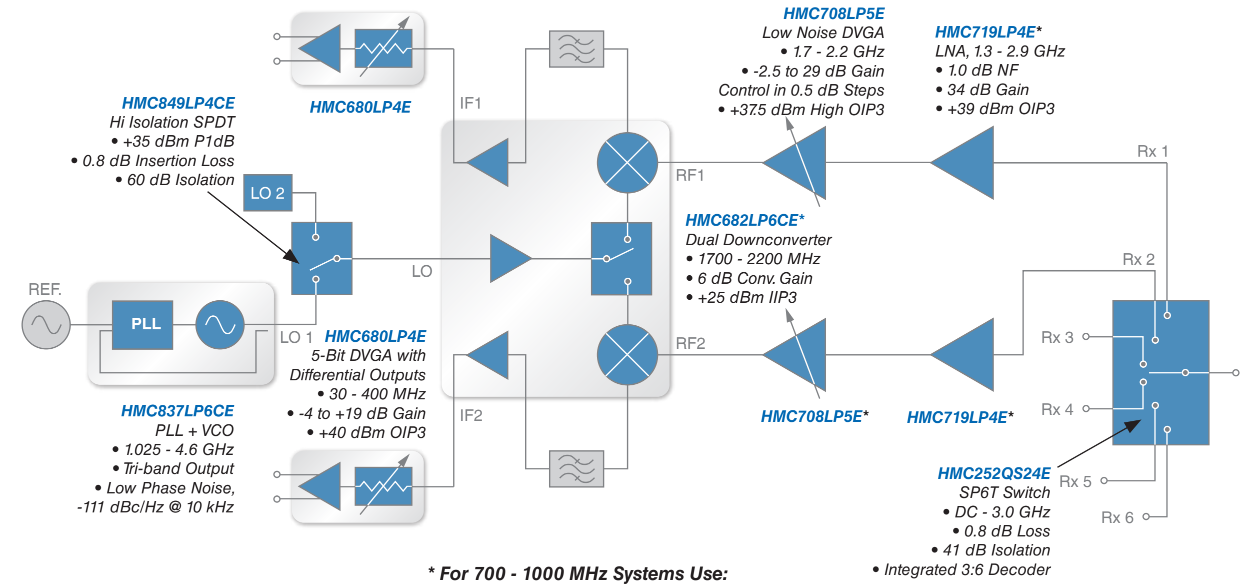
HMC686LP4E	HMC617LP3E
Hi-IP3, DBL-BAL Mixer	LNA, 550 - 1200 MHz
• 0.7 - 1.1 GHz RF	• 0.5 dB Noise Figure
• +34 dBm IIP3	• 16 dB Gain
• 0 dBm LO Drive	• +37 dBm OIP3

[2] For 380 - 500 MHz Systems Use:

HMC585MS8GE	HMC616LP3E
Hi-IP3 Mixer with LO Amp	LNA, 175 - 660 MHz
• 400 - 650 MHz RF	• 0.5 dB Noise Figure
• +33 dBm IIP3	• 24 dB Gain
• 0 dBm LO Drive	• 37 dBm OIP3

Ask About Our Custom VCO Capabilities!

BTS Receiver Solutions Featuring Dual RFIC Downconverter

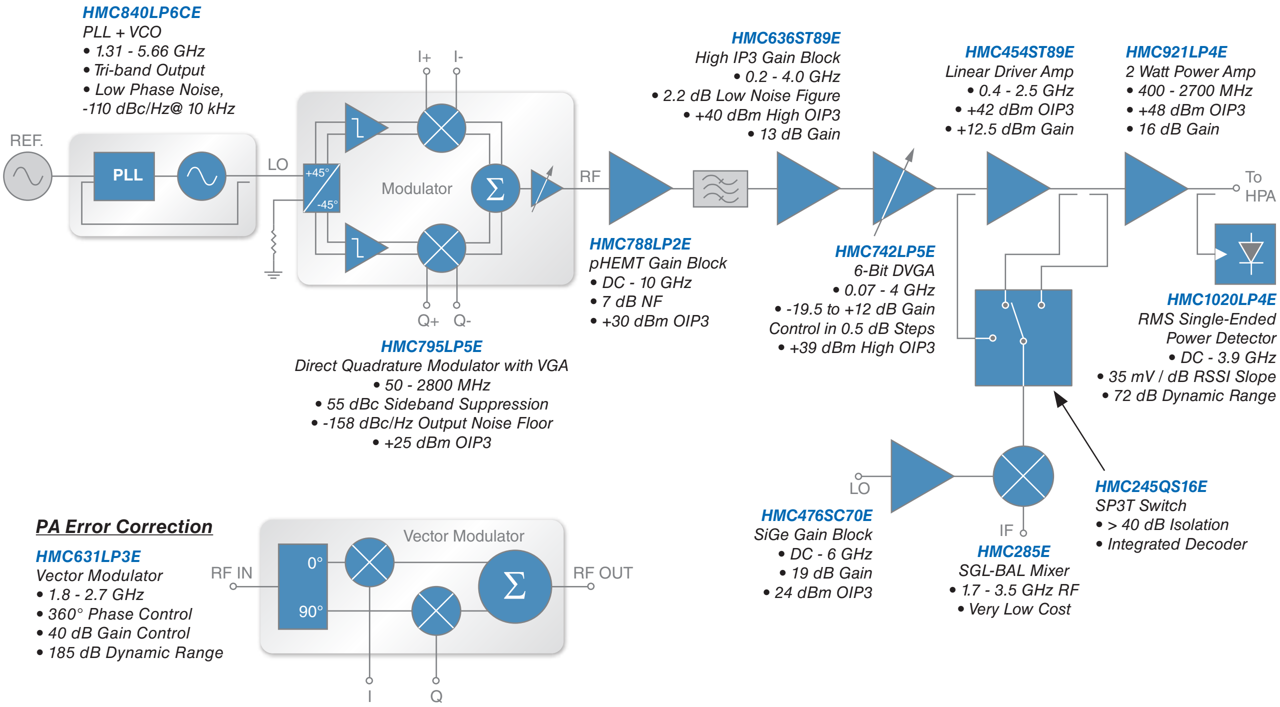


*** For 700 - 1000 MHz Systems Use:**

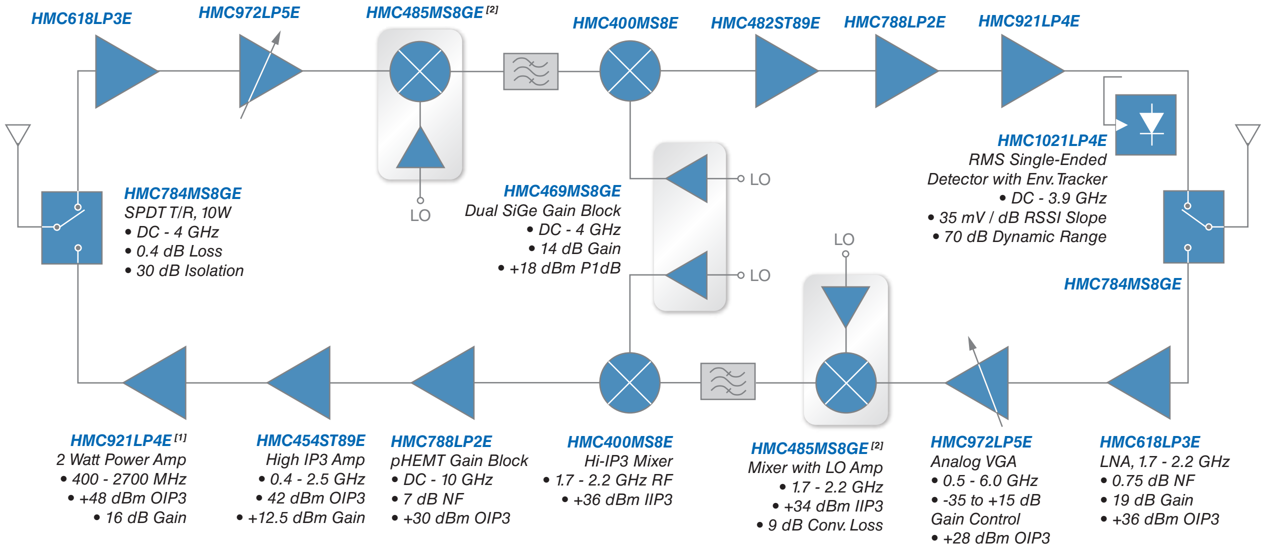
HMC718LP4E	HMC707LP5E	HMC683LP6CE
Low Noise Amplifier	Low Noise DVGA	Dual Downconverter
• 0.6 - 1.4 GHz	• 0.7 - 1.2 GHz	• 700 - 1000 MHz
• 0.9 dB Noise Figure	• -2.5 to 29 dB Gain Control in 0.5 dB Steps	• 7.5 dB Conversion Gain
• 32 dB Gain	• 38.5 dBm High OIP3	• +23 dBm IIP3
• +40 dBm OIP3		

Typical Cellular/PCS/3G applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

BTS TRANSMITTER SOLUTIONS



CDMA / GSM / TD-SCDMA REPEATER SOLUTIONS



[1] High Gain Option:

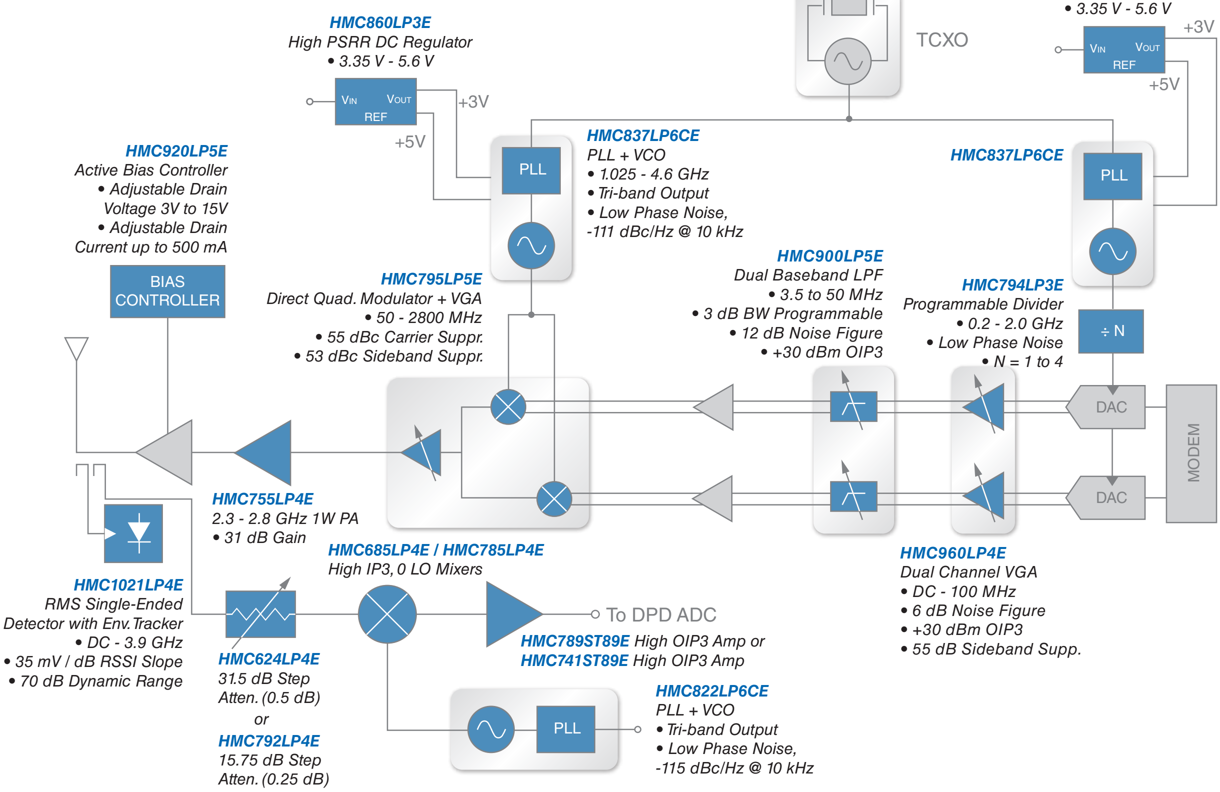
HMC457QS16GE
1 Watt Power Amp
• 1.7 - 2.2 GHz
• +46 dBm OIP3
• 27 dB Gain

[2] For 700 - 1000 MHz Systems Use:

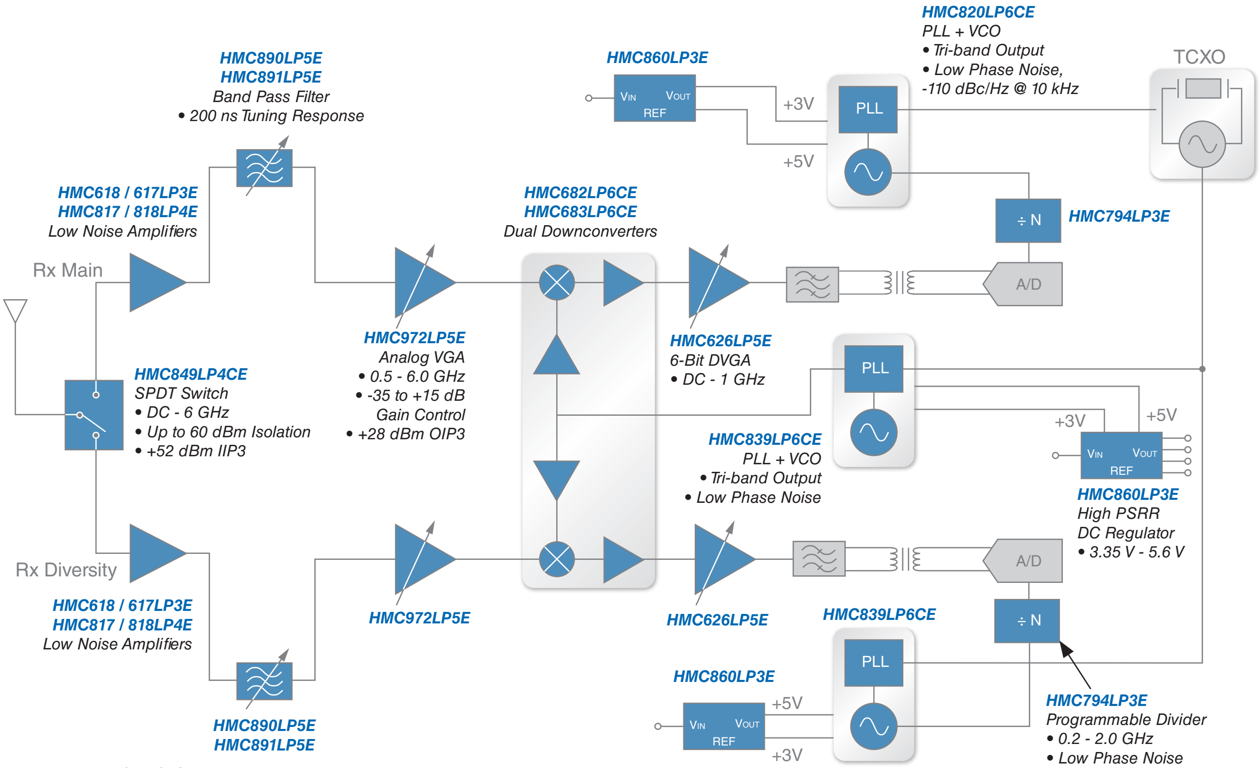
HMC483MS8GE
Mixer with LO Amp
• 0.7 - 1.5 GHz
• 33 dBm IIP3

Typical Cellular/PCS/3G applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

WiMAX / LTE / 4G Transmitter Solutions

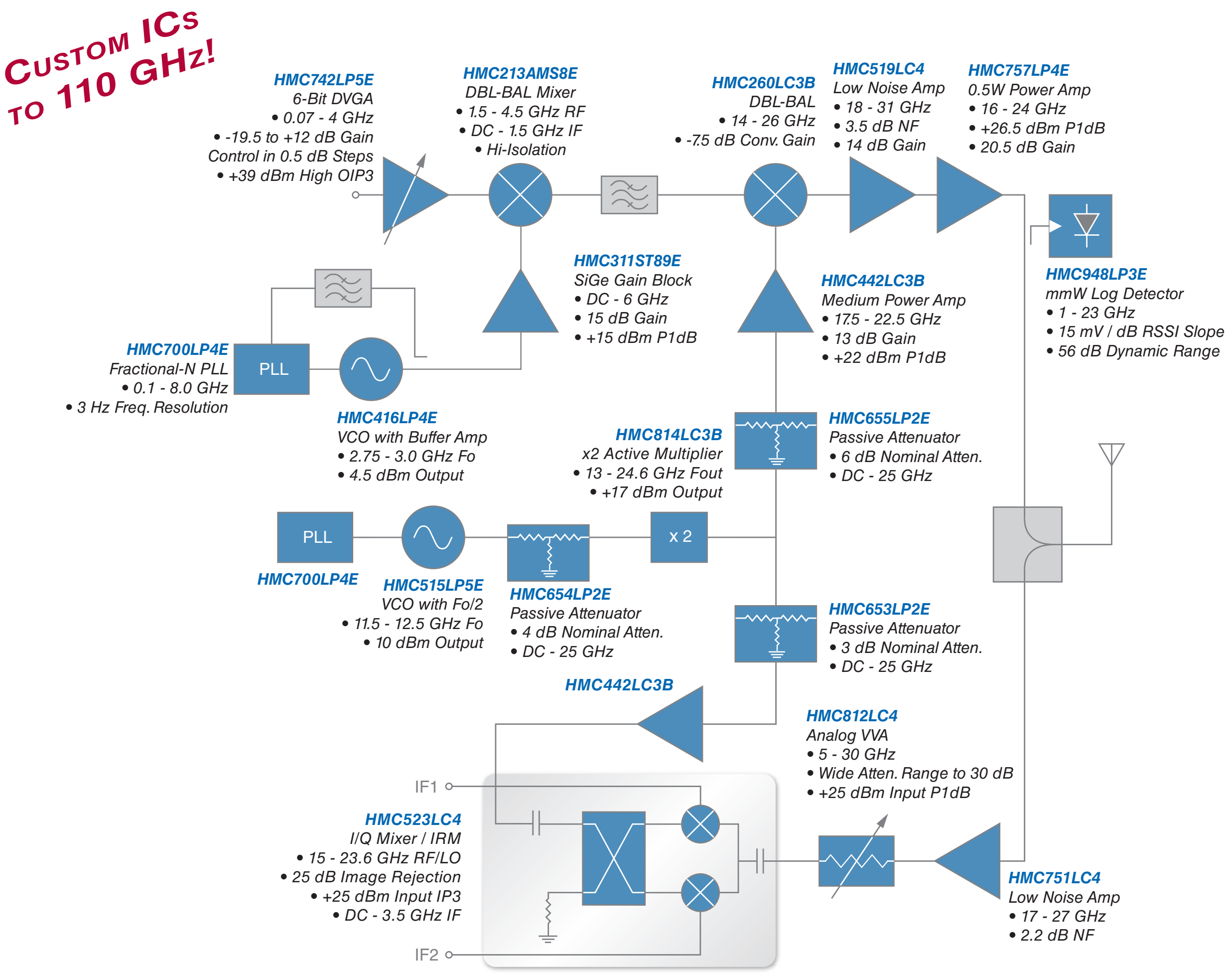


WiMAX / LTE / 4G Receiver Solutions Featuring Heterodyne Downconversion

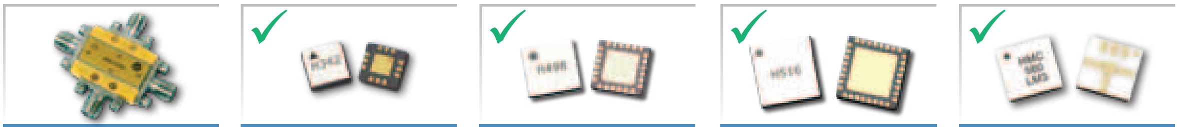


Typical WiMAX/LTE/4G applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

DOUBLE UPCONVERSION & DIRECT DOWNCONVERSION



PRODUCTS AVAILABLE IN DIE, SMT OR CONNECTORIZED PACKAGE FORM TO 86 GHz!



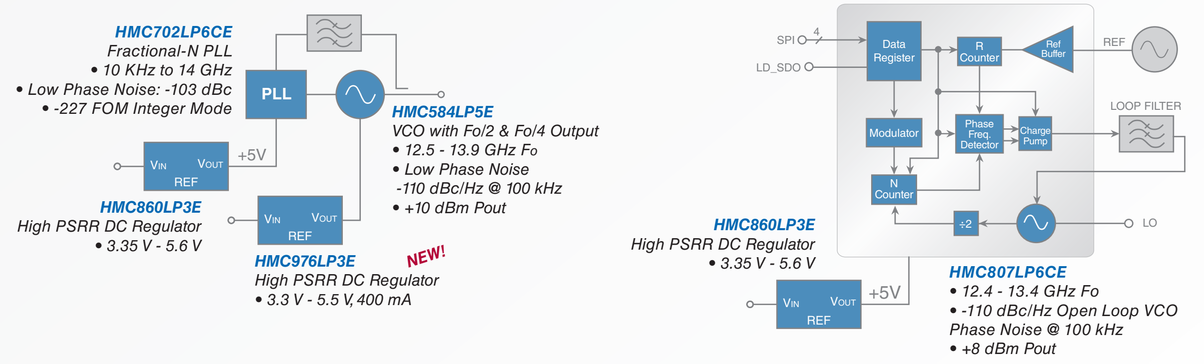
C-4	LC3 / LC3B	LC4 / LC4B	LC5	LM1 / LM3
41.66 x 36.32 x 8.50 mm	3.0 x 3.0 x 1.0 mm	4.0 x 4.0 x 1.0 / 1.2 mm	5.0 x 5.0 x 1.0 mm	5.1 x 5.1 x 1.1 mm

Typical Microwave / Millimeterwave application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

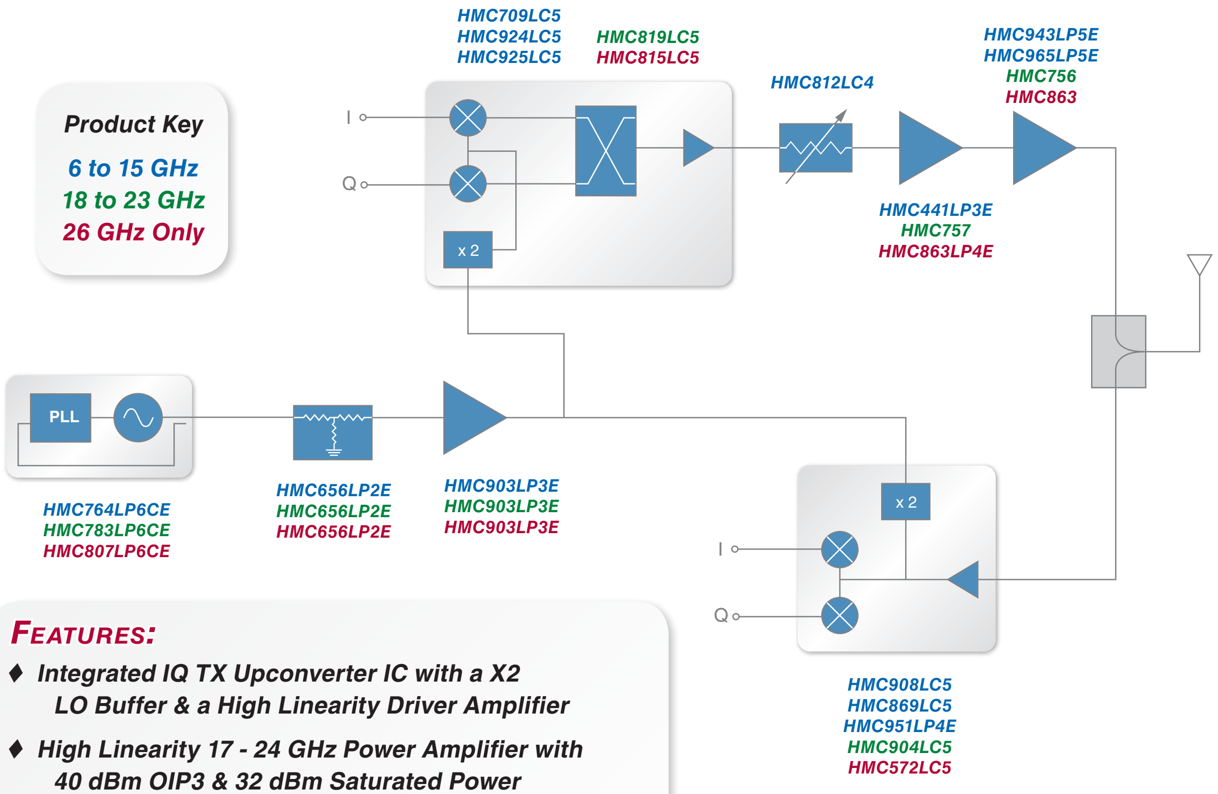
Hittite's High Frequency LO Source Alternatives

PLL & VCO Chipset

PLL with Integrated VCO IC



Chipsets for 6 to 42 GHz Microwave Radio Backhaul

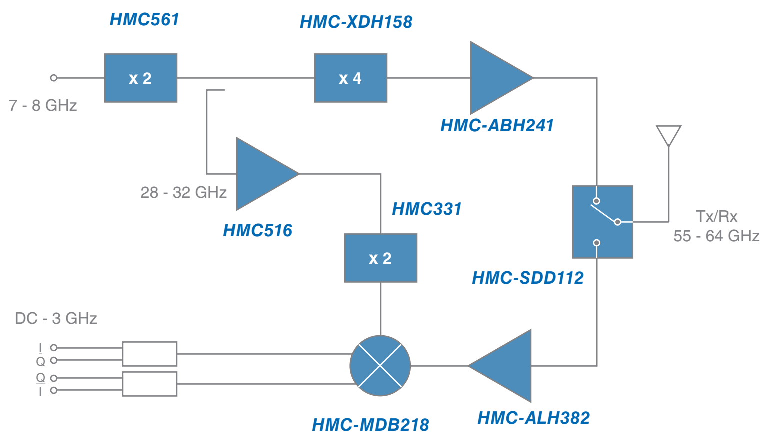


Features:

- ♦ Integrated IQ TX Upconverter IC with a X2 LO Buffer & a High Linearity Driver Amplifier
- ♦ High Linearity 17 - 24 GHz Power Amplifier with 40 dBm OIP3 & 32 dBm Saturated Power
- ♦ Low Noise Image Rejection Downconverter IC with a X2 Integrated LO Buffer
- ♦ Very Low Phase Noise PLL IC with an Integrated VCO

Typical Microwave / Millimeterwave application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

SUB-HARMONIC OPTION FOR 60 GHZ CHIPSET

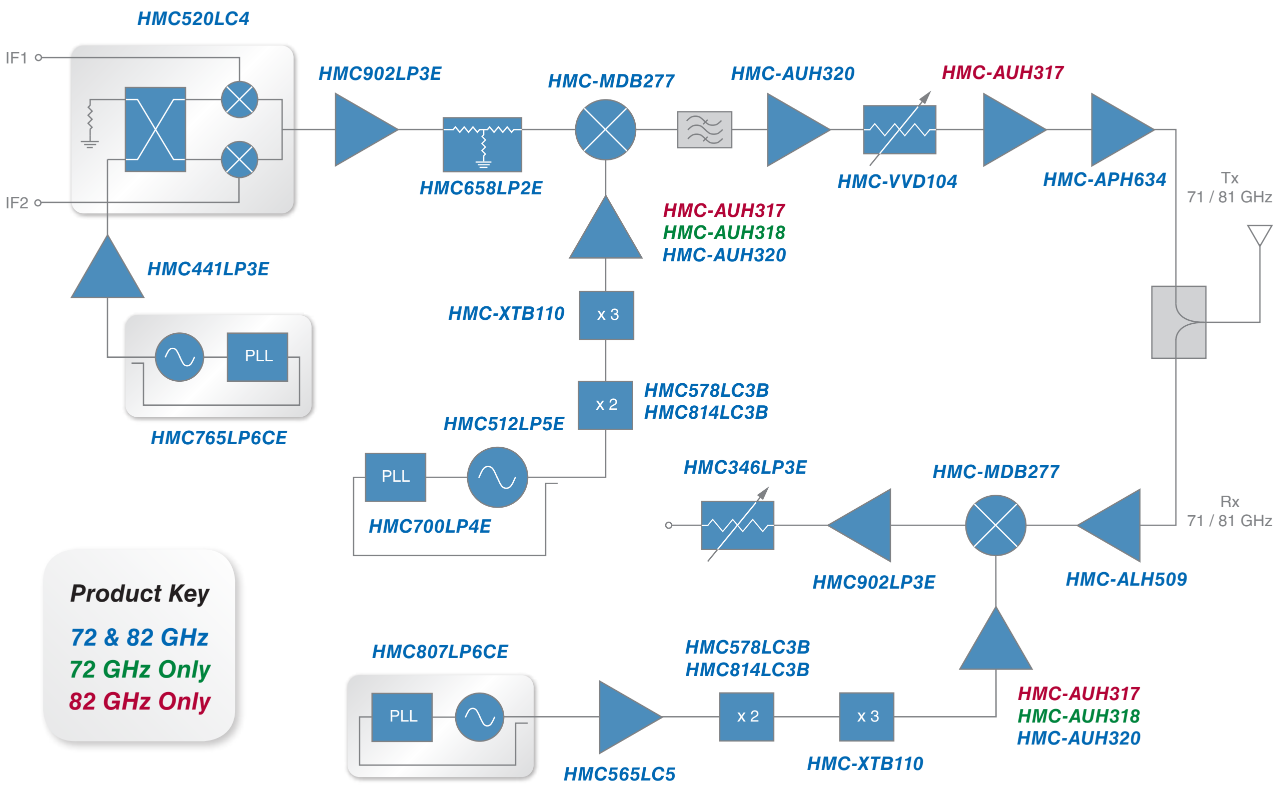


APPLICATIONS:

- Short Haul High Capacity Links
- Picocell Mobile Phone Links
- Network Backbone & Branch Links
- HDTV Wireless Broadcasting

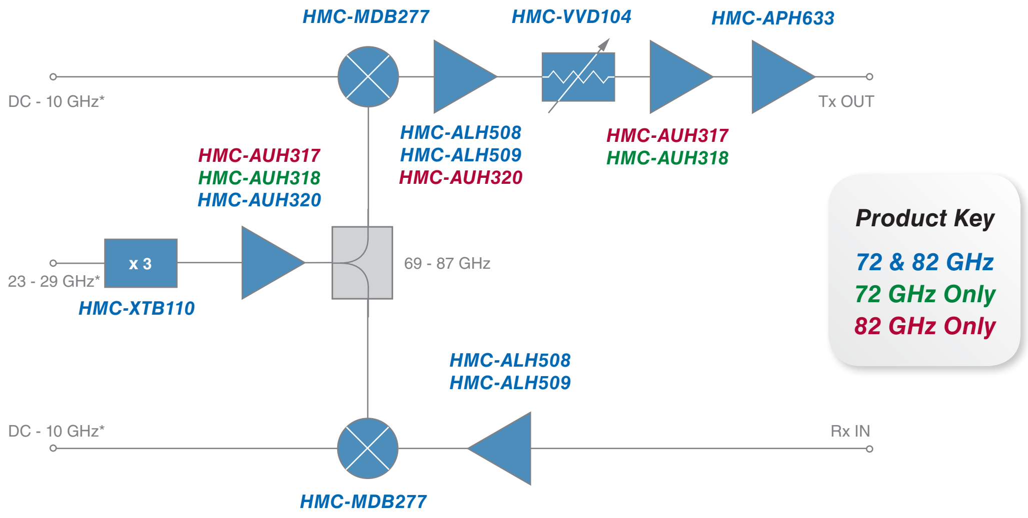
Typical Microwave / Millimeterwave application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

70 / 80 GHZ E-BAND RADIO CHIPSET



Typical Microwave / Millimeterwave application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

72 & 82 GHz Tx/Rx Chipset for High Capacity Communication Links



Typical Microwave / Millimeterwave application is illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

BROADBAND TIME DELAYS - *Analog & Digital*

Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vp-p)	DC Power Consumption (mW)	Vcc Power Supply (Vdc)	Package	ECCN Code	Part Number
32 / 24	Analog Time Delay	14 / 14	6	0.15 - 0.6	1450	+3.3	LC4B	3A001.a.11.b	HMC910LC4B
28 / 28	5-Bit Digital Time Delay	20 / 18	< 2	0.5 - 1.35	610	-3.3	LC5	3A001.a.11.b	HMC856LC5

COMPARATORS - *High Speed Clocked, Latched & Window Comparators*

Analog Input B/W (GHz) / Clock Rate (Gbps)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power (mW)	Vcco / V_{term} [1] Power Supply (Vdc)	Package	ECCN Code	Part Number
10 / 20	Clocked Comparator-RSPECL	<3	120	0.4	150	+3.3 / +1.3	LC3C	3A001.a.11.b	HMC874LC3C
10 / 20	Clocked Comparator-RSCML	<3	120	0.4	130	0 / 0	LC3C	3A001.a.11.b	HMC875LC3C
10 / 20	Clocked Comparator-RSECL	<3	120	0.4	150	0 / -2.0	LC3C	3A001.a.11.b	HMC876LC3C
10 / [2]	Latched Comparator-RSPECL	2	85	0.4	140	+3.3 / 1.3	LC3C	3A001.a.11.b	HMC674LC3C
10 / [2]	Latched Comparator-RSPECL	2	85	0.4	140	+3.3 / 1.3	LP3	3A001.a.11.b	HMC674LP3E
10 / [2]	Latched Comparator-RSCML	2	100	0.4	100	0 / 0	LC3C	3A001.a.11.b	HMC675LC3C
10 / [2]	Latched Comparator-RSCML	2	100	0.4	100	0 / 0	LP3	3A001.a.11.b	HMC675LP3E
10 / [2]	Latched Comparator-RSECL	2	100	0.35	120	0 / -2.0	LC3C	3A001.a.11.b	HMC676LC3C
10 / [2]	Latched Comparator-RSECL	2	100	0.35	120	0 / -2.0	LP3	3A001.a.11.b	HMC676LP3E
10 / -	Window Comparator	2	88	0.4	240	+2 / 0	LC3C	3A001.a.11.b	HMC974LC3C

[1] Vee = -3.0V & Vcci = +3.3V [2] These products are pin for pin compatible

CROSSPOINT SWITCH

Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall Time (ps)	Deterministic Jitter (ps)	Differential Output Swing (Vp-p)	DC Power (mW)	DC Power Supply (Vdc)	Package	ECCN Code	Part Number
14 / 14	2x2 Crosspoint Switch*	21 / 21	2	0.5 - 1.2	345	-3.3	LC5	3A001.a.11.b	HMC857LC5

DATA CONVERTERS - *Low Power Analog-to-Digital Converters*

Sample Rate	Function / Mode	Resolution (bits)	# of Channels	Power Dissipation [2][3]	SNR (dBFS)	SFDR (dBc)	Package	ECCN Code	Part Number
640 MSPS	High Speed, Single Channel	12	1	490 mW	70	60 / 75 [1]	LP7DE	3A001.a.5.a.4	HMCAD1520
320 MSPS	High Speed, Dual Channel	12	2	490 mW	70	60 / 78 [1]		3A001.a.5.a.4	
160 MSPS	High Speed, Quad Channel	12	4	490 mW	70	60 / 78 [1]		3A001.a.5.a.4	
105 MSPS 80 MSPS	Precision, Quad Channel	14	4 4	603 mW 530 mW	74 75	83 85		3A001.a.5.a.4	
1 GSPS	High Speed, Single Channel	8	1	710 mW	49.8	49 / 64 [1]	LP7DE	3A001.a.5.a.1	HMCAD1511
500 MSPS	High Speed, Dual Channel	8	2	710 mW	49.8	44 / 63 [1]		3A001.a.5.a.1	
250 MSPS	High Speed, Quad Channel	8	4	710 mW	49.8	57 / 70 [1]		3A001.a.5.a.1	
500 MSPS	High Speed, Single Channel	8	1	295 mW	49.8	49 / 65 [1]	LP7DE	3A991.c.1	HMCAD1510
250 MSPS	High Speed, Dual Channel	8	2	295 mW	49.8	59 / 69 [1]		3A991.c.1	
125 MSPS	High Speed, Quad Channel	8	4	295 mW	49.7	60 / 69 [1]		3A991.c.1	
80 MSPS	Octal Channel	13 / 12	8	59 mW / Channel	70.1	77	LP9E	3A001.a.5.a.4	HMCAD1102
65 MSPS	Octal Channel	13 / 12	8	51 mW / Channel	72.2	82	LP9E	3A001.a.5.a.4	HMCAD1101
50 MSPS	Octal Channel	13 / 12	8	41 mW / Channel	72.2	82	LP9E	3A001.a.5.a.4	HMCAD1100
40 MSPS	Octal Channel	13 / 12	8	35 mW / Channel	72.2	82		3A001.a.5.a.4	
20 MSPS	Octal Channel	13 / 12	8	23 mW / Channel	72.2	82		3A001.a.5.a.4	
80 MSPS	Dual Channel	13 / 12	2	102 mW	72	77	LP9E	3A001.a.5.a.4	HMCAD1050-80
65 MSPS	Dual Channel	13 / 12	2	85 mW	72.6	81		3A001.a.5.a.4	
40 MSPS	Dual Channel	13 / 12	2	55 mW	72.7	81	LP9E	3A001.a.5.a.4	HMCAD1050-40
20 MSPS	Dual Channel	13 / 12	2	30 mW	72.2	85		3A001.a.5.a.4	
80 MSPS	Single Channel	13 / 12	1	60 mW	72	77	LP6HE	3A001.a.5.a.4	HMCAD1051-80
65 MSPS	Single Channel	13 / 12	1	50 mW	72.6	81		3A001.a.5.a.4	
40 MSPS	Single Channel	13 / 12	1	33 mW	72.7	81	LP6HE	3A001.a.5.a.4	HMCAD1051-40
20 MSPS	Single Channel	13 / 12	1	19 mW	72.2	85		3A001.a.5.a.4	

SMT & Chip (Die) Products

DATA CONVERTERS - *Low Power Analog-to-Digital Converters*

Sample Rate	Function / Mode	Resolution (bits)	# of Channels	Power Dissipation [2][3]	SNR (dBFS)	SFDR (dBc)	Package	ECCN Code	Part Number
80 MSPS	Dual Channel	10	2	78 mW	61.6	75	LP9E	EAR99	HMCAD1040-80
65 MSPS	Dual Channel	10	2	65 mW	61.6	77		EAR99	
40 MSPS	Dual Channel	10	2	43 mW	61.6	81	LP9E	EAR99	HMCAD1040-40
20 MSPS	Dual Channel	10	2	24 mW	61.6	81		EAR99	
80 MSPS	Single Channel	10	1	46 mW	61.6	75	LP6HE	EAR99	HMCAD1041-80
65 MSPS	Single Channel	10	1	38 mW	61.6	77		EAR99	
40 MSPS	Single Channel	10	1	25 mW	61.6	81	LP6HE	EAR99	HMCAD1041-40
20 MSPS	Single Channel	10	1	15 mW	61.6	81		EAR99	

[1] Excluding Interleaving Spurs. [2] Supply Voltage (Vdd): +1.8 Vdc Analog Supply (AVdd) & +1.8 Vdc Digital Supply (DVdd) [3] Output Supply Voltage (OVdd): +1.7 to +3.6 Vdc

DATA CONVERTERS - *Track-and-Hold Amplifiers*

Input Frequency (GHz)	Function	Single Tone THD/SFDR (dB)	Maximum Clock Rate (GS/s)	Output Noise (mV RMS)	Hold Mode Feed-through Rejection (dB)	Package	ECCN Code	Part Number
0.02 - 4.5	Track-and-Hold	-66 / 67	3.0	0.95	>60	LC4B	3A001.a.11.b	HMC660LC4B

DC POWER CONDITIONING - *Linear Voltage Regulators*

Input Voltage (V)	Function	Output Voltage (V)	Output Current (mA)	Power Supply Rejection Ratio (PSRR) (dB)		Output Noise Spectral Density (nV/√Hz)		Regulated Outputs	Package	ECCN Code	Part Number
				1 kHz	1 MHz	1 kHz	10 kHz				
3.35 - 5.6	Quad High PSRR	2.5 - 5.2	15 - 100	80	60	7	3	4	LP3	EAR99	HMC860LP3E
NEW! 4.8 to 5.6	Low Noise, High PSRR	1.8 to 5.1	400	60	30	6	3	1	LP3	EAR99	HMC976LP3E

DC POWER MANAGEMENT - *Active Bias Controller*

Supply Voltage Range (V)	Function	VDRAIN Voltage Range (V)	IDRAIN Bias Current (mA)	IGATE Drive Current (mA)	VGATE Voltage Range (V)	Over / Under IDRAIN Current Alarm	Low VDD Alarm	Package	ECCN Code	Part Number
NEW! 4 to 12	Active Bias Controller	4 to 12	0 to 200	-0.8 to 0.8	-2.5 to 2.5	-	-	LP3	EAR99	HMC981LP3E
5 to 16.5	Active Bias Controller	3 to 15	0 to 500	-4 to 4	-2.5 to 2.5	Yes	Yes	LP5	EAR99	HMC920LP5E

HIGH SPEED DIGITAL LOGIC

Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall Time (ps)	Deterministic Jitter (ps)	Differential Output Swing (Vp-p)	DC Power (mW)	DC Power Supply (Vdc)	Package	ECCN Code	Part Number
1:2 & 1:4 Fanout Buffers									
13 / 13	1:2 Fanout Buffer*	22 / 20	<1	0.4 - 1.1	240	-3.3	LC3C	3A001.a.11.b	HMC670LC3C
13 / 13	Fast Rise Time 1:2 Fanout Buffer*	19 / 18	2	0.6 - 1.1	300	-3.3	LC3C	3A001.a.11.b	HMC720LC3C
13 / 13	Fast Rise Time 1:2 Fanout Buffer*	19 / 18	2	0.6 - 1.1	300	-3.3	LP3	3A001.a.11.b	HMC720LP3E
13 / 13	Fast Rise Time 1:2 Fanout Buffer	19 / 18	2	1.1	300	-3.3	LC3C	3A001.a.11.b	HMC724LC3C
13 / 13	Fast Rise Time 1:2 Fanout Buffer*	22 / 20	2	0.6 - 1.2	290	+3.3	LC3C	3A001.a.11.b	HMC744LC3C
28 / 20	1:2 Fanout Buffer*	16 / 15	2	0.6 - 1.1	315	-3.3	LC3C	3A001.a.11.b	HMC850LC3C
45 / 28	1:2 Fanout Buffer*	11 / 11	3	0.4 - 1.2	465	-3.3	LC4B	3A001.a.11.b	HMC842LC4B
13 / 13	1:4 Fanout Buffer*	26 / 25	4	0.6 - 1.4	440	-3.3	LC4B	3A001.a.11.b	HMC940LC4B
2:1 Selectors									
14 / 14	2:1 Differential Selector*	19 / 20	2	0.5 - 1.3	221	-3.3	LC4B	3A001.a.11.b	HMC858LC4B
13 / 13	2:1 Selector*	17 / 15	2	0.6 - 1.2	250	-3.3	LC3C	3A001.a.11.b	HMC678LC3C
13 / 13	2:1 Selector	17 / 15	2	1.1	250	-3.3	LC3C	3A001.a.11.b	HMC728LC3C
13 / 13	2:1 Selector*	22 / 22	2	0.6 - 1.2	250	+3.3	LC3C	3A001.a.11.b	HMC748LC3C
14 / 14	4:1 Selector*	17 / 17	2	0.5 - 1.3	294	-3.3	LC5	3A001.a.11.b	HMC958LC5
AND / NAND / OR / NORs									
13 / 13	AND / NAND / OR / NOR*	22 / 20	<1	0.4 - 1.1	180	-3.3	LC3C	3A001.a.11.b	HMC672LC3C
13 / 13	Fast Rise Time AND / NAND / OR / NOR*	19 / 18	2	0.6 - 1.1	230	-3.3	LC3C	3A001.a.11.b	HMC722LC3C
13 / 13	Fast Rise Time AND / NAND / OR / NOR*	19 / 18	2	0.6 - 1.1	230	-3.3	LP3	3A001.a.11.b	HMC722LP3E
13 / 13	Fast Rise Time AND / NAND / OR / NOR	19 / 18	2	1.1	230	-3.3	LC3C	3A001.a.11.b	HMC726LC3C
13 / 13	Fast Rise Time AND / NAND / OR / NOR*	22 / 21	2	0.6 - 1.2	230	+3.3	LC3C	3A001.a.11.b	HMC746LC3C
28 / 28	AND / NAND / OR / NOR*	15 / 14	2	0.6 - 1.5	241	-3.3	LC3C	3A001.a.11.b	HMC852LC3C

HIGH SPEED DIGITAL LOGIC

Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall Time (ps)	Deterministic Jitter (ps)	Differential Output Swing (Vp-p)	DC Power (mW)	DC Power Supply (Vdc)	Package	ECCN Code	Part Number
45 / 25	AND / NAND / OR / NOR*	10 / 10	2	0.2 - 0.9	530	-3.3	LC4B	3A001.a.11.b	HMC843LC4B
Clock Dividers									
28 / 28	Clock Divide-by-2/4	12 / 14	-	0.6	660	-3.3	LC4B	3A001.a.11.b	HMC791LC4B
- / 26	Clock Divide-by-4*	19 / 19	-	0.8 - 1.8	281	-3.3	LC3	3A001.a.11.b	HMC959LC3
- / 26	Clock Divide-by-8*	19 / 17	-	0.8 - 1.8	520	-3.3	LC3	3A001.a.11.b	HMC859LC3
D-Type Flip-Flops									
13 / 13	D-Type Flip-Flop*	22 / 20	<1	0.4 - 1.1	210	-3.3	LC3C	3A001.a.11.b	HMC673LC3C
14 / 14	Dual D-Type Flip-Flop with Common Clock*	22 / 20	2	0.6 - 1.3	442	-3.3	LC4B	3A001.a.11.b	HMC953LC4B
13 / 13	Fast Rise Time D-Type Flip-Flop*	19 / 17	2	0.7 - 1.3	260	-3.3	LC3C	3A001.a.11.b	HMC723LC3C
13 / 13	Fast Rise Time D-Type Flip-Flop*	19 / 17	2	0.7 - 1.3	260	-3.3	LC3C	3A001.a.11.b	HMC723LP3E
13 / 13	Fast Rise Time D-Type Flip-Flop	19 / 17	2	1.1	260	-3.3	LC3C	3A001.a.11.b	HMC727LC3C
13 / 13	Fast Rise Time D-Type Flip-Flop*	22 / 20	2	0.7 - 1.2	264	+3.3	LC3C	3A001.a.11.b	HMC747LC3C
28 / 28	D-Type Flip-Flop*	15 / 14	2	0.7 - 1.3	260	-3.3	LC3C	3A001.a.11.b	HMC853LC3C
43 / 43	D-Type Flip-Flop*	12 / 12	2	0.2 - 0.85	630	-3.3	LC4B	3A001.a.11.b	HMC841LC4B
NRZ-to-RZ Converters									
13 / 13	NRZ-to-RZ Converter	15 / 13	2	0.3 - 1.2	594	+3.3	LC3C	3A001.a.11.b	HMC706LC3C
T Flip-Flops									
26 / 26	T Flip-Flop w/ Reset*	18 / 17	2	0.4 - 1.1	270	-3.3	LC3C	3A001.a.11.b	HMC679LC3C
26 / 26	T Flip-Flop w/Reset	18 / 17	2	1.1	270	-3.3	LC3C	3A001.a.11.b	HMC729LC3C
26 / 26	T Flip-Flop w/ Reset*	18 / 17	2	0.6 - 1.2	270	+3.3	LC3C	3A001.a.11.b	HMC749LC3C
XOR / XNORs									
13 / 13	XOR / XNOR*	22 / 20	<1	0.4 - 1.1	180	-3.3	LC3C	3A001.a.11.b	HMC671LC3C
13 / 13	Fast Rise Time XOR / XNOR*	19 / 18	2	0.6 - 1.2	230	-3.3	LC3C	3A001.a.11.b	HMC721LC3C
13 / 13	Fast Rise Time XOR / XNOR*	19 / 18	2	0.6 - 1.2	230	-3.3	LP3	3A001.a.11.b	HMC721LP3E
13 / 13	Fast Rise Time XOR / XNOR	19 / 18	2	1.1	230	-3.3	LC3C	3A001.a.11.b	HMC725LC3C
13 / 13	Fast Rise Time XOR / XNOR*	21 / 19	2	0.6 - 1.2	240	+3.3	LC3C	3A001.a.11.b	HMC745LC3C
28 / 28	XOR / XNOR*	15 / 14	2	0.6 - 1.4	241	-3.3	LC3C	3A001.a.11.b	HMC851LC3C
45 / 28	XOR / XNOR*	11 / 10	3	0.2 - 8.5	512	-3.3	LC4B	3A001.a.11.b	HMC844LC4B

** These products feature programmable output voltage swing.*

IF / BASEBAND PROCESSING - Dual Baseband Low Pass Filter & Dual Baseband Digital VGA

Dual Baseband Low Pass Filter

3 dB Bandwidth Setting (MHz)	Function	3 dB Bandwidth Accuracy (%)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package	ECCN Code	Part Number
3.5 - 50	Dual Low Pass with ADC Driver	± 2.5	0 / 10	12	30	LP5	EAR99	HMC900LP5E

Please Note: 400 Ohm Reference Impedance Are Shown

Dual Baseband Digital VGA

Frequency (MHz)	Function	NF (dB)	Variable Gain (dB)	OIP3 (dBm)	OIP2 (dBm)	Sideband Supp. (dB)	Magnitude (dB) / Phase (deg) Balance	Bias Supply	Package	ECCN Code	Part Number
DC - 100	Digital, Serial & Parallel Control	6	0 to 40	+30	+65	55	±0.1 / ±1	+5V @ 70mA	LP4	EAR99	HMC960LP4E

Please Note: 100 Ohm Reference Impedance Are Shown

INTERFACE - RF Switch, Attenuator & Phase Shifter Digital Drivers

Bit Rate (mbps)	Function	Input	Output Voltage (V)	Output Current (mA)	Bias Supply	Package	ECCN Code	Part Number
10	6-Bit Switch Driver / Controller	TTL/CMOS	-5 / +2.2	1	+5V @ 1.5mA	LP5	EAR99	HMC677LP5E
10	6-Bit Switch Driver / Controller	TTL/CMOS	-5 / +2.2	1	+5V @ 1mA	G32	EAR99	HMC677G32

LIMITING AMPLIFIERS

Data Rate (Gbps)	Function	Small Signal Bandwidth (GHz)	Differential Gain (dB)	Deterministic Jitter (ps p-p)	Additive Random Jitter (ps rms)	Supply Current	Package	ECCN Code	Part Number
12.5	Limiting Amplifier	11	44	5	0.2	+5V @ 106mA	LP4	EAR99	HMC750LP4E
12.5	Limiting Amplifier with LOS	9.5	32	-	0.9	+3.3V @ 47mA	LP4	EAR99	HMC914LP4E

Hittite MICROWAVE CORPORATION

SMT & Chip (Die) Products

LIMITING AMPLIFIERS

Data Rate (Gbps)	Function	Small Signal Bandwidth (GHz)	Differential Gain (dB)	Deterministic Jitter (ps p-p)	Additive Random Jitter (ps rms)	Supply Current	Package	ECCN Code	Part Number
32	Limiting with DC Offset	25	30	5	0.3	+3.3V @ 90mA	LC3C	EAR99	HMC865LC3C
32	Limiting without DC Offset	25	29	7	0.3	+3.3V @ 85mA	LC3C	EAR99	HMC866LC3C

MUX & DEMUX

	Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vp-p)	DC Power Consumption (mW)	Vee Power Supply (Vdc)	Package	ECCN Code	Part Number
NEW!	32 / 16	2:1 Mux*	15 / 15	-	1.25	480	±3.3	LC4B	3A001.a.11.b	HMC954LC4B
	28 / 14	4:1 Mux with Adj. Vout	16 / 16	4	0.7 - 1.25	510	-3.3	LC5	3A001.a.11.b	HMC854LC5
	45 / 22.5	4:1 Mux*	11 / 12	3	0.25 - 0.9	1782	+3.3	LC5	3A001.a.11.b	HMC847LC5
NEW!	32 / 16	1:2 Demux with High Speed Invert*	19 / 18	<3	1.0	644	±3.3	LC4B	3A001.a.11.b	HMC955LC4B
	28 / 14	1:4 Demux with Adj. Vout	22 / 22	-	0.45 - 1.14	644	-3.3	LC5	3A001.a.11.b	HMC855LC5
	45 / 22.5	1:4 Demux with Adj. Vout	25 / 21	4	0.3 - 1.0	1782	+3.3	LC5	3A001.a.11.b	HMC848LC5

** With Programmable Output Voltage and/or Duty Cycle Control*

OPTICAL MODULATOR DRIVERS

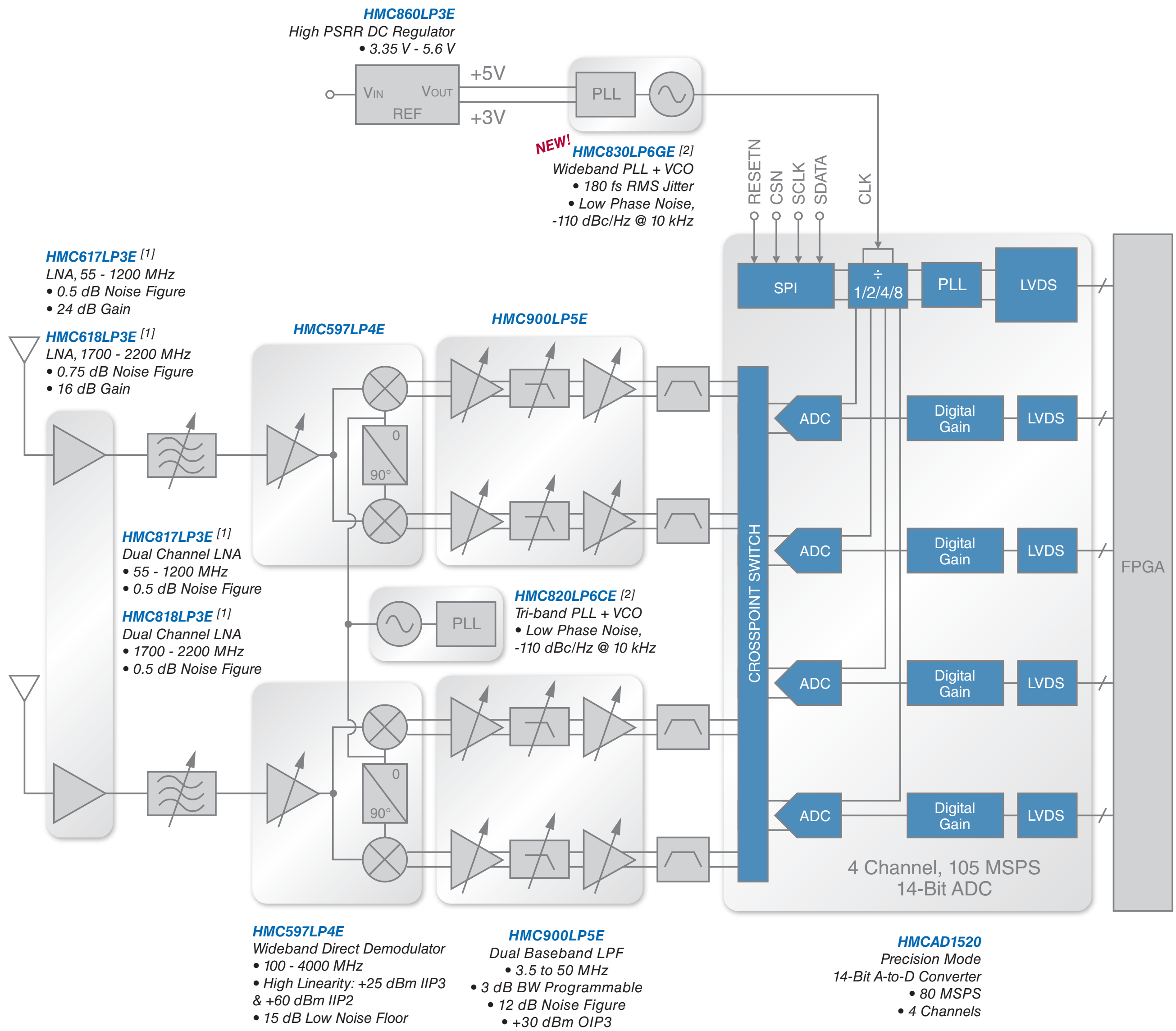
Frequency (GHz)	Function	Gain (dB)	Group Variation Delay (ps)	Additive Jitter (ps)	P1dB (dBm)	Output Voltage Level (Vp-p)	Package	ECCN Code	Part Number
DC - 20	MZ Optical Modulator Driver	18	±15	0.3	22	2.5 - 8	LC5	EAR99	HMC870LC5 [1]
DC - 20	EA Optical Modulator Driver	15	±15	0.3	16.5	2.5 - 4	LC5	EAR99	HMC871LC5 [1]

[1] Drivers that benefit from Hittite Active Bias Controllers

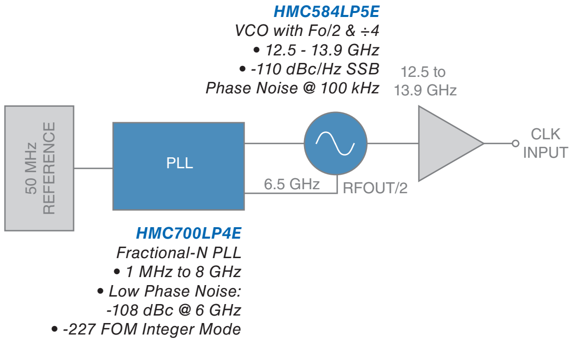
TRANSIMPEDANCE AMPLIFIERS

Data Rate (Gbps)	Function	Transimpedance (kΩ)	Input Overload (mApp)	Small Signal Bandwidth (GHz)	Deterministic Jitter (ps)	Noise (pA/√Hz)	Package	ECCN Code	Part Number
0.1 - 1.0	Low Noise Transimpedance Amplifier	10	20	0.7	<100	4.6	LP3	EAR99	HMC799LP3E
1 - 10	Transimpedance Amplifier	1.25	3	7.5	<10	11	Chip	EAR99	HMC690

DIRECT CONVERSION RECEIVER WITH DIVERSITY FEATURING THE HMCAD1520 A/D CONVERTER

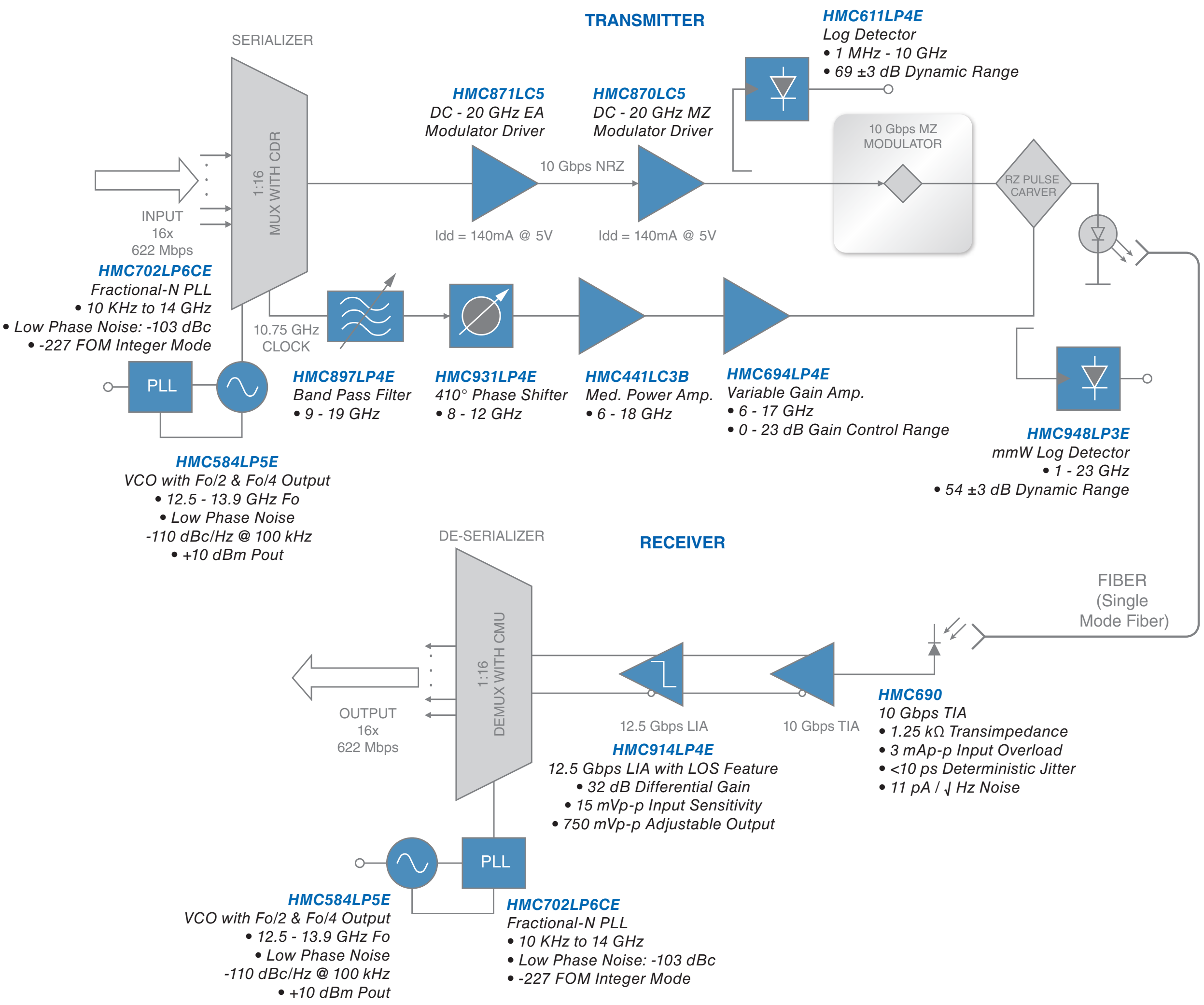


ADC / DAC CLOCK DRIVER CIRCUIT



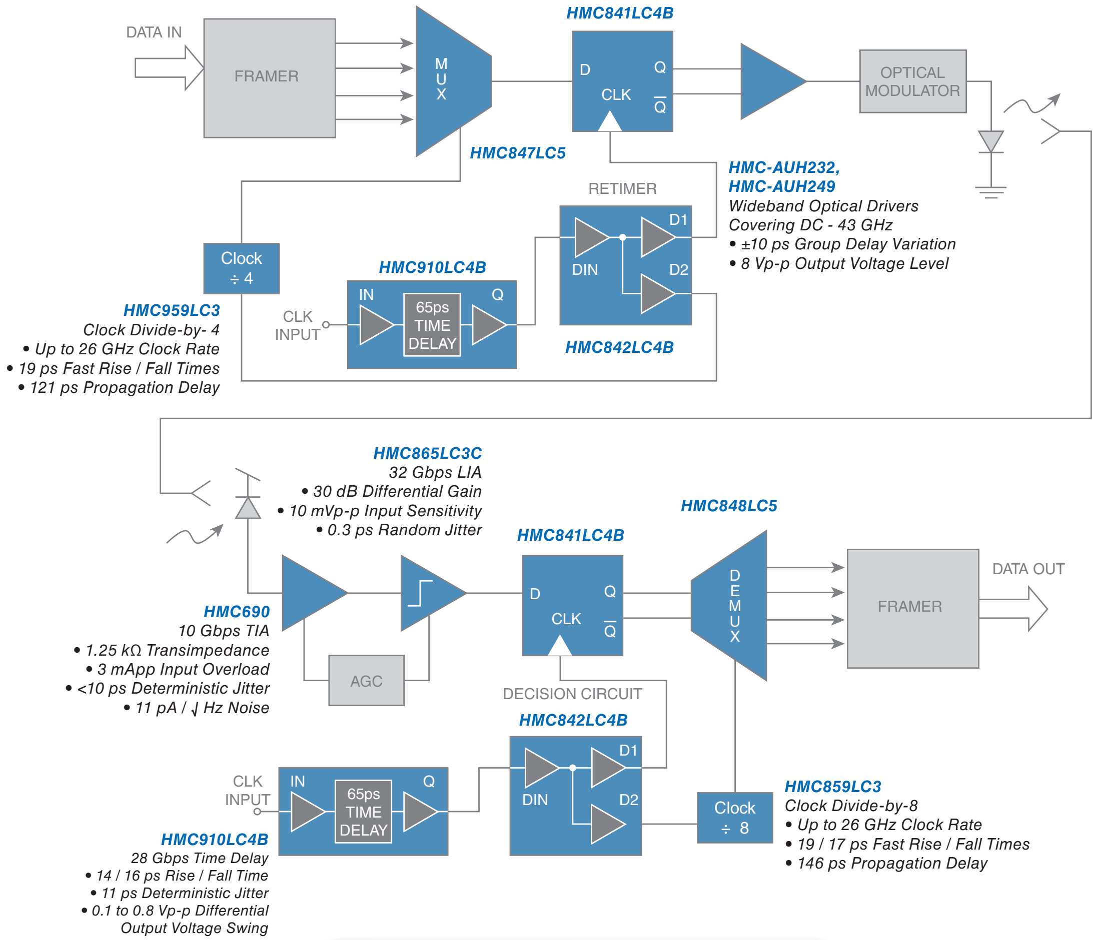
Typical Fiber Optic & Networking applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

10 Gbps Long Range Solutions



Typical Fiber Optic & Networking applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

TYPICAL SERIAL FIBER OPTIC DATA TRANSMISSION SYSTEM



HMC841LC4B
43 Gbps D-Type Flip-Flop
- 12 / 12 ps Rise / Fall Time
- 2 ps Deterministic Jitter
- 0.2 to 0.85 Vp-p Differential Output Voltage Swing

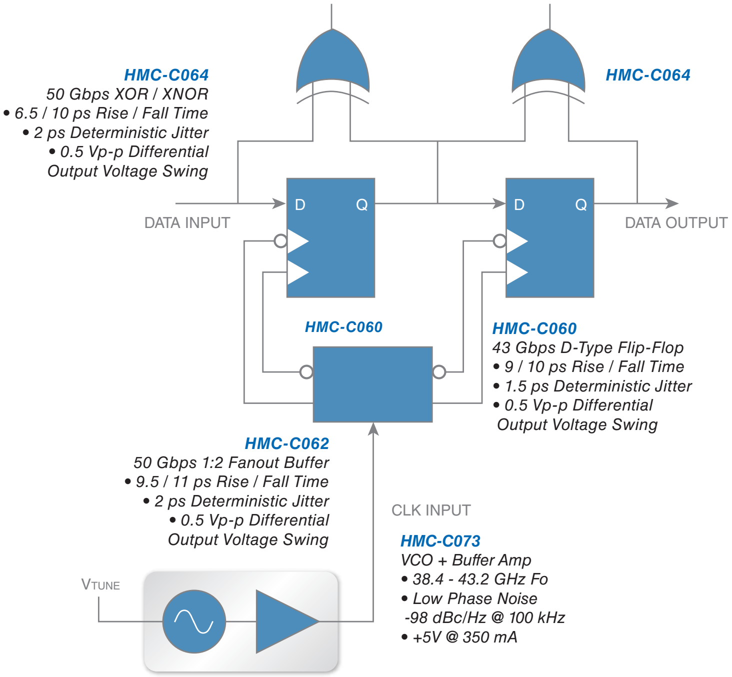
HMC847LC5
45 Gbps 4:1 Mux
- 11 / 12 ps Rise / Fall Time
- 3 ps Deterministic Jitter
- 0.25 to 0.9 Vp-p Differential Output Voltage Swing

HMC842LC4B
45 Gbps 1:2 Fanout Buffer
- 11 / 11 ps Rise / Fall Time
- 2 ps Deterministic Jitter
- 0.4 to 1.2 Vp-p Differential Output Voltage Swing

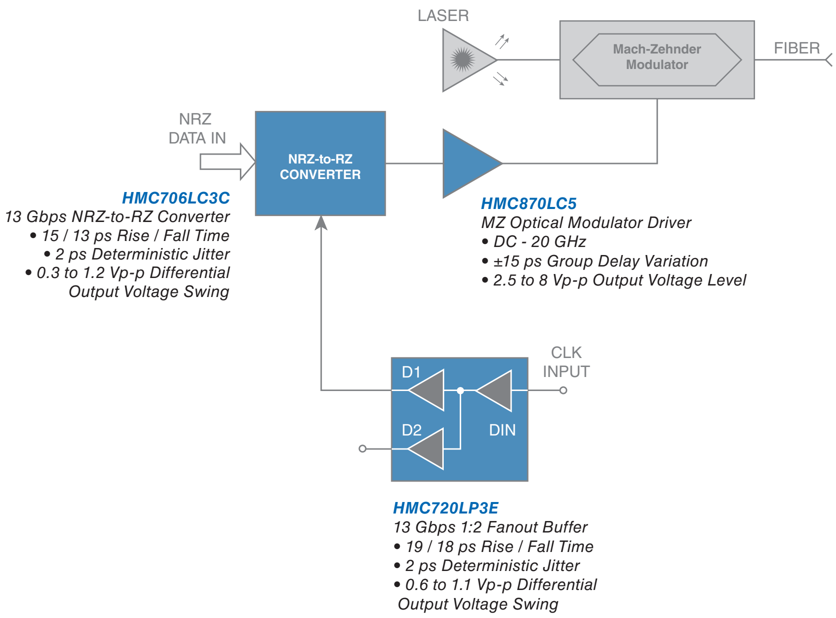
HMC848LC5
45 Gbps 1:4 Demux
- 25 / 21 ps Rise / Fall Time
- 4 ps Deterministic Jitter
- 0.3 to 1.0 Vp-p Differential Output Voltage Swing

Typical Fiber Optic & Networking applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

43 Gbps Hogge Phase Detector for Clock & Data Recovery



13 Gbps, NRZ-to-RZ Conversion



Typical Fiber Optic & Networking applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

DC POWER CONDITIONING - *Linear Voltage Regulators*

Input Voltage (V)	Function	Output Voltage (V)	Output Current (mA)	Power Supply Rejection Ratio (PSRR) (dB)		Output Noise Spectral Density (nV/√Hz)		Regulated Outputs	Package	ECCN Code	Part Number
				1 kHz	1 MHz	1 kHz	10 kHz				
3.35 - 5.6	Quad High PSRR	2.5 - 5.2	15 - 100	80	60	7	3	4	LP3	EAR99	HMC860LP3E
NEW! 4.8 to 5.6	Low Noise, High PSRR	1.8 to 5.1	400	60	30	6	3	1	LP3	EAR99	HMC976LP3E

FREQUENCY DIVIDERS (PRESCALERS) & DETECTORS

Input Frequency (GHz)	Function	Input Power (dBm)	Output Power (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
DC - 8	Divide-by-2	-12 to +12	-6	-148	+3V @ 42mA	SOT26	3A001.a.11.b	HMC432E
DC - 10	Divide-by-2	-15 to +10	3	-148	+5V @ 83mA	S8G	3A001.a.11.b	HMC361S8GE
DC - 11	Divide-by-2	-15 to +10	3	-148	+5V @ 105mA	Chip	3A001.a.11.b	HMC361
DC - 12.5	Divide-by-2	-15 to +10	2	-145	+5V @ 105mA	S8G	3A001.a.11.b	HMC364S8GE
DC - 13	Divide-by-2	-15 to +10	1	-145	+5V @ 105mA	Chip	3A001.a.11.b	HMC364
DC - 13	Divide-by-2	-15 to +10	5	-145	+5V @ 110mA	G8 Hermetic	3A001.a.11.b	HMC364G8
DC - 18	Divide-by-2	-15 to +10	-4	-150	+5V @ 77mA	LP3	3A001.a.11.b	HMC492LP3E
DC - 7	Divide-by-3	-12 to +12	-2	-153	+5V @ 69mA	MS8G	3A001.a.11.b	HMC437MS8GE
DC - 4	Divide-by-4	-15 to +10	3.5	-146	+3V @ 13mA	MS8	3A001.a.11.b	HMC426MS8E
DC - 8	Divide-by-4	-12 to +12	-3	-150	+3V @ 53mA	SOT26	3A001.a.11.b	HMC433E
DC - 11	Divide-by-4	-15 to +10	-6	-149	+5V @ 68mA	Chip	3A001.a.11.b	HMC362
DC - 12	Divide-by-4	-15 to +10	-6	-149	+5V @ 68mA	S8G	3A001.a.11.b	HMC362S8GE
DC - 13	Divide-by-4	-15 to +10	2	-151	+5V @ 110mA	Chip	3A001.a.11.b	HMC365
DC - 13	Divide-by-4	-15 to +10	7	-151	+5V @ 120mA	G8 Hermetic	3A001.a.11.b	HMC365G8
DC - 13	Divide-by-4	-15 to +10	2	-151	+5V @ 110mA	S8G	3A001.a.11.b	HMC365S8GE
DC - 18	Divide-by-4	-15 to +10	-4	-150	+5V @ 96mA	LP3	3A001.a.11.b	HMC493LP3E
10 - 26	Divide-by-4	-15 to +10	-4	-150	+5V @ 96mA	LC3	3A001.a.11.b	HMC447LC3
DC - 7	Divide-by-5	-12 to +12	-1	-153	+5V @ 80mA	MS8G	3A001.a.11.b	HMC438MS8GE
DC - 8	Divide-by-8	-5 to +12	-2	-150	+3V @ 62mA	SOT26	3A001.a.11.b	HMC434E
DC - 12	Divide-by-8	-15 to +10	-9	-153	+5V @ 70mA	Chip	3A001.a.11.b	HMC363
DC - 12	Divide-by-8	-15 to +10	4	-153	+5V @ 90mA	G8 Hermetic	3A001.a.11.b	HMC363G8
DC - 12	Divide-by-8	-15 to +10	-9	-153	+5V @ 70mA	S8G	3A001.a.11.b	HMC363S8GE
DC - 18	Divide-by-8	-15 to +10	-4	-150	+5V @ 105mA	LP3	3A001.a.11.b	HMC494LP3E
0.1 - 6.5	Programmable Divider (N = 1 to 17)	-15 to +10	0	-153	+5V @ 200mA	LP4	3A001.a.11.b	HMC705LP4E
0.1 - 15	Programmable Divider (N = 1, 2, 4, 8)	-5 to 10	2	-153	+5V @ 105mA	LP3	3A001.a.11.b	HMC862LP3E
0.2 - 2.0	Programmable Divider (N = 1 to 4)	-2 to +10	10	-160	+5V @ 135mA	LP3	3A001.a.11.b	HMC794LP3E
0.4 - 6.0	Programmable Divider (N = 1 to 6)	0 to +9	5	-156	+3.3V @ 100mA	LP3	3A001.a.11.b	HMC905LP3E
DC - 2.2	5-bit Counter, ÷2 to 32	-15 to +10	4	-153	+5V @ 194mA	LP4	3A001.a.11.b	HMC394LP4E
Phase / Frequency Detectors								
0.01 - 1.3	Phase Frequency Detector	-10 to +10	2 Vp-p	-153	+5V @ 96mA	QS16G	3A001.a.11.b	HMC439QS16GE

FREQUENCY MULTIPLIERS - *Active*

Input Frequency (GHz)	Function	Output Frequency (GHz)	Input Power (dBm)	Output Power (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Package	ECCN Code	Part Number
3 - 4	x2 Active	6 - 9	0	17	-140	LP4	EAR99	HMC575LP4E
4.0 - 10.5	x2 Active	8 - 21	5	17	-139	Chip	EAR99	HMC561
4.0 - 10.5	x2 Active	8 - 21	5	14	-139	LP3	EAR99	HMC561LP3E
4 - 11	x2 Active	8 - 22	5	12	-134	LC3B	EAR99	HMC573LC3B
4.5 - 8.0	x2 Active	9 - 16	2	15	-140	LP4	EAR99	HMC368LP4E
4.95 - 6.35	x2 Active	9.9 - 12.7	0	4	-142	LP3	EAR99	HMC369LP3E
6.5 - 12.3	x2 Active	13.0 - 24.6	4	17	-136	Chip	EAR99	HMC814
6.5 - 12.3	x2 Active	13.0 - 24.6	4	17	-136	LC3B	EAR99	HMC814LC3B
9.0 - 14.5	x2 Active	18 - 29	3	17	-132	Chip	EAR99	HMC576
9.0 - 14.5	x2 Active	18 - 29	3	15	-132	LC3B	EAR99	HMC576LC3B
9.5 - 12.5	x2 Active	19 - 25	0	11	-135	Chip	EAR99	HMC448
10.0 - 12.5	x2 Active	20 - 25	0	11	-135	LC3B	EAR99	HMC448LC3B
11 - 23	x2 Active	22 - 46	5	15	-	Chip	EAR99	HMC598
12.0 - 16.5	x2 Active	24 - 33	3	17	-132	Chip	EAR99	HMC578
12.0 - 16.5	x2 Active	24 - 33	3	15	-132	LC3B	EAR99	HMC578LC3B
12.5 - 15.5	x2 Active	25 - 31	3	21	-	LP4	EAR99	HMC942LP4E
13.5 - 15.5	x2 Active	27 - 31	0	9	-132	LC3B	EAR99	HMC449LC3B
13.5 - 15.5	x2 Active	27 - 31	5	20	-128	LC4B	EAR99	HMC577LC4B
13.5 - 16.5	x2 Active	27 - 33	0	10	-132	Chip	EAR99	HMC449
16 - 23	x2 Active	32 - 46	3	13	-127	Chip	EAR99	HMC579
2.66 - 5.33	x3 Active	8 - 16	5	2	-152	LP3	EAR99	HMC916LP3E
1.5 - 2.5	x4 Active	6 - 10	5	2	-148	LP3	EAR99	HMC917LP3E
2.45 - 2.8	x4 Active	9.8 - 11.2	-15	3	-142	LP4	EAR99	HMC443LP4E
2.85 - 3.3	x4 Active	11.4 - 13.2	-15 to +5	7	-140	LP4	EAR99	HMC695LP4E
3.6 - 4.1	x4 Active	14.4 - 16.4	-15	0	-140	LP4	EAR99	HMC370LP4E

LO & Clock Generation ICs

SMT & Chip (Die) Products

FREQUENCY MULTIPLIERS - Active

Input Frequency (GHz)	Function	Output Frequency (GHz)	Input Power (dBm)	Output Power (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Package	ECCN Code	Part Number
14 - 16	x4 Active	56 - 64	2	-6	-	Chip	3A001.b.2.f	HMC-XDH158
1.2375 - 1.4	x8 Active	9.9 - 11.2	-15	6	-136	LP4	EAR99	HMC444LP4E
0.61875 - 0.6875	x16 Active	9.9 - 11	-15	7	-130	LP4	EAR99	HMC445LP4E

FREQUENCY MULTIPLIERS - Passive

Input Frequency (GHz)	Function	Output Frequency (GHz)	Conversion Loss (dB)	1Fo / 4Fo Isolation (dB)	Input Drive (dBm)	Package	ECCN Code	Part Number
0.7 - 2.4	x2 Passive	1.4 - 4.8	15	47 / 38	10 to 20	Chip	EAR99	HMC156
0.7 - 2.4	x2 Passive	1.4 - 4.8	15	47 / 38	10 to 20	C8	EAR99	HMC156C8
0.85 - 2.0	x2 Passive	1.7 - 4.0	15	45 / 40	10 to 20	MS8	EAR99	HMC187AMS8E
1.25 - 3.0	x2 Passive	2.5 - 6.0	15	45 / 45	10 to 20	MS8	EAR99	HMC188MS8E
1.3 - 4.0	x2 Passive	2.6 - 8.0	15	45 / 40	10 to 20	Chip	EAR99	HMC158
1.3 - 4.0	x2 Passive	2.6 - 8.0	15	45 / 40	10 to 20	C8	EAR99	HMC158C8
2 - 4	x2 Passive	4 - 8	13	34 / 40	10 to 15	MS8	EAR99	HMC189AMS8E
4 - 8	x2 Passive	8 - 16	20	45 / 38	10 to 15	Chip	EAR99	HMC204
4 - 8	x2 Passive	8 - 16	17	41 / 40	10 to 15	C8	EAR99	HMC204C8
4 - 8	x2 Passive	8 - 16	17	42 / 50	10 to 15	MS8G	EAR99	HMC204MS8GE
6 - 12	x2 Passive	12 - 24	17	32 / 32	10 to 15	Chip	EAR99	HMC205
10 - 15	x2 Passive	20 - 30	13	30	+13	Chip	5A991.h	HMC-XDB112
12 - 18	x2 Passive	24 - 36	14	50 / 60	11 to 15	Chip	EAR99	HMC331
24 - 30	x3 Passive	72 - 90	19	-	+13	Chip	5A991.h	HMC-XTB110

PHASE LOCKED LOOP - Fractional-N & Integer-N ICs

Frequency	Function	Max. PFD Frequency	Max. Reference Frequency	Figure of Merit (Frac/Int) (dBc/Hz)	Frequency Resolution w/ 50 MHz Ref.	Bias Supply	Package	ECCN Code	Part Number
10 kHz - 8 GHz	Fractional-N with Sweeper	75 MHz	200 MHz	-221 / -227	3 Hz	+5V @ 37mA +3.3V @ 90mA	LP6C	3A001.a.11.b	HMC701LP6CE
10 kHz - 14 GHz	Fractional-N with Sweeper	75 MHz	200 MHz	-221 / -227	6 Hz	+5V @ 37mA +3.3V @ 136mA	LP6C	3A001.a.11.b	HMC702LP6CE
10 MHz - 8 GHz	Fractional-N	70 MHz	200 MHz	-221 / -226	3 Hz	+5V @ 7mA +3.3V @ 95mA	LP4	3A001.a.11.b	HMC700LP4E
NEW! DC - 8 GHz	Fractional-N with Sweeper	100 MHz	350 MHz	-230 / -233	3 Hz	+5V @ 6mA +3.3V @ 52mA	LP4	3A001.a.11.b	HMC703LP4E
DC - 8 GHz	Fractional-N	100 MHz	350 MHz	-230 / -233	3 Hz	+5V @ 6mA +3.3V @ 52mA	LP4	3A001.a.11.b	HMC704LP4E
80 MHz - 7 GHz	Integer-N	1300 MHz	1300 MHz	-233	50 MHz	+5V @ 310mA	LP5	3A001.a.11.b	HMC698LP5E
160 MHz - 7 GHz	Integer-N	1300 MHz	1300 MHz	-233	50 MHz	+5V @ 310mA	LP5	3A001.a.11.b	HMC699LP5E
10 MHz - 2.8 GHz	Integer-N	1300 MHz	1300 MHz	-233	50 MHz	+5V @ 250mA	QS16G	3A001.a.11.b	HMC440QS16GE

PLLs with INTEGRATED VCOs - Microwave & RF PLLs with Integrated VCOs

Frequency (MHz)	Function	Closed Loop SSB Phase Noise @ 10 kHz Offset	Open Loop VCO Phase Noise @ 1 MHz Offset	Pout (dBm)	RMS Jitter Fractional Mode (fs)	Integrated PN Fractional Mode (deg rms)	Package	ECCN Code	Part Number
fo/2									
665 - 825	Tri-Band RF VCO	-118 dBc/Hz	-148 dBc/Hz	11	180	0.05	LP6C	3A001.a.11.b	HMC822LP6CE
795 - 945	Tri-Band RF VCO	-123 dBc/Hz	-148 dBc/Hz	10	180	0.06	LP6C	3A001.a.11.b	HMC838LP6CE
780 - 870	RF VCO	-116 dBc/Hz	-148 dBc/Hz	14	180	0.06	LP6C	3A001.a.11.b	HMC824LP6CE
860 - 1040	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.07	LP6C	3A001.a.11.b	HMC821LP6CE
990 - 1105	RF VCO	-114 dBc/Hz	-146 dBc/Hz	11	180	0.07	LP6C	3A001.a.11.b	HMC826LP6CE
NEW! 1025 - 1150	Tri-Band RF VCO	-123 dBc/Hz	-147 dBc/Hz	12	180	0.07	LP6C	3A001.a.11.b	HMC837LP6CE
1050 - 1205	Tri-Band RF VCO	-121 dBc/Hz	-146 dBc/Hz	10	180	0.08	LP6C	3A001.a.11.b	HMC839LP6CE
1095 - 1275	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.08	LP6C	3A001.a.11.b	HMC820LP6CE
NEW! 1310 - 1415	Tri-Band RF VCO	-121 dBc/Hz	-145 dBc/Hz	10	180	0.09	LP6C	3A001.a.11.b	HMC840LP6CE
fo									
1285 - 1415	RF VCO	-112 dBc/Hz	-143 dBc/Hz	10	180	0.09	LP6C	3A001.a.11.b	HMC828LP6CE
1330 - 1650	Tri-Band RF VCO	-112 dBc/Hz	-142 dBc/Hz	6.5	180	0.11	LP6C	3A001.a.11.b	HMC822LP6CE
1590 - 1890	Tri-Band RF VCO	-118 dBc/Hz	-143 dBc/Hz	7.5	180	0.12	LP6C	3A001.a.11.b	HMC838LP6CE
1720 - 2080	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.13	LP6C	3A001.a.11.b	HMC821LP6CE
1815 - 2010	RF VCO	-112 dBc/Hz	-143 dBc/Hz	7.5	180	0.13	LP6C	3A001.a.11.b	HMC831LP6CE
NEW! 2050 - 2300	Tri-Band RF VCO	-117 dBc/Hz	-141 dBc/Hz	10.5	180	0.15	LP6C	3A001.a.11.b	HMC837LP6CE
2100 - 2410	Tri-Band RF VCO	-115 dBc/Hz	-140 dBc/Hz	7.5	180	0.16	LP6C	3A001.a.11.b	HMC839LP6CE
2190 - 2550	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.17	LP6C	3A001.a.11.b	HMC820LP6CE
NEW! 2620 - 2830	Tri-Band RF VCO	-115 dBc/Hz	-139 dBc/Hz	9	180	0.18	LP6C	3A001.a.11.b	HMC840LP6CE
2fo									
2660 - 3300	Tri-Band RF VCO	-106 dBc/Hz	-136 dBc/Hz	-4	180	0.21	LP6C	3A001.a.11.b	HMC822LP6CE
3180 - 3780	Tri-Band RF VCO	-112 dBc/Hz	-135 dBc/Hz	-4	180	0.24	LP6C	3A001.a.11.b	HMC838LP6CE
3365 - 3705	RF VCO	-107 dBc/Hz	-135 dBc/Hz	0	190	0.25	LP6C	3A001.a.11.b	HMC836LP6CE

PLLs with INTEGRATED VCOs - *Microwave & RF PLLs with Integrated VCOs*

	Frequency (MHz)	Function	Closed Loop SSB Phase Noise @ 10 kHz Offset	Open Loop VCO Phase Noise @ 1 MHz Offset	Pout (dBm)	RMS Jitter Fractional Mode (fs)	Integrated PN Fractional Mode (deg rms)	Package	ECCN Code	Part Number
	3440 - 4160	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.27	LP6C	3A001.a.11.b	HMC821LP6CE
	4100 - 4600	Tri-Band RF VCO	-111 dBc/Hz	-135 dBc/Hz	-0.5	180	0.30	LP6C	3A001.a.11.b	HMC837LP6CE
	4200 - 4820	Tri-Band RF VCO	-108 dBc/Hz	-135 dBc/Hz	-4	180	0.31	LP6C	3A001.a.11.b	HMC839LP6CE
	4380 - 5100	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.33	LP6C	3A001.a.11.b	HMC820LP6CE
	5240 - 5660	Tri-Band RF VCO	-109 dBc/Hz	-133 dBc/Hz	-3	180	0.37	LP6C	3A001.a.11.b	HMC840LP6CE
	7300 - 8200	Microwave VCO	-101 dBc/Hz	-140 dBc/Hz	15	196	0.58	LP6C	3A001.a.11.b	HMC764LP6CE
	7800 - 8800	Microwave VCO	-101 dBc/Hz	-140 dBc/Hz	13	193	0.61	LP6C	3A001.a.11.b	HMC765LP6CE
NEW!	9600 - 10800	Microwave VCO	-100 dBc/Hz	-135 dBc/Hz	9	185	0.7	LP6C	3A001.a.11.b	HMC778LP6CE
	11500 - 12500	Microwave VCO	-99 dBc/Hz	-134 dBc/Hz	10	181	0.81	LP6C	3A001.a.11.b	HMC783LP6CE
	12400 - 13400	Microwave VCO	-98 dBc/Hz	-132 dBc/Hz	8	175	0.84	LP6C	3A001.a.11.b	HMC807LP6CE
	Wideband Continuous Tuning									
NEW!	25 - 3000	Wideband RF VCO	-114 dBc/Hz @ 2 GHz Fract Mode	-141 dBc/Hz @ 2 GHz	5	180	0.13	LP6G	3A001.a.11.b	HMC830LP6GE

VOLTAGE CONTROLLED OSCILLATORS*

Fo Frequency (GHz)	Function	Fo Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
VCOs with Buffer Amplifier								
2.05 - 2.25	VCO with Buffer	3.5	-89	-112	+3V @ 35mA	LP4	EAR99	HMC384LP4E
2.25 - 2.5	VCO with Buffer	4.5	-89	-115	+3V @ 35mA	LP4	EAR99	HMC385LP4E
2.6 - 2.8	VCO with Buffer	5	-88	-115	+3V @ 35mA	LP4	EAR99	HMC386LP4E
2.75 - 3.0	VCO with Buffer	4.5	-89	-114	+3V @ 37mA	LP4	EAR99	HMC416LP4E
3.15 - 3.4	VCO with Buffer	4.9	-88	-113	+3V @ 39mA	LP4	EAR99	HMC388LP4E
3.35 - 3.55	VCO with Buffer	4.7	-89	-112	+3V @ 41mA	LP4	EAR99	HMC389LP4E
3.55 - 3.9	VCO with Buffer	4.7	-87	-112	+3V @ 42mA	LP4	EAR99	HMC390LP4E
3.9 - 4.45	VCO with Buffer	5	-81	-106	+3V @ 30mA	LP4	EAR99	HMC391LP4E
4.45 - 5.0	VCO with Buffer	4	-79	-105	+3V @ 30mA	LP4	EAR99	HMC429LP4E
5.0 - 5.5	VCO with Buffer	2	-80	-103	+3V @ 27mA	LP4	EAR99	HMC430LP4E
5.5 - 6.1	VCO with Buffer	2	-80	-102	+3V @ 27mA	LP4	EAR99	HMC431LP4E
5.8 - 6.8	VCO with Buffer	10	-82	-105	+3V @ 100mA	MS8G	EAR99	HMC358MS8GE
6.1 - 6.72	VCO with Buffer	4.5	-73	-101	+3V @ 31mA	LP4	EAR99	HMC466LP4E
6.8 - 7.4	VCO with Buffer	11	-80	-106	+3V @ 80mA	LP4	EAR99	HMC505LP4E
7.1 - 7.9	VCO with Buffer	14	-80	-101	+3V @ 85mA	LP4	EAR99	HMC532LP4E
7.8 - 8.7	VCO with Buffer	14	-80	-103	+3V @ 77mA	LP4	EAR99	HMC506LP4E
8.6 - 10.2	VCO with ÷4	18	-70	-100	+5V @ 220mA	LP5	3A001.a.11.b	HMC734LP5E
10.5 - 12.2	VCO with ÷4	17	-75	-100	+5V @ 220mA	LP5	3A001.a.11.b	HMC735LP5E
13.2 -13.5	VCO with ÷8	-8	-83	-110	+5V @ 230mA	QS16G	3A001.a.11.b	HMC401QS16GE
14.0 - 15.0	VCO with ÷8	6	-75	-110	+5V @ 260mA	QS16G	3A001.a.11.b	HMC398QS16GE
23.8 - 24.8	VCO with ÷16	12	-70	-95	+5V @ 220mA	LP4	3A001.a.11.b	HMC533LP4E
Wideband VCOs								
4 - 8	Wideband VCO	5	-75	-100	+5V @ 55mA	LC4B	EAR99	HMC586LC4B
5 - 10	Wideband VCO	5	-65	-95	+5V @ 55mA	LC4B	EAR99	HMC587LC4B
6 - 12	Wideband VCO	1	-65	-95	+5V @ 57mA	LC4B	EAR99	HMC732LC4B
8 - 12.5	Wideband VCO	5	-65	-93	+5V @ 55mA	LC4B	EAR99	HMC588LC4B
10 - 20	Wideband VCO	3	-60	-90	+5V @ 70mA	LC4B	EAR99	HMC733LC4B

** HMC VCOs integrate resonator, negative resistance generator and tuning varactor circuits on-chip. No external components are required.*

VOLTAGE CONTROLLED OSCILLATORS WITH Fo/2 OUTPUT

Fo Frequency (GHz)	Fo/2 Frequency (GHz)	Function	Fo Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
VCOs with Fo/2									
6.65 - 7.65	3.325 - 3.825	VCO with Fo/2	13	-90	-115	+5V @ 230mA	LP5	EAR99	HMC507LP5E
7.3 - 8.2	3.65 - 4.1	VCO with Fo/2	15	-90	-116	+5V @ 240mA	LP5	EAR99	HMC508LP5E
7.8 - 8.8	3.9 - 4.4	VCO with Fo/2	13	-90	-115	+5V @ 250mA	LP5	EAR99	HMC509LP5E
9.05 - 10.15	4.525 - 5.075	VCO with Fo/2	13	-88	-115	+5V @ 265mA	LP5	EAR99	HMC511LP5E
14.5 - 15.0	7.25 - 7.5	VCO with Fo/2	9	-80	-105	+4.2V @ 150mA	LP4	EAR99	HMC736LP4E
14.9 - 15.5	7.45 - 7.75	VCO with Fo/2	9	-80	-105	+4.2V @ 150mA	LP4	EAR99	HMC737LP4E
VCOs with Fo/2 & ÷4									
8.45 - 9.55	4.225 - 4.775	VCO with Fo/2 & ÷4	13	-92	-116	+5V @ 315mA	LP5	3A001.a.11.b	HMC510LP5E
9.5 - 10.8	4.75 - 5.4	VCO with Fo/2 & ÷4	11	-85	-110	+5V @ 350mA	LP5	3A001.a.11.b	HMC530LP5E
9.6 - 10.8	4.8 - 5.4	VCO with Fo/2 & ÷4	9	-85	-111	+5V @ 330mA	LP5	3A001.a.11.b	HMC512LP5E
10.43 - 11.46	5.215 - 5.73	VCO with Fo/2 & ÷4	7	-85	-110	+3V @ 275mA	LP5	3A001.a.11.b	HMC513LP5E
10.6 - 11.8	5.3 - 5.9	VCO with Fo/2 & ÷4	11	-82	-110	+5V @ 350mA	LP5	3A001.a.11.b	HMC534LP5E
11.1 - 12.4	5.55 - 6.2	VCO with Fo/2 & ÷4	9	-83	-110	+5V @ 350mA	LP5	3A001.a.11.b	HMC582LP5E

SMT & Chip (Die) Products

VOLTAGE CONTROLLED OSCILLATORS WITH Fo/2 OUTPUT

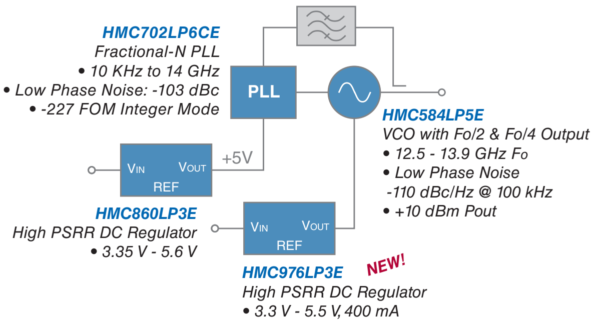
Fo Frequency (GHz)	Fo/2 Frequency (GHz)	Function	Fo Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
11.17 - 12.02	5.585 - 6.01	VCO with Fo/2 & ÷4	7	-87	-110	+3V @ 275mA	LP5	3A001.a.11.b	HMC514LP5E
11.5 - 12.5	5.75 - 6.25	VCO with Fo/2 & ÷4	10	-83	-110	+5V @ 200mA	LP5	3A001.a.11.b	HMC515LP5E
11.5 - 12.8	5.75 - 6.4	VCO with Fo/2 & ÷4	11	-80	-110	+5V @ 350mA	LP5	3A001.a.11.b	HMC583LP5E
12.4 - 13.4	6.2 - 6.7	VCO with Fo/2 & ÷4	8	-83	-110	+5V @ 260mA	LP5	3A001.a.11.b	HMC529LP5E
12.5 - 13.9	6.25 - 6.95	VCO with Fo/2 & ÷4	10	-81	-110	+5V @ 330mA	LP5	3A001.a.11.b	HMC584LP5E
13.6 - 14.9	6.8 - 7.45	VCO with Fo/2 & ÷4	7	-82	-110	+5V @ 260mA	LP5	3A001.a.11.b	HMC531LP5E
14.25 - 15.65	7.125 - 7.825	VCO with Fo/2 & ÷4	9	-80	-107	+5V @ 350mA	LP5	3A001.a.11.b	HMC632LP5E
VCOs with Fo/2 & ÷16									
20.9 - 23.9	10.45 - 11.95	VCO with Fo/2 & ÷16	9	-65	-95	+5V @ 200mA	LP4	3A001.a.11.b	HMC738LP4E
23.8 - 26.8	11.9 - 13.4	VCO with Fo/2 & ÷16	8	-64	-93	+5V @ 200mA	LP4	3A001.a.11.b	HMC739LP4E

PHASE LOCKED OSCILLATOR

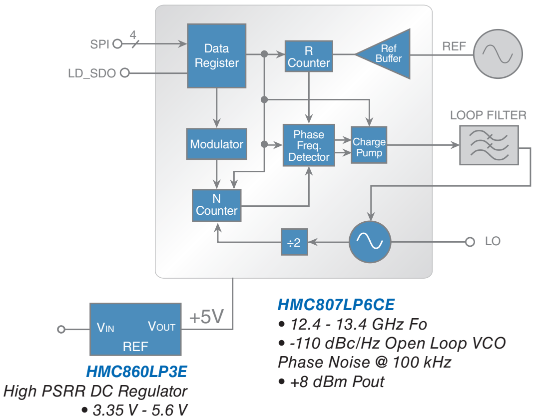
Fo Frequency (GHz)	Function	Fo Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package	ECCN Code	Part Number
14.7 - 15.4	Phase Locked Oscillator	9	-80	-110	+5V @ 340mA +12V @ 28mA	LP4	3A001.a.11.b	HMC535LP4E

HITTITE'S HIGH FREQUENCY LO SOURCE ALTERNATIVES

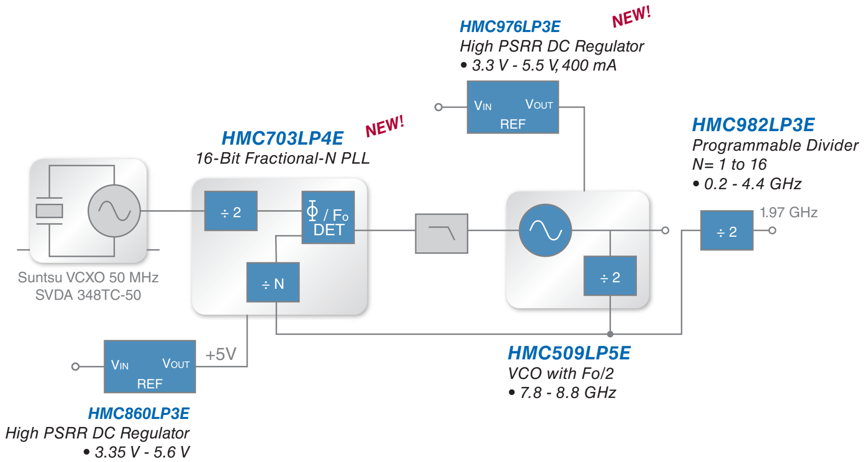
PLL & VCO CHIPSET



PLL WITH INTEGRATED VCO IC



REFERENCE CLOCK SOLUTIONS FOR 100G DP-QPSK

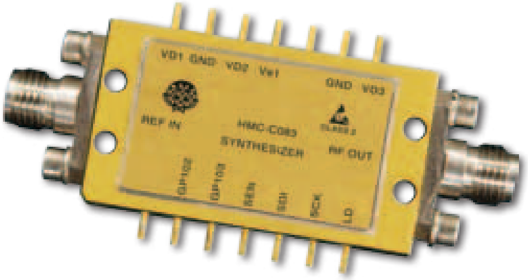


Typical LO & Clock Generation IC applications are illustrated.
See the full product listing for alternatives to the select HMC products shown in each functional block.

CONNECTORIZED MODULES

Robust, High Performance RF to Light Solutions

Our hermetic module product line is expanding with two new module families. The new *SDLVA* joins our already popular amplifier, attenuator, DRO, high speed digital logic, frequency multiplier, MicroSynth® integrated synthesizer, mixer, phase shifter, prescaler, switch & VCO product portfolio. Utilizing our standard MMIC products, we take advantage of our design, manufacturing and quality knowledge base. Contact us to discuss your custom module requirements.



Features:

- ***Off-The-Shelf Availability***
- ***Hermetically Sealed***
- ***Internal DC Power Regulation***
- ***Field Replaceable Connectors***
- ***Military & Space Upscreening***
- ***Customization Offered***

AMPLIFIERS

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package / Connector	ECCN Code	Part Number
1 - 12	Low Noise	16	30	1.8	16	+6V @ 60mA	C-10B / SMA	EAR99	HMC-C059
1.8 - 4.2	Low Noise	26	26	0.7	15.5	+8V @ 112mA	C-10 / SMA	EAR99	HMC-C045
5 - 9	Low Noise	24	25	1.4	15	+12V @ 105mA	C-10 / SMA	EAR99	HMC-C048
29 - 36	Low Noise	20	22	2.9	11	+3V @ 80mA	C-10 / 2.92mm	3A001.b.4.c	HMC-C027
2 - 20	Wideband LNA	15	25	2.5	14	+12V @ 65mA	C-1 / SMA	EAR99	HMC-C001
2 - 20	Wideband LNA	14	26	2	18	+12V @ 60mA	C-2 / SMA	EAR99	HMC-C002
2 - 20	Wideband LNA	14	27	2	16	+8V @ 75mA	C-2B / SMA	EAR99	HMC-C022
7 - 17	Wideband LNA	22	25	2	14	+8V @ 93mA	C-1 / SMA	EAR99	HMC-C016
17 - 27	Wideband LNA	18	25	3	14	+8V @ 96mA	C-1B / 2.92mm	EAR99	HMC-C017
0.01 - 20	Wideband Driver	16	33	3	23	+12V @ 195mA	C-3 / SMA	3A001.b.4.f	HMC-C004
0.01 - 20	Wideband Driver	15	30	3	23	+12V @ 225mA	C-3B / SMA	3A001.b.4.f	HMC-C024
2 - 35	Wideband Driver	12	29	3	18	+11V @ 92mA	C-10 / 2.92mm	3A001.b.4.c	HMC-C038
0.01 - 6.0	Single Stage Power Amplifier, 1 Watt	13	40	5	29.5	-5V @ 5mA +15V @ 450mA	C-17 / SMA	EAR99	HMC-C074
0.01 - 6.0	Two Stage Power Amplifier, 1 Watt	24	42	5	29.5	-5V @ 5mA +15V @ 740mA	C-17 / SMA	EAR99	HMC-C075
0.01 - 15	Wideband Power Amplifier, 1/2 Watt	12	36	4	28	+11V @ 360mA	C-10B / SMA	3A001.b.4.f	HMC-C036
0.01 - 15	Wideband Power Amplifier, 1/2 Watt	12	36	4	28	+11V @ 360mA	C-12 / SMA	3A001.b.4.f	HMC-C037
2 - 20	Wideband Power Amplifier	15	34	4	26	+12V @ 310mA	C-2 / SMA	3A001.b.4.f	HMC-C003
2 - 20	Wideband Power Amplifier	15	34	4	26	+12V @ 310mA	C-2B / SMA	3A001.b.4.f	HMC-C023
2 - 20	Wideband Power Amplifier	31	33	3	26	+12V @ 400mA	C-3B / SMA	3A001.b.4.f	HMC-C026
17 - 24	Wideband Power Amplifier	22	33	3.5	24	+8V @ 250mA	C-10 / 2.92mm	EAR99	HMC-C020
21 - 31	Wideband Power Amplifier	15	32	5	24	+8V @ 215mA	C-10 / 2.92mm	3A001.b.4.c	HMC-C021
0.8 - 2.0	Power Amplifier, 10 Watt	43	56	12	40	+12V @ 6.5A	C-7 / SMA	EAR99	HMC-C013

AMPLIFIERS - Low Phase Noise

Frequency (GHz)	Function	Gain / NF (dB)	OIP3 (dBm)	10 kHz Phase Noise (dBc/Hz)	P1dB / Psat (dBm)	Bias Supply	Package / Connector	ECCN Code	Part Number
1.5 - 5.0	Low Phase Noise	14 / 4.5	26.5	-171	17 / 22	+7V @ 170mA	C-16 / SMA	EAR99	HMC-C077
2 - 18	Low Phase Noise	13.5 / 5	22.5	-160	15 / 18.5	+5V @ 80mA	C-1 / SMA	EAR99	HMC-C050
3 - 8	Low Phase Noise	9 / 6	33	-168	22 / 25	+7V @ 300mA	C-16 / SMA	EAR99	HMC-C079
6 - 12	Low Phase Noise	11 / 4.5	34	-176	20 / 22	+7V @ 170mA	C-16 / SMA	EAR99	HMC-C072
7 - 11	Low Phase Noise	9 / 6	33	-170	22 / 25	+7V @ 300mA	C-16 / SMA	EAR99	HMC-C076

ATTENUATORS - Analog & Digital

Frequency (GHz)	Function	Loss (dB)	Attenuation Range (dB)	IIP3 (dBm)	Control Input (Vdc)	Package / Connector	ECCN Code	Part Number
DC - 20	Analog VVA	5.5	35	10	-5	C-10 / SMA	EAR99	HMC-C053
DC - 13	6-Bit Digital, Serial Control	3.6	0.5 to 31.5	32	Serial/CMOS	C-6 / SMA	EAR99	HMC-C018
DC - 13	6-Bit Digital	3.2	0.5 to 31.5	38	0 / +5V	C-6 / SMA	EAR99	HMC-C025

DIELECTRIC RESONATOR OSCILLATORS (DRO)

Frequency (GHz)	Function	Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Frequency Drift (ppm/°C)	Bias Supply	Package	ECCN Code	Part Number
8.0 - 8.3	Dielectric Resonator Oscillator	14.5	-122	-140	2	+6 to +15V @ 125mA	C-18 / SMA	EAR99	HMC-C200

CONNECTORIZED MODULES

Robust, High Performance RF to Light Solutions

FREQUENCY DIVIDERS (PRESCALERS)

Input Freq. (GHz)	Function	Input Power (dBm)	Output Power (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package / Connector	ECCN Code	Part Number
DC - 18	Divide-by-2	-15 to +10	-4	-150	+5V @ 75mA	C-1 / SMA	3A001.a.11.b	HMC-C005
DC - 18	Divide-by-4	-15 to +10	-4	-150	+5V @ 93mA	C-1 / SMA	3A001.a.11.b	HMC-C006
0.5 - 8	Divide-by-5	-15 to +10	-1	-155	+5V @ 80mA	C-1 / SMA	3A001.a.11.b	HMC-C039
DC - 18	Divide-by-8	-15 to +10	-4	-150	+5V @ 98mA	C-1 / SMA	3A001.a.11.b	HMC-C007
0.5 - 17	Divide-by-10	-15 to +10	-1	-155	+5V @ 152mA	C-1 / SMA	3A001.a.11.b	HMC-C040

FREQUENCY MULTIPLIERS - Active

Input Freq. (GHz)	Function	Output Freq. (GHz)	Input Power (dBm)	Output Power (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Package / Connector	ECCN Code	Part Number
3 - 5	x2 Active	6 - 10	3	17	-140	C-10 / SMA	EAR99	HMC-C031
9.0 - 14.5	x2 Active	18 - 29	3	16	-132	C-10 / 2.92mm	EAR99	HMC-C032
12.0 - 16.5	x2 Active	24 - 33	3	17	-132	C-10 / 2.92mm	EAR99	HMC-C033
16 - 23	x2 Active	32 - 46	3	13	-130	C-10 / 2.92mm	EAR99	HMC-C034
4.0 - 10.5	x2 Active	8 - 21	6	14	-142	C-10 / SMA	EAR99	HMC-C056

HIGH SPEED DIGITAL LOGIC

Data / Clock Rate (Gbps / GHz)	Function	Rise / Fall Time (ps)	Deterministic Jitter (ps)	Differential Output Swing (Vp-p)	DC Power (mW)	Vee Power Supply (Vdc)	Package / Connector	ECCN Code	Part Number
50 / 30	1:2 Fanout Buffer	9.5 / 11	2	0.5	455	-3.3	C-13 / 1.85mm	3A001.a.11.b	HMC-C062
50 / 25	AND / NAND / OR / NOR	9 / 10	2	0.5	560	-3.3	C-13 / 1.85mm	3A001.a.11.b	HMC-C065
43 / 43	D-Type Flip-Flop	9 / 10	1.5	0.5	580	-3.3	C-13 / 1.85mm	3A001.a.11.b	HMC-C060
50 / 25	D-Type Flip-Flop Double Edge Triggered	9 / 11	1.5	0.5	690	-3.3	C-13 / 1.85mm	3A001.a.11.b	HMC-C061
50 / 25	XOR / XNOR	6.5 / 10	2	0.5	550	-3.3	C-13 / 1.85mm	3A001.a.11.b	HMC-C064

I/Q MIXERS

RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Image Rejection (dB)	IIP3 (dBm)	Package / Connector	ECCN Code	Part Number
4 - 8.5	I/Q Mixer / IRM	DC - 3.5	-7.5	35	23	C-4 / SMA	EAR99	HMC-C009
6 - 10	I/Q Mixer / IRM	DC - 3.5	-7.5	35	25	C-4 / SMA	EAR99	HMC-C041
8.5 - 13.5	I/Q Mixer / IRM	DC - 2	-8	28	25	C-4 / SMA	EAR99	HMC-C042
11 - 16	I/Q Mixer / IRM	DC - 3.5	-9	30	28	C-4 / SMA	EAR99	HMC-C043
15 - 23	I/Q Mixer / IRM	DC - 3.5	-8	30	25	C-4 / 2.92mm & SMA	EAR99	HMC-C044
20 - 31	I/Q Mixer / IRM	DC - 4.5	-10	24	22.5	C-4B / 2.92mm & SMA	EAR99	HMC-C046
30 - 38	I/Q Mixer / IRM	DC - 3.5	-10.5	15	19	C-4 / 2.92mm & SMA	EAR99	HMC-C047

MIXERS

RF Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	LO/RF Isolation (dB)	IIP3 (dBm)	Package / Connector	ECCN Code	Part Number
7 - 14	+13 LO, DBL-BAL	DC - 5	-7	48	20	C-11 / SMA	EAR99	HMC-C049
11 - 20	+13 LO, DBL-BAL	DC - 6	-7	43	18	C-11 / SMA	EAR99	HMC-C051
16 - 32	+13 LO, DBL-BAL	DC - 8	-8	35	19	C-11 / 2.92mm & SMA	EAR99	HMC-C014
23 - 37	+13 LO, DBL-BAL	DC - 13	-9	35	19	C-11 / 2.92mm & SMA	EAR99	HMC-C035
24 - 38	+13 LO, DBL-BAL	DC - 8	-8.5	35	20	C-11 / 2.92mm & SMA	EAR99	HMC-C015

PHASE SHIFTERS - Analog

Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	2nd harmonic Pin = 10 dBm (dBc)	Control Voltage Range (Vdc)	Package / Connector	ECCN Code	Part Number
6 - 15	Analog	7	750° @ 6 GHz 450° @ 15 GHz	40	0V to +5V	C-1 / SMA	EAR99	HMC-C010

PHASE SHIFTERS - Digital

Frequency (GHz)	Function	Insertion Loss (dB)	Phase Range (deg)	IIP3 (dBm)	Control Voltage Range (Vdc)	Package / Connector	ECCN Code	Part Number
8 - 12	4-Bit Digital	7	22.5 to 360	38	0V to +5V	C-6 / SMA	EAR99	HMC-C055

SDLVAs - Successive Detection Log Video Amplifier

Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV / dB)	RF Threshold Level (dBm)	Bias Supply	Package / Connector	ECCN Code	Part Number
1 - 20	SDLVA	59	14	-67	+12V @ 86mA	C-10 / 2.92mm	EAR99	HMC-C052
2 - 20	SDLVA with Limited RF Output	50	45	-45	+12V @ 370mA -5V @ 20mA	C-21 / SMA	EAR99	HMC-C078

Robust, High Performance RF to Light Solutions

SWITCHES - SPST, SPDT & SP4T

Frequency (GHz)	Function	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Switching Speed (ns)	Package / Connector	ECCN Code	Part Number
DC - 20	SPST, Hi Isolation	3	100	23	8.5	C-9 / SMA	EAR99	HMC-C019
DC - 18	SPDT, Hi Isolation	2	55	27	3	C-14 / SMA	EAR99	HMC-C058
DC - 20	SPDT, Hi Isolation	2	40	23	5	C-5 / SMA	EAR99	HMC-C011
DC - 20	SP4T, Hi Isolation	3	40	24	14	C-15 / SMA	EAR99	HMC-C071

SYNTHESIZED MODULES - MicroSynth®

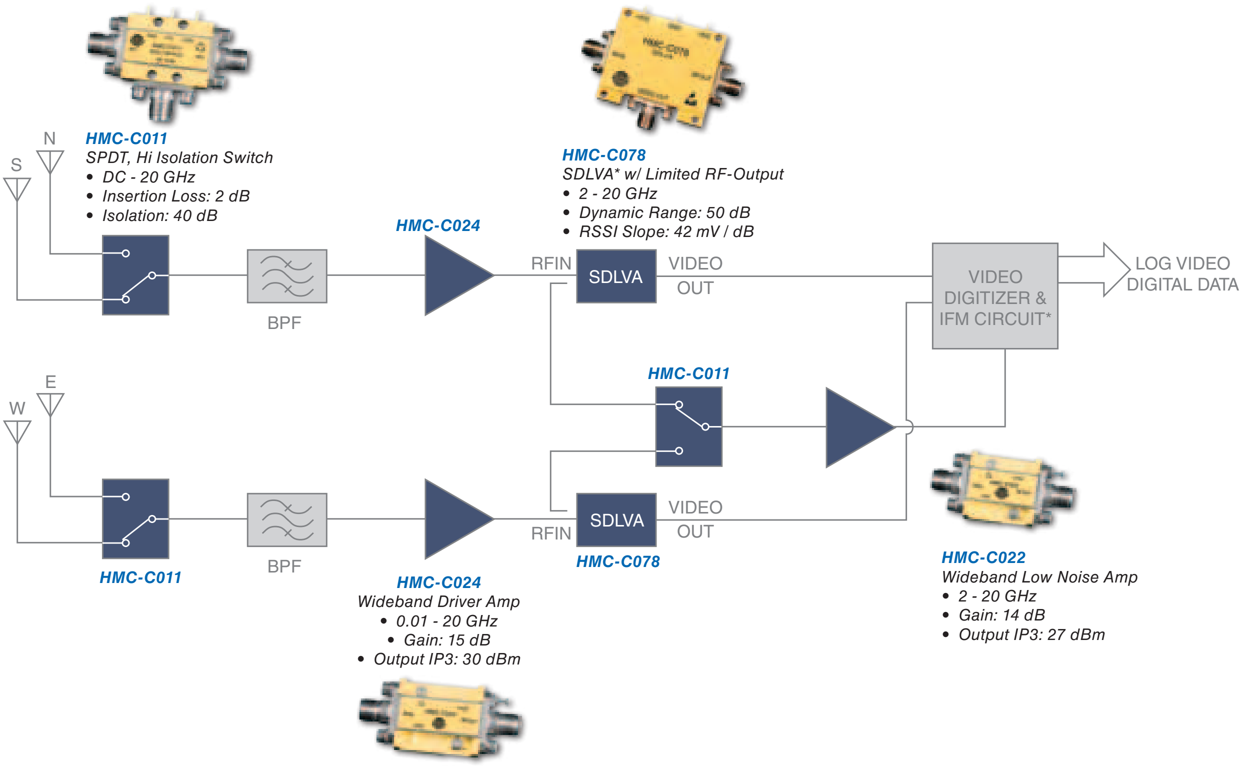
Frequency (GHz)	Function	Min. Step Size Resolution (Hz)	Reference Frequency (MHz)	SSB Phase Noise @ 100 kHz Offset (dBc/Hz)	Output Power (dBm)	Bias Supply	Package	ECCN Code	Part Number
2 - 6	MicroSynth® Synthesizer	0.6	10	-93	17	+20V @ 7mA +6V @ 330mA	C-20 / SMA	EAR99	HMC-C083
5.5 - 10.5	MicroSynth® Synthesizer	1.2	10	-92	21	+20V @ 20mA +6V @ 300mA +3.6V @ 100mA	C-20 / SMA	EAR99	HMC-C070

VOLTAGE CONTROLLED OSCILLATORS

Frequency (GHz)	Function	Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Package / Connector	ECCN Code	Part Number
4 - 8	Wideband VCO	20	-75	-95	+12V @ 185mA	C-1 / SMA	EAR99	HMC-C028
5 - 10	Wideband VCO	20	-64	-93	+12V @ 195mA	C-1 / SMA	EAR99	HMC-C029
8 - 12.5	Wideband VCO	21	-59	-83	+12V @ 195mA	C-1 / SMA	EAR99	HMC-C030
38.4 - 43.2	VCO	13	-74	-98	+5V @ 350mA	C-19 / 2.4mm	EAR99	HMC-C073

Hittite Microwave can offer any of our Die or SMT IC products in a connectorized module. Full specifications for each product are available at www.hittite.com.

RADAR RECEIVER APPLICATION

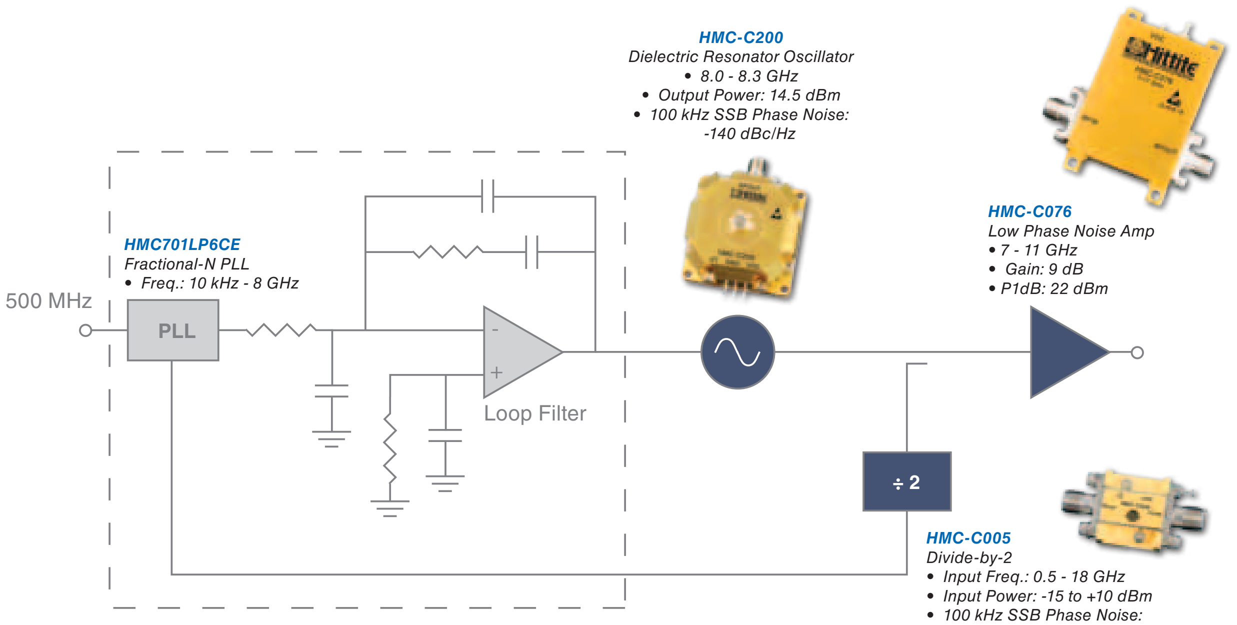


****Successive Detection Log Video Amplifier***

Hittite MICROWAVE CORPORATION

Robust, High Performance RF to Light Solutions

Ultra Low Phase Noise Phase Locked Oscillator (PLO) Application



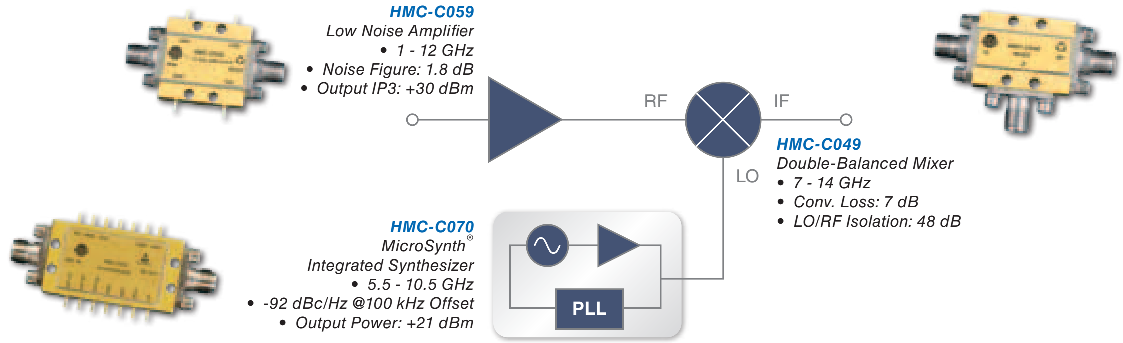
HMC-C200
Dielectric Resonator Oscillator
- 8.0 - 8.3 GHz
- Output Power: 14.5 dBm
- 100 kHz SSB Phase Noise: -140 dBc/Hz

HMC701LP6CE
Fractional-N PLL
- Freq.: 10 kHz - 8 GHz

HMC-C076
Low Phase Noise Amp
- 7 - 11 GHz
- Gain: 9 dB
- P1dB: 22 dBm

HMC-C005
Divide-by-2
- Input Freq.: 0.5 - 18 GHz
- Input Power: -15 to +10 dBm
- 100 kHz SSB Phase Noise: -150 dBc/Hz

X-Band Downconverter Application

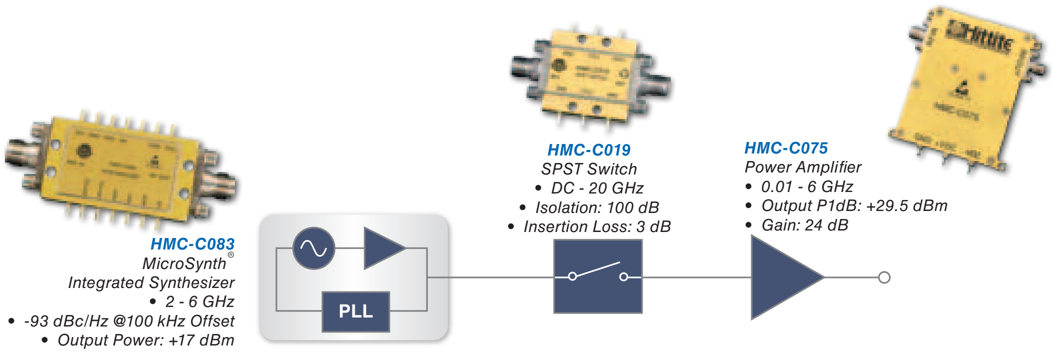


HMC-C059
Low Noise Amplifier
- 1 - 12 GHz
- Noise Figure: 1.8 dB
- Output IP3: +30 dBm

HMC-C049
Double-Balanced Mixer
- 7 - 14 GHz
- Conv. Loss: 7 dB
- LO/RF Isolation: 48 dB

HMC-C070
MicroSynth®
Integrated Synthesizer
- 5.5 - 10.5 GHz
- -92 dBc/Hz @100 kHz Offset
- Output Power: +21 dBm

Pulsed 0.5W C-Band Synthesizer Application



HMC-C019
SPST Switch
- DC - 20 GHz
- Isolation: 100 dB
- Insertion Loss: 3 dB

HMC-C075
Power Amplifier
- 0.01 - 6 GHz
- Output P1dB: +29.5 dBm
- Gain: 24 dB

HMC-C083
MicroSynth®
Integrated Synthesizer
- 2 - 6 GHz
- -93 dBc/Hz @100 kHz Offset
- Output Power: +17 dBm

Expanded Synthesized Signal Generator Family to 70 GHz

$3,998
HMC-T2000
700 MHz to 8 GHz

$7,998
HMC-T2100
10 MHz to 20 GHz

$14,998
HMC-T2220B
10 MHz to 20 GHz
Battery Powered

Our Signal Generator Products

- ***Wide Frequency Range:*** *10 MHz to 70 GHz*
- ***Versatile:*** *High Output Power Simplifies Test Set-Ups*
- ***Efficient:*** *Fast Frequency Switching Below 500 µs*
- ***Flexible:*** *Manual or USB / GPIB / Ethernet Control*

$9,998
HMC-T2220
10 MHz to 20 GHz

HMC-T2240
10 MHz to 40 GHz

$19,498

Performance

- *High Output Power: +20 dBm @ 40 GHz*
- *Excellent 10 GHz SSB Phase Noise: -92 dBc/Hz @ 100 kHz Offset*
- *Spurious: < -65 dBc @ 10 GHz*
- *Resolution: 0.1 dB & 1 Hz*
- *Fast Switching: 500 µs*

NEW!

HMC-T2270
10 MHz to 70 GHz

Performance

- *+19 dBm @ 40 GHz, +2 dBm @ 70 GHz*
- *Excellent 30 GHz SSB Phase Noise: -85 dBc/Hz @ 100 kHz Offset*
- *Spurious: < -60 dBc @ 70 GHz*
- *Call for Price*

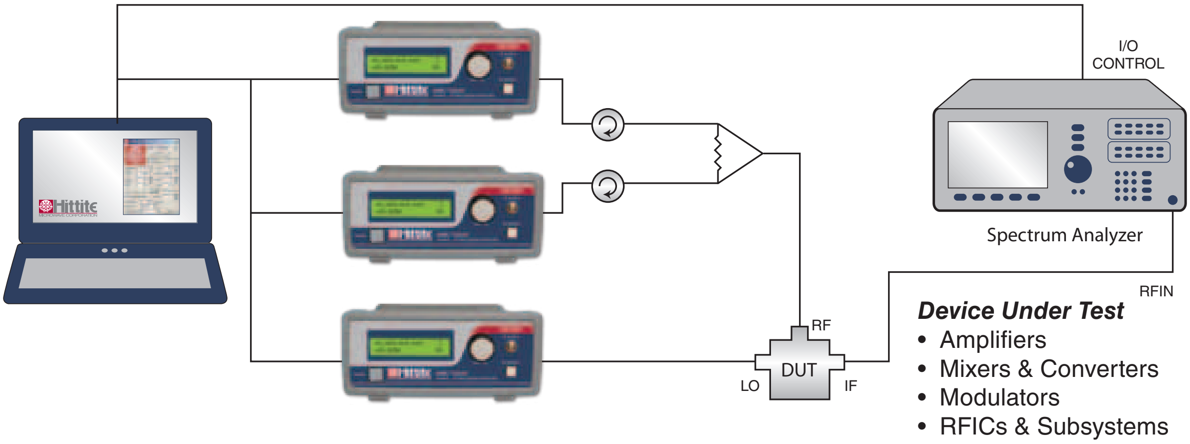
Hittite MICROWAVE CORPORATION

Expanded Synthesized Signal Generator Family to 40 GHz

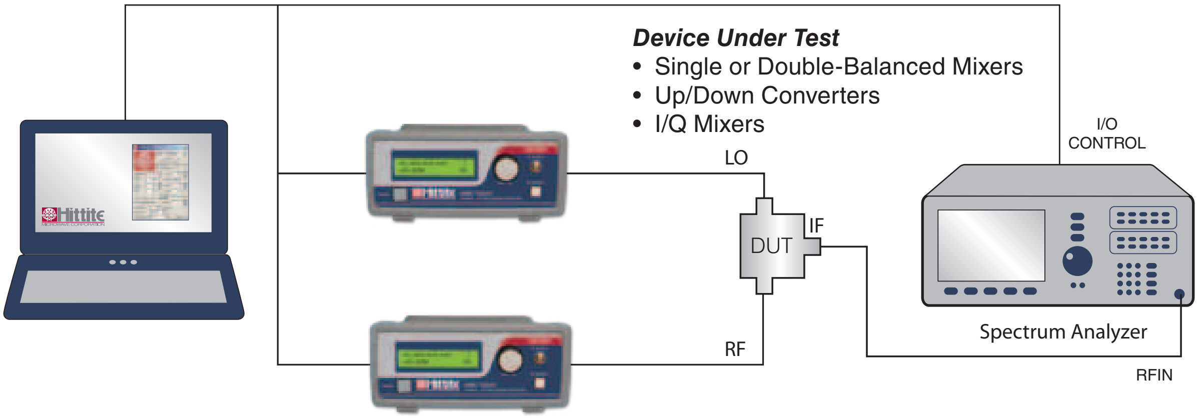
SIGNAL GENERATORS - Precise RF Signal Generation for ATE & Lab Environments

	Frequency (GHz)	Function	Frequency Resolution	Maximum Power Output (dBm)	100 kHz SSB Phase Noise (dBc/Hz)	Spurious (dBc)	Switching Speed Steps (µs)	Package	ECCN Code	Part Number
	0.7 - 8.0	Signal Generator	1 MHz	+17 @ 1 GHz +10 @ 8 GHz	-87 @ 4 GHz	< -45	200	Rack Mountable / Benchtop	EAR99	**HMC-T2000**
	0.01 - 20	Signal Generator	10 kHz	+25 @ 1 GHz +22 @ 20 GHz	-93 @ 10 GHz	< -27	300	Rack Mountable / Benchtop	EAR99	**HMC-T2100**
	0.01 - 20	Portable Signal Generator	1 Hz	+28 @ 1 GHz +24 @ 20 GHz	-99 @ 10 GHz	< -57	300	Portable / Benchtop	EAR99	**HMC-T2220B**
	0.01 - 20	Signal Generator	1 Hz	+28 @ 1 GHz +24 @ 20 GHz	-99 @ 10 GHz	< -57	300	Rack Mountable / Benchtop	EAR99	**HMC-T2220**
	0.01 - 40	Signal Generator	1 Hz	+29 @ 1 GHz +20 @ 40 GHz	-92 @ 10 GHz	< -60	500	Rack Mountable / Benchtop	EAR99	**HMC-T2240**
NEW!	0.01 - 70	Signal Generator	1 Hz	+28 @ 1 GHz +2 @ 70 GHz	-118 @ 1 GHz -80 @ 70 GHz	< -60 Below 10 GHz < -65 @ 70 GHz	300	Rackmountable / Benchtop	3A002.d.3.e	**HMC-T2270**

Two Tone Third Order Intercept Test Set-up



Efficient Mixer Conversion Loss, Isolation & MxN Spurious Test Set-up



HMC-T2000, HMC-T2100, HMC-T2220, HMC-T2240 & HMC-T2270 Rack Mount Kit Available!

Dual Rack Mounting Plate 19” 2u Chassis

Contact Us Today with Your Custom Test Instrumentation Requirements at TE@hittite.com

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High Reliability Solutions for Land, Sea, Air & Space

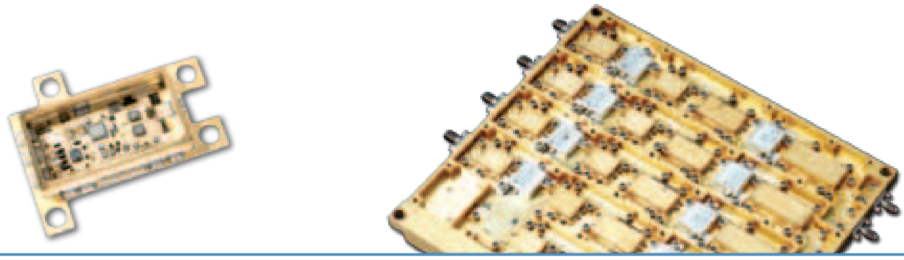
Military Level Components, Modules & Subsystems

- Class B screening on standard & custom product die and SMT packaging.
- Design, production & screening of highly integrated MIC sub-assemblies for major defense OEMs.
- Military & Space Upscreening to Customer Specifications.

Military Solution Inquiries: MIL@hittite.com

Class B Screening & Qualification

- ***VI to Method 2010B & 2017H***
- ***Bond Pull & Die Shear Test***
- ***Solderability Test***
- ***High Temp Burn-In Test***
- ***Vibration Stress Test***
- ***Temp Cycle Stress Test***
- ***Constant Acceleration Stress Test***
- ***Fine & Gross Hermeticity Test***
- ***Serialized Test Data***
- ***ESD Characterization***



Space Level Components, Modules & Subsystems

Class S Screening & Qualification

- ***VI to Methods 2010A & 2017K***
- ***Temp Cycle Stress Test***
- ***High Temp Burn-In & Life Test***
- ***Wafer Lot Acceptance Test***
  - ***Bond Pull & Die Shear Test***
  - ***SEM Inspection***
  - ***Metal & Glass Thicknesses***
- ***Serialized Test Data***
- ***Qualification Report***

- Class S screening on standard & custom product die and SMT packaging.
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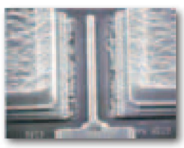
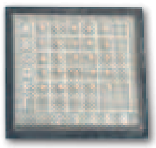
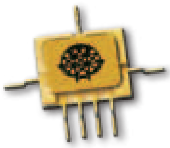
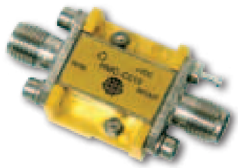
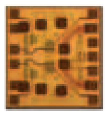

FET Channel SEM


Serialized Die in GEL-PAK


Hermetic SMT Package


Hermetic Modules


Chip (Die)

Contact Us Today With Your High Reliability Mixed-Signal RF, Microwave & Millimeterwave Requirements!

Designer's Kits

Evaluation Boards & ICs Reduce Design Cycle Time

7 Designer's Kits Available to Choose From!

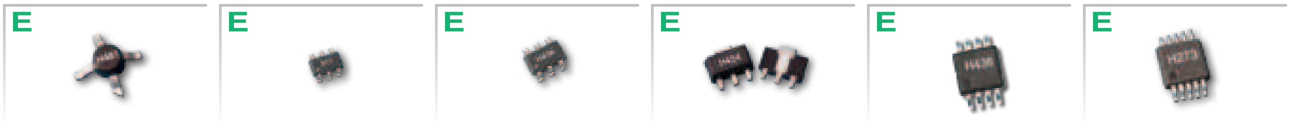
- ***Gain Blocks DC - 6 GHz, HMC-DK001***
- ***Linear Driver Amplifiers 0.4 - 2.5 GHz, HMC-DK002***
- ***High IP3 Mixers 0.45 - 4.0 GHz, HMC-DK003***
- ***Digital Attenuators DC - 6 GHz, HMC-DK004***
- ***SPDT Switches DC - 12 GHz, HMC-DK005***
- ***Passive Attenuator Chips DC - 50 GHz, HMC-DK006***
- ***Serial/Parallel USB Interface Kit, HMC-DK008***

Design engineers can order pre-packaged MMIC Designer's Kits which enable them to quickly assess which Hittite product is the best choice for their application. The end result is a design that goes to layout more quickly and with fewer subsequent changes.

Each Hittite Designer's Kit contains an assembled & tested connectorized evaluation board, 5 to 10 ICs of each part and the latest Hittite CD-ROM catalog.

Designer's Kit	Kit Contents			
	ICs		Eval Boards	
Gain Blocks **DC - 6 GHz** **HMC-DK001**	HMC474MP86E HMC476MP86E HMC313E HMC311ST89E HMC478MP86E HMC478ST89E	HMC479MP86E HMC479ST89E HMC481ST89E HMC480ST89E HMC481MP86E HMC482ST89E	104217 – HMC313E 110161 – HMC478ST89E 107490 – HMC481MP86E	
Linear Driver Amps **0.4 - 2.5 GHz** **HMC-DK002**	HMC454ST89E HMC450QS16GE HMC413QS16GE	HMC452ST89E HMC453ST89E HMC457QS16GE	107749 – HMC454ST89E 108349 – HMC450QS16GE 105000 – HMC413QS16GE	108712 – HMC452ST89E 108718 – HMC453ST89E 106043 – HMC457QS16GE
Hi-IP3 Mixers **0.45 - 4.0 GHz** **HMC-DK003**	HMC387MS8E HMC483MS8GE HMC399MS8E HMC316MS8E HMC400MS8E HMC485MS8GE	HMC402MS8E HMC214MS8E HMC478ST89E HMC481ST89E HMC480ST89E	110161 – HMC478ST89E 105188 – HMC485MS8GE	106334 – HMC399MS8E 101830 – HMC400MS8E
Digital Attenuators **DC - 6 GHz** **HMC-DK004**	HMC291E HMC468LP3E HMC274QS16E HMC271ALP4E HMC273MS10GE	HMC305ALP4E HMC306MS10E HMC470LP3E HMC472LP4E	103372 – HMC291E 107302 – HMC468LP3E 104976 – HMC274QS16E 108782 – HMC271ALP4E 103393 – HMC273MS10GE	108782 – HMC305AMS10E 103393 – HMC306MS10E 107006 – HMC470LP3E 107010 – HMC472LP4E
SPDT Switches **DC - 12 GHz** **HMC-DK005**	HMC221AE HMC284MS8GE HMC349MS8GE HMC232LP4E HMC544E	HMC595E HMC574MS8E HMC784MS8GE HMC536MS8GE	101675 – HMC221AE 107662 – HMC349MS8GE 107723 – HMC232LP4E	104124 – HMC574MS8E 104124 – HMC784MS8GE 105143 – HMC536MS8GE
Passive Attenuators **DC - 50 GHz** **HMC-DK006**	HMC650 HMC651 HMC652 HMC653 HMC654	HMC655 HMC656 HMC657 HMC658		
Serial/Parallel **USB Interface Kit** **HMC-DK008**	The HMC-DK008 Serial/Parallel Interface Designer's kit enables users to interface with Hittite's family of digital attenuators, interface and variable gain amplifiers.			

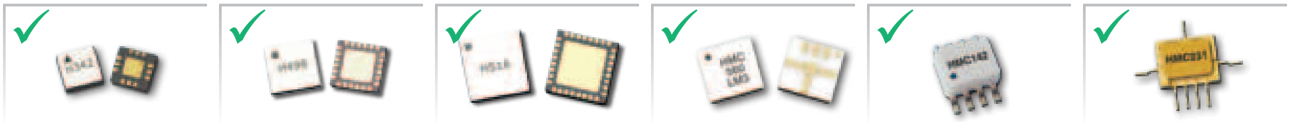
Available Plastic, Ceramic, Hermetic SMT & Connectorized Module Packages



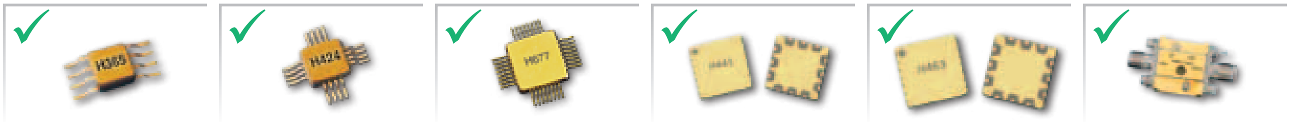
MP86 "Micro-P"	SC70	SOT26	ST89	MS8 / MS8G	MS10 / MS10G
5.21 x 5.08 x 1.57 mm	2.15 x 2.1 x 0.9 mm	2.8 x 2.9 x 1.2 mm	4.50 x 4.14 x 1.54 mm	4.9 x 3.0 x 1.0 mm	4.9 x 3.0 x 1.0 mm

S8 / S8G	S14	LP2 "DFN"	LP3 "QFN"	LP4 / LP4B / LP4C "QFN"	LP5 "QFN"
6.0 x 4.9 x 1.6 mm	6.0 x 8.7 x 1.6 mm	2.0 x 2.0 x 1.0 mm	3.0 x 3.0 x 1.0 mm	4.0 x 4.0 x 1.0 mm	5.0 x 5.0 x 1.0 mm

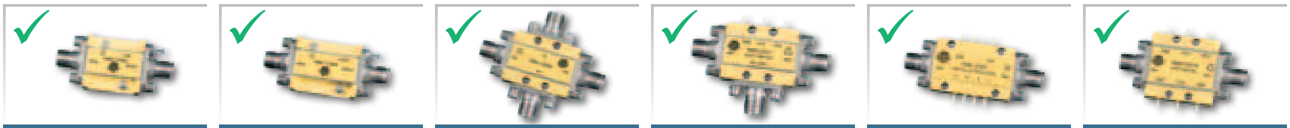
LP6 / LP6C "QFN"	LP6H "QFN"	LP7D "QFN"	LP9 "QFN"	QS16 / QS16G	QS24
6.0 x 6.0 x 1.0 mm	6.0 x 6.0 x 1.0 mm	7.0 x 7.0 x 1.0 mm	9.0 x 9.0 x 1.0 mm	6.0 x 4.9 x 1.5 mm	6.0 x 8.7 x 1.6 mm



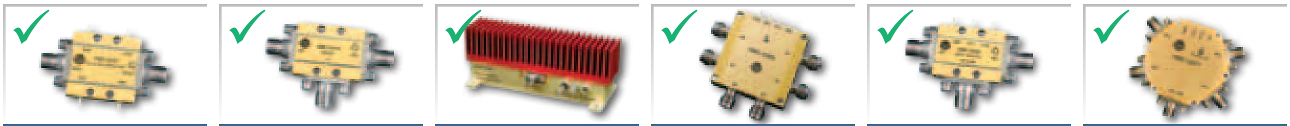
LC3 / LC3B / LC3C	LC4 / LC4B	LC5	LM1 / LM3	C8	G7 Hermetic
3.0 x 3.0 x 1.0 / 1.45 mm	4.0 x 4.0 x 1.0 / 1.2 mm	5.0 x 5.0 x 1.0 mm	5.1 x 5.1 x 1.1 mm	7.4 x 5.1 x 2.4 mm	16.1 x 17.3 x 1.7 mm



G8 Hermetic	G16 Hermetic	G32 Hermetic	LH250 Hermetic	LH5 Hermetic	C-1 / C-1B
10.2 x 4.6 x 1.8 mm	10.4 x 10.4 x 1.7 mm	16 x 16 x 1.96 mm	6.35 x 6.35 x 1.27 mm	5.0 x 5.0 x 1.0 mm	35.31 x 17.78 x 7.38 mm



C-2 / C-2B	C-3 / C-3B	C-4	C-5	C-6	C-9
38.1 x 17.78 x 7.38 mm	40.89 x 17.78 x 7.38 mm	41.66 x 36.32 x 8.50 mm	41.66 x 26.8 x 8.79 mm	45.34 x 17.27 x 8.50 mm	44.45 x 21.59 x 8.76 mm



C-10 / C-10B	C-11	C-12	C-13	C-14	C-15
46.63 x 21.59 x 8.50 mm	41.66 x 26.8 x 8.64 mm	107.6 x 43.0 x 43.0 mm	39.43 x 47.12 x 11.42 mm	41.91 x 29.85 x 9.65 mm	59.69 mm DIA x 9.14 mm

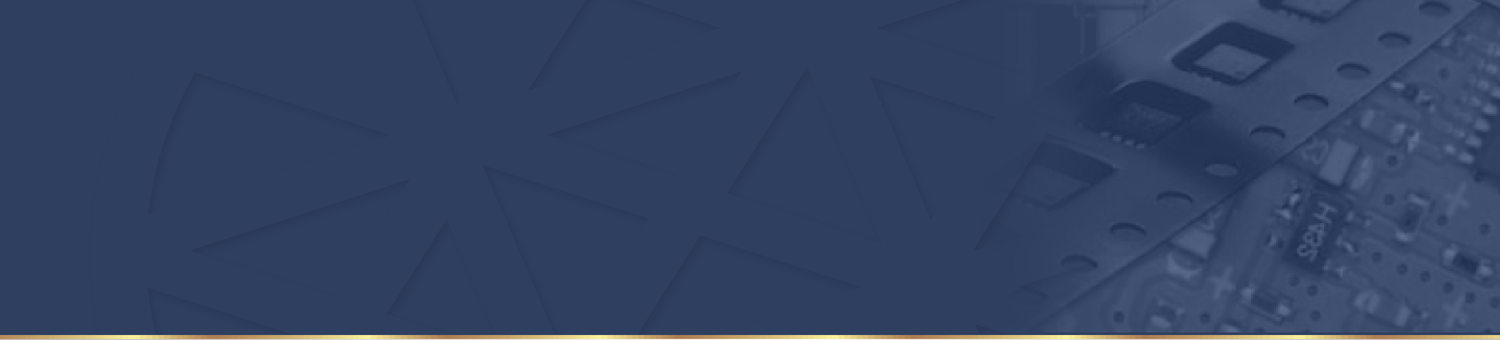
C-16	C-17	C-18	C-19	C-20	C-21
48.0 x 48.26 x 14.10 mm	68.5 x 66.0 x 14.2 mm	38.10 x 47.62 x 26.67 mm	27.31 x 25.15 x 5.84 mm	53.59 x 19.05 x 6.22 mm	38.10 x 33.53 x 5.84 mm

E or ✓ = *RoHS Compliant.*

For more information on our "Green" component program, please contact earthfriendly@hittite.com for details on our RoHS Compliant products or see the RoHS Compliant Components link on our web site.

Hittite MICROWAVE CORPORATION

Part Number Index



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