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RF design™

engineering principles and practices

October 1994

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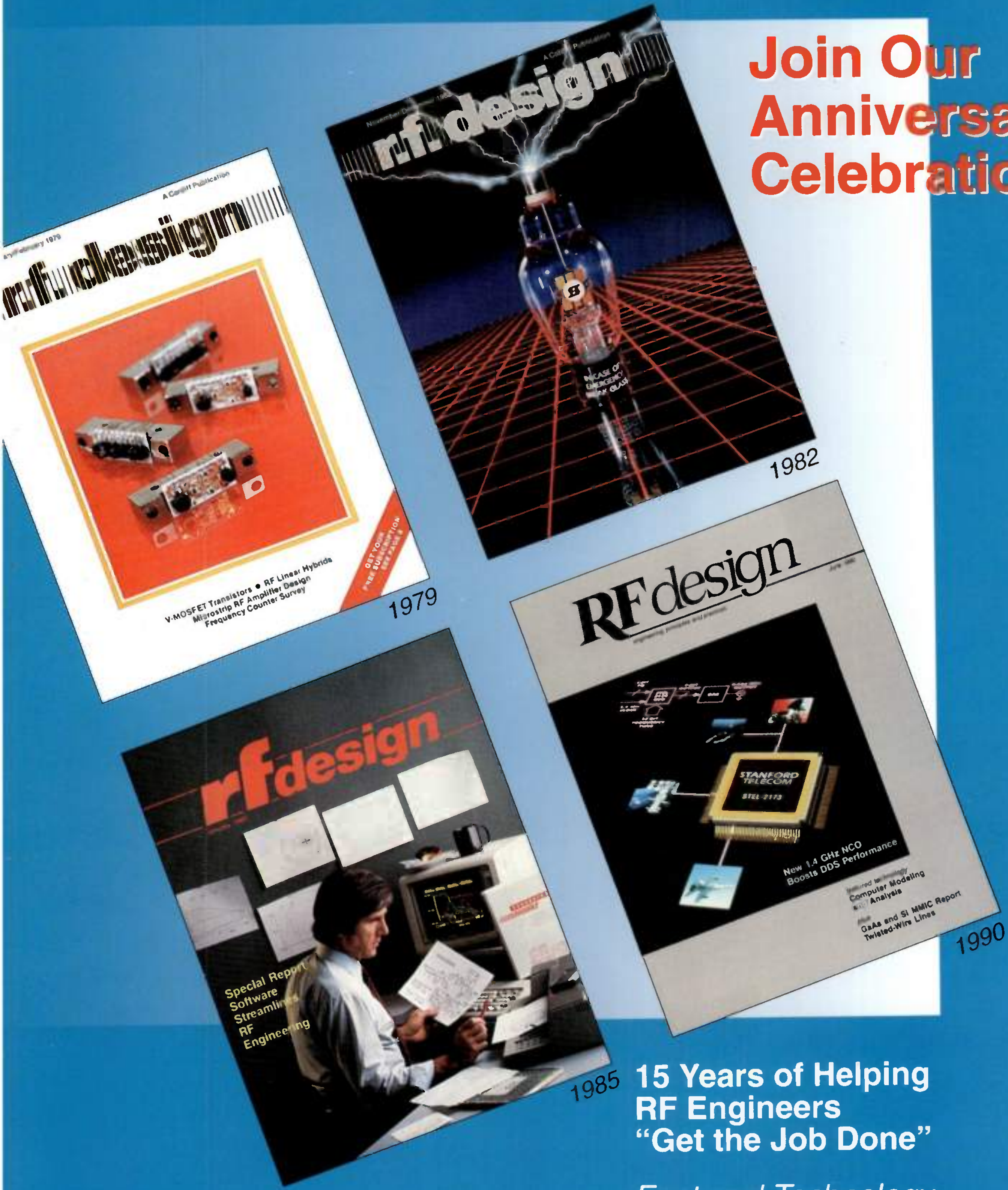
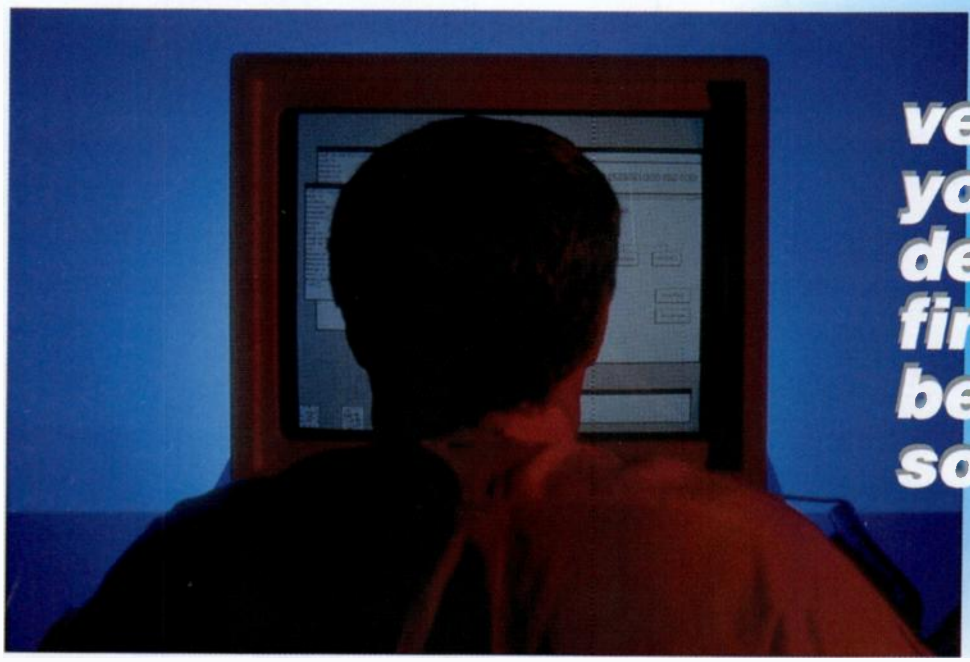


15 Years of Helping RF Engineers "Get the Job Done"

Featured Technology

RF Test Methods

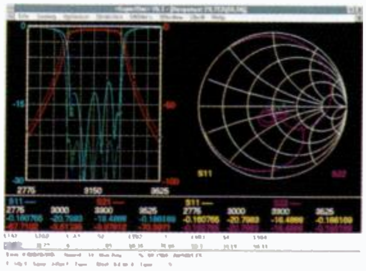
New System 32 Software...



verify your designs... find better solutions.

Typical design flow

Initial synthesis in =M/FILTER=



Tune or optimize in =SuperStar= simulator

Layout to plotter, printer, HPGL and DXF files

REAL-TIME CIRCUIT SIMULATION
- Accurate models
- Huge library
- Easy nodal entry
- Schematic entry
- Tune by tapping
- Super-fast optimization
- Unrestricted noise
- Statistical analysis
- 3-D plotting

CIRCUIT SYNTHESIS

=FILTER= (L-C filters)
- Coupled-resonator, zig-zag, symmetric, Blinchikoff, conventional, other structures
- All popular transfer shapes
- Group-delay equalizers

=M/FILTER= (microwave filters)
- End, edge, hairpin, combline, elliptic, interdigital, stepped-Z, lowpass, bandstop, highpass
- Microstrip, rod, stripline, coax, generic
- Layout generation

=OSCILLATOR=
- L-C, SAW, crystal, T-line
- VCOs
- Noise estimation

=MATCH=
- Multiple algorithms
- General synthesis & order
- Active or passive
- Arbitrary terminations

=A/FILTER= (active filters)
- Multiple structures
- All popular transfer shapes
- Non-ideal op-amps

System 32 available for...

MS DOS · MICROSOFT WINDOWS · MICROSOFT WINDOWS NT

Windows versions are 32-bit
Complete packages from $695
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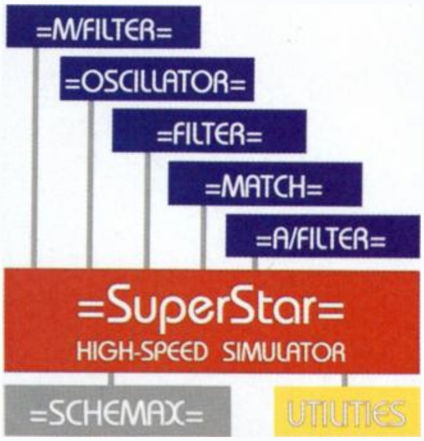
No annual fees



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INFO/CARD 1

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SPECIFICATIONS

	MODEL	Freq. (GHz)	Price $ea. (1-9)
■	ZC2PD-900	.80-.90	64.95
■	ZN2PD-920	.80-.92	59.95
■	ZN2PD-920W	.70-1.05	54.95
■	IZY2PD-64	5.80-6.40	69.95
■	IZY2PD-86	7.0-8.60	94.95
■●▼	ZAPD-1	.50-1.0	54.95
■●▼	ZAPD-2	1.0-2.0	54.95
■●	ZAPD-4	2.0-4.20	59.95
■●▼	ZAPD-21	.50-2.0	59.95
■	ZN3PD-900	.80-.90	74.95
■	ZN3PD-900W	.65-1.05	69.95
■●	ZA3PD-1	.50-1.0	89.95
■●	ZA3PD-1.5	.75-1.50	89.95
■●	ZA3PD-2	1.0-2.0	89.95
■●	ZA3PD-4	2.0-4.20	89.95
■	ZC6PD-960	.89-.96	124.95
■	ZC6PD-960W	.70-1.0	119.95
■	ZC6PD-1900	1.70-1.90	134.95
■	ZC6PD-1900W	1.50-2.0	129.95
■●	ZB6PD1-900	.80-.90	139.95
■●	ZB6PD1-960	.89-.96	139.95
■●	ZB6PD1-1900	1.70-1.90	149.95
■●	ZAPDQ-2 (90°)	1.0-2.0	79.95
■●	ZAPDQ-4 (90°)	2.0-4.20	79.95

	MODEL	Freq. (GHz)	Price $ea. (1-9)
■●▼	ZAPDJ-2 (180°)	1.0-2.0	71.95
■●	ZA4PD-2	1.0-2.0	89.95
■●	ZA4PD-4	2.0-4.20	89.95
■●	ZB4PD-42	1.70-4.20	99.95
■●	ZB4PD-4	3.70-4.20	94.95
▼	ZB4PD-1750-75	.875-1.75	99.95
■●	ZB4PD1-930	.85-.93	99.95
■●	ZB4PD1-930W	.725-1.05	94.95
●	ZB4PD1-8.4	6.70-8.40	149.95
■	ZC4PD-900	.80-.90	89.95
■	ZN4PD-920	.80-.92	84.95
■	ZN4PD-920W	.67-1.0	79.95
■	ZC8PD-900	.80-.90	158.95
■●	ZB8PD-2	1.0-2.0	138.95
■●	ZB8PD-4	2.0-4.20	138.95
●	ZB8PD-8.4	7.10-8.40	149.95
■	ZC9PD-1000	.80-1.0	169.95
■	ZC10PD-900	.80-.90	178.95
■	ZC16PD-900	.80-.90	295.00
■	ZC16PD-960	.89-.96	295.00
■	ZC16PD-960W	.70-1.0	265.00
■	ZC16PD-1900	1.70-1.90	349.00
■	ZC16PD-1900W	1.50-2.10	319.00

For detailed specs refer to Mini-Circuits Short Form Catalog, Trade Directories listed below or consult factory.
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F 177 Rev A

INFO/CARD 3

F134 Rev D

RF design

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October 1994

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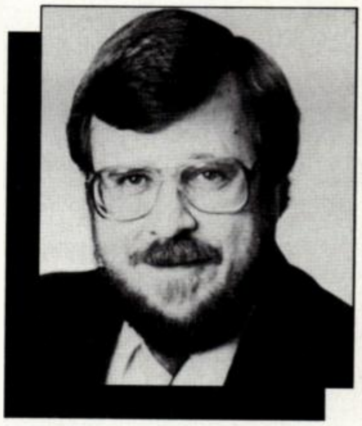
RF editorial

Change is Everywhere You Look



By Gary A. Breed
Editor

We're wrapping up a year of celebration in this issue. 15 and 5/6 years have passed since the first issue. As we prepare to turn sixteen, it's fun to look back at the changes that have happened around us over this period of time.

At the end of 1978, I was working for a consulting firm — designing, building, tuning and fixing broadcast radio and television stations around the country. Unfortunately, I didn't discover *RF Design* until 1982. Till then, I was still a reader of those "other" electronics magazines that were abandoning RF in favor of the more glamorous computer technology.

In 1985, *RF Design* had become a monthly magazine, and needed a larger staff to handle more frequent publication. They made the wise (!) decision to advertise for a new editor in their own magazine. The timing was perfect. I was ready to move from my broadcast specialty into a wider realm, and as the cliche goes — the rest is history.

More than nine years later, I'm still here. Hey! RF is a fascinating technology, and an editor's vantage point is unique. Everyone I deal with is a specialist in some area of RF, and I can learn a lot from them. The nice part is that I get to sit back and "put the pieces together," something very few specialists have an opportunity to do.

What have I learned from watching the RF industry go on around me?

First, I have learned that the RF industry has the most approachable experts in any area of technology. No question about it. Great minds in components, instruments, modulation theory, computer modeling, and everything else have proven to be extremely cooperative. Arrogance is a lot harder to find in the RF industry than any other industry I am aware of. Many of these gurus have become legendary *because* of their accessibility — people are thoroughly impressed with an expert that anyone can talk to!

The other major lesson I have learned in nine years is that the basic principles of RF change very slowly, and the specific implementations of those principles can change overnight. Kirchhoff and Maxwell haven't been revised significantly, a transistor is still a transistor, and all the major oscillator configurations were developed by 1940.

However, 256-QAM was barely thinkable in 1978, and cellular phone service was just getting ready for the first extensive trials. 1 GHz was considered microwaves and the words "wireless," "portable," "computer," and "communications" could not possibly be used in the same sentence! I would have committed serious crimes to gain access to a circuit synthesis and analysis computer program and a Pentium-speed machine. In 1978, stuff like that would have been stamped *CLASSIFIED* and confiscated by the government!

Don't ask me what to expect in 15 more years. It's more fun to watch it happen than to make wrong guesses. I can predict one thing with certainty, however — RF technology will still be extremely important in 15 years. The rise of computer technology sure didn't slow it down 15 years ago!

Like I said, basic principles don't change rapidly. Electromagnetism is a fundamental force in nature, and RF engineering is the profession that puts that force to work.

INFO/CARD 6

RF design

Established 1978

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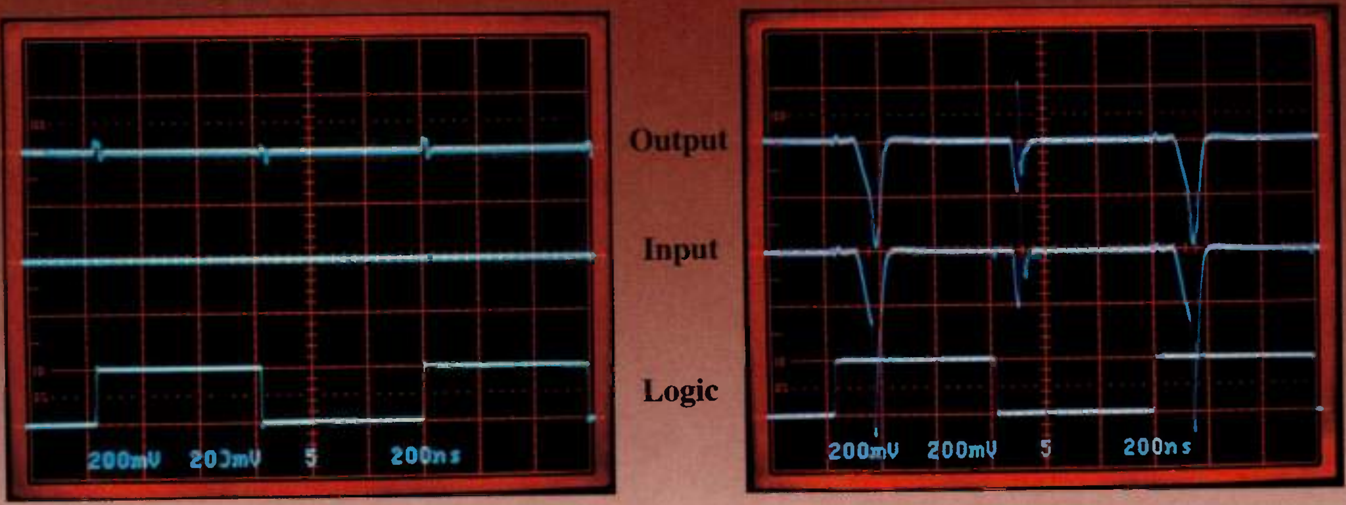
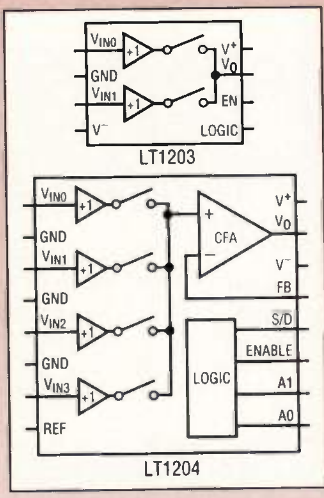


LT1203 CMOS MUX

LTC Video Multiplexers Have 90dB Isolation.

LTC's family of video multiplexers deliver professional quality solutions on your PC board without cascading switches to improve channel separation and isolation. The LT1203, LT1204 and LT1205 provide 90dB of isolation at 10MHz on real printed circuit boards. Forget those old switch buffers too, because all LTC multiplexers include buffers, are easily expandable and operate on ±5V to ±15V supplies. Switching glitches are almost invisible. The 2-input and 4-input LT1203/05 switch channels in only 25nsec and unlike CMOS switches, are virtually glitch-free at both output and input.

The LT1203/1205 are ideally suited for high speed graphics, multimedia, video routers or crosspoint applications delivering 150MHz bandwidth, 0.1dB gain flatness to 30MHz and Differential Gain/Phase of 0.02%/0.02° for true color fidelity.



For multiplexing where more output current is needed such as cable driving, the LT1204 4-input Video Multiplexer has an on-chip 75MHz Current Feedback Amplifier with 50mA output drive and 0.1dB gain flatness to 30MHz. A unique bootstrapping feature allows you to create larger multiplexers (8:1, 16:1) by just connecting the LT1204's outputs together, and you still get 90dB isolation at 10MHz on your PC board.

So, for multimedia, graphics or broadcast quality video, make LTC your first stop for ALL of your multiplexer needs. Pricing starts at $2.96 in 1000-piece quantities for the LT1203CS8. The LT1204CN is $4.78 and the surface mount LT1205CS starts at $5.06, both in 1000-piece quantities.

For details, contact Linear Technology Corporation, 1630 McCarthy Boulevard, Milpitas, California 95035/ 408-432-1900. For literature only, call **1-800-4-LINEAR.**

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INFO/CARD 8

GIGA-TRONICS 6080A & 6082A SYNTHESIZED RF SIGNAL GENERATORS

Giga-tronics Presents The Alternative To $30,000 And $40,000 RF Synthesizers.

Hewlett-Packard makes a couple of very good RF synthesizers. And if you can afford the luxury of paying $30,000 or $40,000 for the name, by all means, call HP right now. They'll be happy to take your order, and your money.

However, if you're looking for an RF synthesizer with outstanding performance and proven reliability for about half the price, you'd better call Giga-tronics.

Here's why:

Performance.
Check the charts. In virtually every category, the Giga-tronics 6080A and 6082A RF Synthesizers meet or exceed the specs of the HP machines. And they use the same GPIB command set, for direct replacement without expensive new software.

Experience.
Granted, Hewlett-Packard has been around a long time. But, Giga-tronics is no Johnny-come-lately.

Giga-tronics has a 14-year history of building test and measurement gear for the most demanding requirements. We've shipped thousands of instruments for use in the testing of radar, EW and communications systems.

Reliability.
Making reliable RF synthesizers is usually no fluke.

However, in this case, it is.

The Giga-tronics 6080A and 6082A RF Synthesizers give you great performance and proven reliability for a lot less money.

Specifications	Hewlett-Packard HP 8642A	Giga-tronics 6080A	Hewlett-Packard HP 8642B	Giga-tronics 6082A
Frequency Range Switching speed	.1 to 1057 MHz <85 ms	.01 to 1056 MHz <100 ms	.1 to 2115 MHz <85 ms	.1 to 2112 MHz <100 ms
Spectral Purity* Spurious Subharmonics	<-100 dBc None	<-100 dBc None	<-94 dBc <-45 dBc	<-94 dBc <-45 dBc
Phase Noise* @ 20 kHz offset	<-134 dBc/Hz	<-131 dBc/Hz	<-125 dBc/Hz	<-125 dBc/Hz
Residual FM* (.3 to 3 kHz BW)	<2 Hz	<1.5 Hz	<5 Hz	<3 Hz
Output Range* Accuracy Reverse Power Protection	+16 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+17 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+16 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc	+13 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc
Amplitude Modulation Depth Distortion @ 30%	0–99.9% <2%	0–99.9% <1.5%	0–99.9% <2%	0–99.9% <1.5%
Frequency Modulation Max. Deviation* Distortion	3 MHz <2%	4 MHz <1% @ 50% Dev.	3 MHz <2%	8 MHz <1% @ 50% Dev.
Phase Modulation Max. Deviation*	100 Rad.	40/400 Rad.	200 Rad.	80/800 Rad.
Pulse Modulation On/off Rise/fall time Minimum Pulse Width	>40 dB <400 ns <2 µs	>40/60 dB <15 ns (Typ 7.5 ns) <30 ns	>40/80 dB <400 ns <2 µs	>80 dB <15 ns (Typ 7.5 ns) <30 ns
Internal Modulation Source Level Range Waveforms Programmable	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes
Memory Locations (NVM)	51 Full Function	50 Full Function	51 Full Function	50 Full Function
U.S. List Price	**$30,340**	**$16,950**	**$41,680**	**$22,950**

The question is not why Giga-tronics is so much less, but rather, why Hewlett-Packard wants so much more.

*Specifications for both the 6080A and the HP 8642A are at 1GHz. Specifications for both the 6082A and the HP 8642B are at 2GHz. Prices and specifications for the HP 8642A and HP 8642B are from the Hewlett-Packard 1993 catalog. Prices for the Giga-tronics 6080A and 6082A are U.S. list prices.

Both the 6080A and 6082A were originally introduced in 1990 by John Fluke Manufacturing Company. To date, thousands have performed flawlessly in the field.

For added confidence, the instruments incorporate self-testing, internal diagnostics and modular design for easy fault isolation and repair.

Service.

If a problem occurs, Giga-tronics technical support staff can often help you find and fix the problem over the phone.

If you need to return an instrument for repair, we can service it at our factory in California, or at one of our worldwide sales and service centers.

But at Giga-tronics, customer service starts even before you become a customer.

Whether you're looking to buy one unit or one hundred, you'll get the same assistance, including a demonstration at your facility.

Price.

Considering all this, the real question is not why Giga-tronics is so much less, but rather, why Hewlett-Packard wants so much more?

So, if you're interested in paying a lot less for great performance and proven reliability, backed by a worldwide network of service and support, call us toll free at **800 726 GIGA** (4442). We'll send you more information and arrange for a demonstration.

Giga-tronics

Giga-tronics Incorporated
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Telephone: 800 726 4442 or 510 328 4650
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INFO/CARD 9

RF letters

Letters should be addressed to: Editor, RF Design, *6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Letters may be edited for length or clarity.*

Line Length Corrections

Editor:

I have written some comments regarding the article, "An S-Parameter Based Amplifier Design Program", published in the December 1993 issue. Regarding the minimum noise figure amplifier design example, matching networks for both the input and output are not exact. $Z_s = 13.98 + j7.57$ corresponds to a reflection coefficient of $G_s = 0.5713\angle 161.38$. Then the lengths of the 30 Ω and 26.55 Ω lines should be 0.2419λ and 0.3856λ respectively. Similarly, $Z_l = 17.92 + j35.64$ corresponds to $G_l = 0.6251\angle 104.3$. In this case we cannot realize this impedance if the characteristic impedance of the series line is less than 66.631 Ω. So, with the series and stub lines characteristic impedances of 66.73 Ω and 43.45 Ω, the corresponding lengths should be 0.2368λ and 0.3791λ.

Ramesh Mangipudi
BE/CRL
Bangalore, India

Corrections

Several schematics in Dan Pleasant's June article, "Using Design of Experiments to Optimize Filter Tuning Steps", contain printing errors. The quantity 0.01 which appears under the inductance values for the coils in Figures 2, 4 and 6 are the coils' resistance, and should have the symbol Ω after them. The variable capacitors in Figures 4 and 6 should be variable from 0 to 2 nF, not 10 to 21. The labels on the x-axis of Figure 3 refer to start and stop frequencies, and the units for the y-axis are dB(S21).

Thanks to William B. Lurie of Boynton Beach, Florida for pointing out these errors.

RF calendar

October

9-13 **31st Annual AOC International EW Technical Symposium and Convention**
Washington, DC
Information: The Association of Old Crows, The AOC Building, 1000 North Payne Street, Alexandria, VA 22314–1696. Tel: (703) 549–1600.

18-21 **ICSPST 94 - International Conference on Signal Processing Applications and Technology**
Dallas, TX
Information: DSP Associates, 49 River Street, Waltham, MA 02154. Tel: (617) 891–6000. Fax: (617) 899–4449.

24-25 **Soft Ferrite Users' Conference**
Chicago, IL
Information: MMPA Headquarters, 11 South La Salle, Suite 1400, Chicago, IL 60603. Tel: (312) 922–6222.

25-27 **Microwaves 94**
London, England
Information: Anna Tapster, Nexus Business Communications, Warwick House, Swanley, Kent BR8 8HY, United Kingdom. Tel: 44 322 660070. Fax: 44 322 614898.

November

8-12 **Electronica 94**
Munich Germany
Information: Jerry Kallman Jr., Kallman Associates, Inc., 20 Harrison Ave., Waldwick, NJ 07463–1709. Tel: (201) 652–7070. Fax: (201) 652–3898.

14-17 **RF Expo East**
Orlando, FL
Information: RF Expo East, Registration Coordinator, 6151 Powers Ferry Rd. NW, Atlanta, GA 30339. Tel: (800) 828–0420. Fax: (404) 618–0441.

15-17 **International Society for Hybrid Microelectronics Symposium**
Boston, MA
Information: ISHM - The Microelectronics Society, 1850 Centennial Park Drive, Suite 105, Reston, VA 22091. Tel: (703) 758–1060. Fax: (703) 758–1066.

January

29-1 **RF Expo West**
San Diego, CA
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29-1 **EMC/ESD International**
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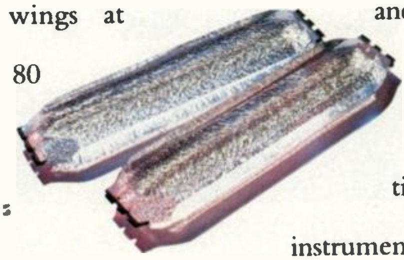

C-MAC's frequency control products are equally renowned for their perfect stability, even at frequencies up to 2.6 GHz.

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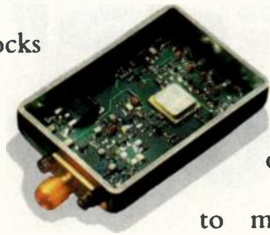
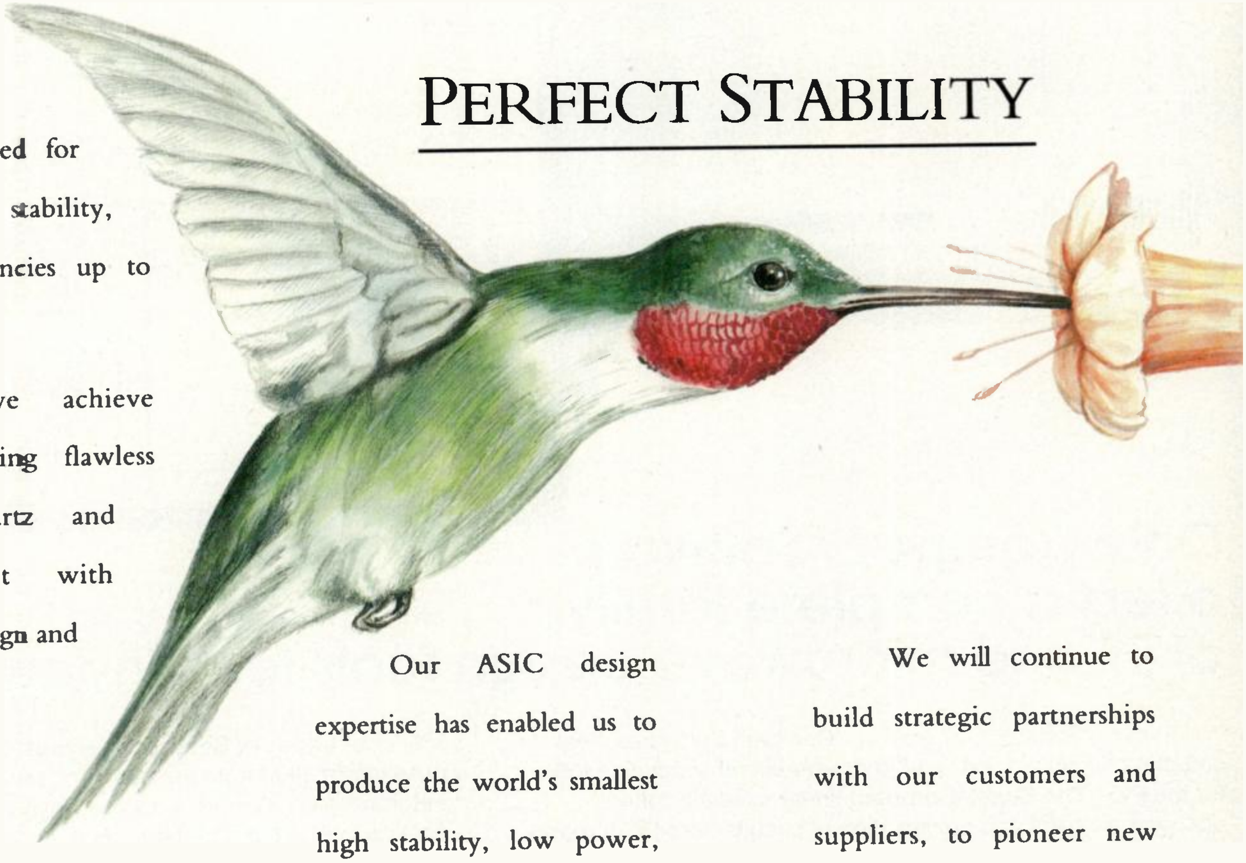
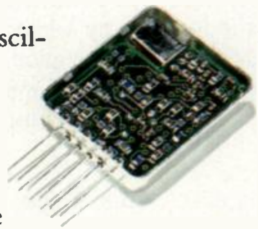


We have been providing frequency control products of the utmost reliability to many of the world's leading manufacturers of communications equipment for nearly 50 years.



Our ASIC design expertise has enabled us to produce the world's smallest high stability, low power, temperature controlled oscillator (TCXO), which is highly successful in tactical radios and satellite navigation and positioning equipment for GPS.

Further development of our ASIC technology is in progress for a new generation of miniature oscillators.



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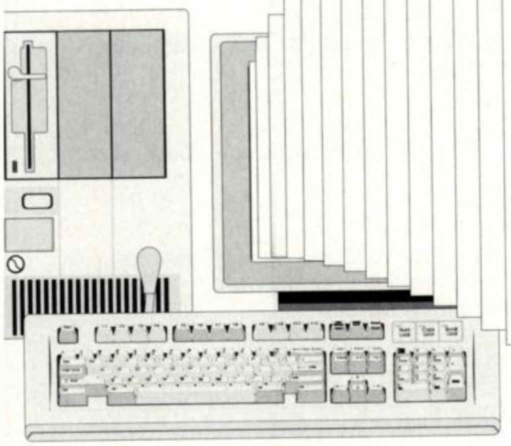
INFO/CARD 10

For more information and a free demo disk . . .



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RF courses

Wireless Voice and Data Communications
October 18-21, 1994, Los Angeles, CA
Advanced Communication Systems Using Digital Signal Processing
November 14-18, 1994, Los Angeles, CA
Active Circuit Design for Wireless Systems: Principles and Applications
November 28 - December 2, 1994, Los Angeles, CA
Information: UCLA Extension, Engineering Short Courses, 10995 LeConte Ave., Ste. 542, Los Angeles, CA 90024. Tel: (310) 825–1047. Fax: (310) 206–2815.

High Speed & Microwave Devices & Applications
October 24-27, 1994, Boston, MA
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel: (818) 995–6335. Fax: (818) 995–2932.

Digital, Cellular and PCS Communications: The Radio Interface
October 17-21, 1994, Washington, DC
Marketing in the Global Economy
October 19-21, 1994, Washington, DC
Video Transmission and Broadcasting via Satellite
October 31-November 1, 1994, Washington, DC
Antennas and Antenna Systems: Practical Design, Implementation, and Testing
October 31-November 3, 1994, Washington, DC
Microwave System Engineering
October 31-November 4, 1994, Orlando, FL
December 5-9, 1994, San Diego, CA
Space System Principles and Applications: An Introduction
November 1-4, 1994, Washington, DC
Grounding, Bonding, Shielding, and Transient Protection
November 1-4, 1994, Orlando, FL
December 6-9, 1994, San Diego, CA
Global Positioning Systems: Principles and Practice
November 7-10, 1994, Washington, DC
Lightning Protection
November 9-10, 1994, Washington, DC
Low Earth Orbit Satellite Systems (LEO's)
November 14-16, 1994, Washington, DC
Spread-Spectrum Communication Systems: Commercial and Government Applications
November 14-18, 1994, Washington, DC
Electromagnetic Interference and Control
November 14-18, 1994, Washington, DC
Digital Transmission Systems
December 5-9, 1994, Washington, DC
New HF Communication Technology: Advanced Techniques
December 5-9, 1994, Washington, DC
Satellite Electrical Power Systems: Energy Conversion, Storage, and Electronic Power Processing
December 12-15, 1994, Washington, DC
Modern Digital Modulation Techniques
December 12-16, 1994, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Academic Center, Room T-308, 801 22nd Street, N.W., Washington, DC 20052. Tel: (202) 994–6106 or (800) 424–9773. Fax: (202) 872–0645.

EMI/EMC Metrology Challenges for Industry: A Workshop on Measurements, Standards, Calibrations, and Accreditation
January 25-26, 1995, Boulder, CO
Information: Ann Bradford, NIST, 813.07, 325 Broadway, Boulder, CO 80303. Tel: (303) 497–3321. Fax: (303) 497–6665.

RF/MW Circuit Design: Linear/Non-Linear, Theory and Applications
October 17-21, 1994, Spain
March 13-17, 1995, Switzerland
Active and Passive RF Components: Measurements, Models, and Data Extraction
October 19-25, 1994, Spain
March 9-14, 1995, Switzerland
Digital Cellular and PCS Communications - The Radio Interface
October 24-28, 1994, Spain
May 15-19, 1995, Sweden
Digital Design for High Speed Circuits and Systems
November 7-11, 1994, United Kingdom
Wireless Digital Communications
November 7-11, 1994, United Kingdom
March 20-24, 1995, Switzerland
Information: CEI-Europe/Elsevier, Mrs. Tina Persson. Tel: (46) 122-175-70. Fax: (46) 122-143-47.

RF/MW Circuit Design II
October 17-21, 1994, Spain
RF Component Measurements, Models and Data Extraction
October 19-25, 1994, Spain
Information: Besser Associates, 4600 El Camino Real, Suite 210, Los Altos, CA 94022. Tel: (415) 949–3300. Fax: (415) 949–4400.

1994 Wireless Workshop
October 16-19, 1994, Paradise Valley, AZ
Information: Rogers Corporation, Richard Jansen. Tel: (602) 961-1382.

European Compliance Seminar - Safety & EMC
November 8, 1994, Chicago, IL
November 15, 1994, Columbus, OH
November 29, 1994, St. Louis, MO
European Compliance Seminar - Medical
November 9, 1994, Chicago, IL
November 16, 1994, Columbus, OH
November 30, 1994, St. Louis, MO
Information: European Compliance Seminars, ICC D/FW Headquarters. Tel: (817) 491–3696.

HIRF Planning & Awareness
October 19-21, 1994, Mariposa, CA
February 8-10, 1995, Mariposa, CA
EMCAD1™ Seminar
November 17-18, 1994, Mariposa, CA
March 9-10, 1995, Mariposa, CA
HIRF Design & Testing Seminar
December 6-9, 1994, Mariposa, CA
Medical Seminar
February 4-7, 1995, Fremont, CA
Information: CKC Laboratories Inc., 5473A Clouds Rest, Mariposa, CA 95338. Tel: (800) 500–4EMC. Fax: (209) 742–6133.

Study Highlights Needs of Power Industry Customers

Wireless industry power supply and conversion equipment customers want to strengthen ties with the power industry, according to a study commissioned by The Power Sources Manufacturers Association. The survey respondents were most interested in improving products, packaging, and performance, and lowering costs. While those surveyed were generally satisfied with power industry performance, there was an underlying request for increased dialogue among many respondents. Specific technology needs mentioned include improved power management techniques and components, more external power supplies for recharging battery modules, and "smart" power supplies to interface with a system controller to report on load status. The report noted the intense competitive nature of the wireless market and emphasized the need for power suppliers to control costs across the board.

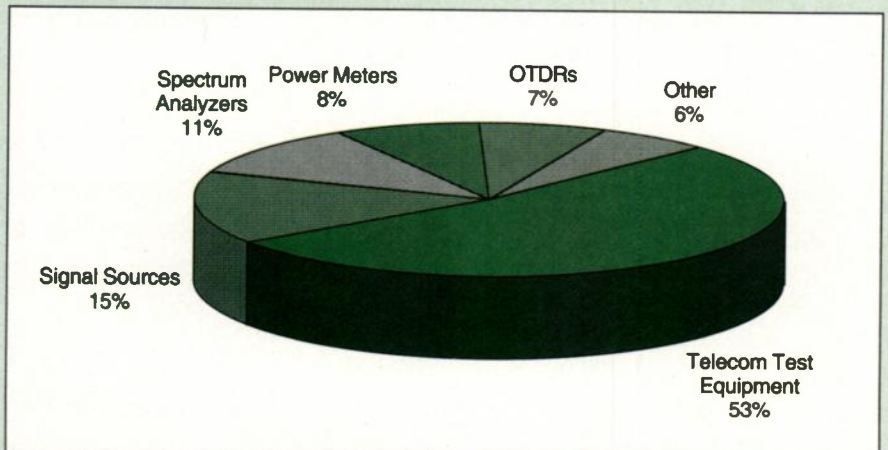
Electronica Highlights DSPs

Electronica 94 organizers report that DSPs are undergoing a veritable power explosion driven as much by the requirements of the market as by advances in technology and architectures. At the same time, DSPs were recently the fastest growing segment in the semiconductor industry, a situation many experts feel will remain unchanged during the next few years. The lion's share of these components are currently used in modems and computer disk drives. Cellular communications and multimedia markets are expected to have the highest growth rate in the foreseeable future. DSPs are also being tested for use in automobile airbags, as well as for noise suppression, adaptive suspension systems, engine control systems, and automobile radios. DSPs also have a promising future in image-processing applications in medicine and industry. The current sales revenues from DSPs are expected to expand from $1.6 billion to approximately $3 billion by 1999. However, an increase in number of units produced will cause prices to drop due to strong competition among leading suppliers. Electronica 94 will be held in Munich, Germany. November 8-12.

Study Predicts $1.3 Billion Communication Test Equipment Market

The U.S. communication test equipment market will grow from $776 million in 1993 to $1.3 billion by the year 2000, an 8 percent annual rate, according to a new study just released by Frost & Sullivan. The largest growth opportunities will come in the data communication and telecommunication segments serving the computer and telecom industries. Test equipment including protocol analyzers, transmission impairment equipment, and BERTs will grow rapidly. Aerospace, government and radio/TV with be slow growth end user markets.

Communication test products will become increasingly sophisticated, with more features, higher performance, and greater functionality. The report forecasts that data communication and telecommunication test equipment will form 53% of market revenues, signal sources 15%, spectrum analyzers 11%, power meters 8%, and optical time domain reflectometers 7% by the year 2000.



ISRAMT Call for Papers

The Fifth International Symposium on Recent Advances in Microwave Technology announces the Call for Papers for the 1995 symposium, scheduled from September 11-15, in Kiev and Black Sea, Ukraine. The symposium will cover all the topics in microwave technology and applications including materials, components, solid state devices, MICs and MMICs, microwave on board equipment, communication systems, antenna and radar technology, remote sensing, electro-optics, biological effects and applications, CAD techniques, propagation and measurement, microwave superconductivity, industry and environment, and microwave education. Prospective authors should contact the Technical Program co-chair: Banmali Rawat, Department of Electrical Engineering, University of Nevada, Reno, Nevada 89557-0153; tel: (702) 784-6927; fax: (702) 784-6627; e-mail: rawat@moriah.ee.unr.edu. Four-page manuscripts prepared according to the instructions provided must be submitted by January 30, 1995.

NASA Determines New Antenna Pointing Error Determination Scheme

NASA's Jet Propulsion Laboratory has reported a new method of estimating antenna-pointing error that eliminates mechanical dithering. The strategy consists of augmenting the usual single collecting horn in the focal plane of the antenna with additional horns closely packed around it, then applying a two-dimensional Discrete Fourier Transform (DFT) to the complex output voltages of the focal plane horns. Resulting data are analyzed by least squares analysis of the phases of the samples to get the best least squares estimate of the phase gradient. This determines the propagation vector of the wave and the direction of the source. While the adopted probability value increases with the noise level, the noise power is automatically determined by the least squares processing. An explicit expression for this "measured power" could be used to serve as a constant monitor of the system's health.

RF Business Briefs

Bell Atlantic Mobile Expands South Carolina Service – Bell Atlantic Mobile has acquired rights to provide cellular service to seven more counties, providing customers with calling advantages that were previously unavailable. Bell Atlantic Mobile now provides seamless cellular service to an 18,000 square mile area. The acquisition is part of BAM's plans to expand its presence in the Carolinas, as well as the entire East Coast corridor.

MFC Achieves Record Third Quarter Sales – Net sales increased 32.4% during the third quarter at Microwave Filter Company, when compared to third quarter 1993. Net sales increased 22.9% over the same period, but operating income was down 32% due to an increase in product development costs and promotional expenses, as well as a higher cost of goods sold during 1994. MFC provides electronic filters for cable, satellite, and broadcast television and government communications. They also manufacture an addressable converter system for the wireless cable industry.

AR and Holaday in Exclusive Distributorship Agreement–Amplifier Research, Souderton, PA, has acquired exclusive worldwide distribution of Holaday Industries' electric and magnetic field monitoring systems. The new agreement extends the former North American distributorship to worldwide exclusivity.

Boonton Sales and Earnings Dip – Boonton Electronics Corporation announced that its sales and earnings for the fiscal year as of June 30 were 13.1% below the previous year. Gross profit declined by $611,336, primarily due to the reduction in sales volume. Boonton has submitted Chapter 11 reorganization plans to the Newark, NJ United States Bankruptcy Court, and plans sales of its real estate holding, excess inventory, and other assets to reduce the company's existing bank debt.

AT&T and New Media Plan First Wireless Computing PCMCIA Solution – AT&T Global Information Solutions and New Media have announced plans to jointly develop the industry's first true plug-and-play PCMCIA solution for wireless computing applications. The two companies will exchange driver and utility software, resources and documentation to enhance AT&T's WaveLAN wireless PCMCIA LAN products. The resulting co-developed wireless PCMCIA card will be compatible across a wide range of portable computing platforms. The WaveLAN wireless PCMCIA will aslo broaden its current market distribution by its introduction to the small office/home office market.

Johnstech Makes Marketing Contacts – Johnstech International, Minneapolis, MN, manufacturer of high-performance standard and custom IC test sockets, has introduced "The Right Contacts" marketing program in cooperation with over a dozen leading test equipment manufacturers. By sharing socket technology expertise with carefully chosen partners, Johnstech and its co-marketers will be equipped to provide manufacturers with cutting edge product solutions, co-application notes, and simplified test equipment integration.

Andrew Opens Hong Kong Facility – Andrew Corporation has opened a HELIAX™ distribution and cable assembly facility in Hong Kong to serve customers in the Asia-Pacific region. The mainland facility will initially offer value added services including cable cutting, connector fitting, electrical testing, and custom made cable assemblies. Services and products will change over time to keep pace with developments in Asia-Pacific markets.

STC Trades on American Stock Exchange – Signal Technology Corporation, Weymouth, MA and Sunnyvale, CA, began trading common stock on the American Stock exchange August 25. Signal Technology designs, develops, manufactures, and markets electronic components and subsystems for radio and microwave generation, control, and management. The company's products are utilized in a broad range of advanced military, intelligence, communications, space, and commercial applications.

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RF Business Briefs *continued*

Peninsula Changes Name – Peninsula Engineering, Sunnyvale, CA, has changed its name to Peninsula Wireless Communications. The name change has been made to more clearly define the true nature of the company. Peninsula Wireless Communications designs, manufactures, and distributes products used by telephone companies and cellular providers to enhance coverage and capacity within their networks.

M-Wave Acquires PC Dynamics – M-Wave Inc. has completed the acquisition of PC Dynamics, a printed circuit board manufacturer specializing in precision circuits for microwave applications. M-Wave intends to combine the technical capability of PC Dynamics with the volume capacity of Poly Circuits to promote a more effective approach toward servicing the microwave market.

Crystallume Makes a Move – Crystallume has moved to new facilities in Santa Clara, CA. The manufacturer of advanced synthetic diamond products for electronics applications can now be reached at 3506 Bassett Street, Santa Clara, CA 95054, phone (408) 653-1700 or (800) 789-4DCC, fax (408) 653-1710.

Production Begins at New RF Monolithics Facility – RF Monolithics, Inc. has begun production at its new Dallas surface mount manufacturing facility. The new facility is RFM's first specifically designed for high volume production and assembly of surface mount SAW devices. When fully operational, the facility will double the company's production capacity.

Contract News

Olivetti Buys Cadence Systems Tools – Olivetti has chosen Cadence Design Systems Inc. to supply a complete suite of standardized electronic design automation tools to implement an integrated design environment in all Olivetti facilities. The first phase of the agreement is valued at over $1.5 million.

Marconi to be Sole US Kikusui Distributor – Marconi Instruments has announced an agreement with Kikusui Electronics of Japan, making Marconi the sole distributor of Kikusui products in the U.S. and Mexico. Marconi will stock Kikusui products and provide warranty, applications assistance, parts, and service at its New Jersey facility.

Motorola Enters Digital Technology Licensing Agreements – Motorola's Land Mobile Products Sector has signed an agreement with BK Radio, Stanilite, and Transcrypt International in which Motorola will license digital technology for the development and production of Associated Public-Safety Officials International Project 25 compliant public safety communications products. The agreement will accelerate the development of digital public safety communications systems compliant with the APCO Project 25 digital standards initiative.

Stanford Telecom Gets China Wireless Positioning System Order – Stanford Telecom has signed an agreement with Golden Lake, Los Angeles, for its ASIC & Custom Products Division to deliver equipment for use in a wireless vehicle positioning system trial in Schenzen City, China. Vehicle-based mobile units transmit encoded wireless signals that are received by many receiver base stations, where they are dated and analyzed mathematically to determine the position of the vehicle with a nominal accuracy of 50 feet.

Immarsat Chooses Analog Devices for World Wide Pager System – Immarsat has chosen Analog Device's ADSP-2166 for its global paging system. The system will allow users to instantly receive messages anywhere in the world on a portable receiver.

EST Selected as Supplier to Army AIT Contract–Electronic Systems Technology, Kennewick, WA, has been selected as a provider of VHF and UHF narrowband modems for the U.S. Government's Automated Identification Technology contract. The AIT contract is a five year, indefinite quantity procurement to obtain commercially available, off-the-shelf, state-of-the-art bar coding technology and microcircuitry devices. The anticipated delivery of EST hardware over the life on the contract is $2 million. *RF*

Finding Marketshare Offshore

by Andy Kellett
Technical Editor

Telecommunications makes up the bulk of many companies' RF equipment and component sales, and much of that market exists outside the U.S.

Telecom Markets

Telecomunications markets are expanding nearly everywhere. In Western Europe, the second generation of cellular phone service is expected to find more users than the first generation of systems. This has a lot to do with the widespread acceptance of GSM as the cellular standard. Where Europe was once a patchwork of incompatible cellular phone systems, GSM allows users to use their phones nearly anywhere in Western Europe.

Eastern Europe is also an attractive market, but for different reasons. Analog systems such as AMPS are being used in this region to quickly connect users to a phone system of any kind. The current phone system in much of Eastern Europe is woefully inadequate for the people in those regions who are now trying to buy and sell in markets around the world.

In Asia, telecommunications sophistication can range from highly advanced systems in places like Tokyo and Hong Kong, to virtually no telecommunications in rural areas, and Asian markets reflect that variety.

Latin America is another area that is seeing increased use of RF technology to quickly bring telecommunications to remote areas and connect the region with global telecomm systems.

How long will this boom in telecommunications infrastructure building last? The next decade will bring the most rapid activity, and it will slowly tail off, predicts Bob Clarke, Sr. Product Marketing Engineer at Analog Devices.

It is the availability of capital that may extend the demand for equipment. Eastern Europe is ready for new telecommunication systems, but its countries are short on cash, says Clarke, "... given that, countries will put in x amount per year based on what they can afford to put in," says Clarke. Parts of the Asian market are similarly stretched. According to David Hartshorn, editor of *TeleCommunique Asia*, a Hong-Kong-based newsletter covering the Asian Telecom market, a goal of many in Asia is to increase telephone availability from roughly 2 per 100 people, to 20 or 30 by the turn of the century. However, lack of capital may prevent even that modest goal from being achieved, says Hartshorn.

Design and Manufacturing Abroad

Of course, the U.S. is not the only country poised to take advantage of these lucrative markets. Figures in the EIA 1994 Electronic Data Book show that Japan exported over $3.5 billion in telecommunications equipment in 1992. Several European companies like Ericsson, Seimens, and Alcatel are major equipment suppliers. Canada's Northern Telecom was the fourth largest supplier of telecommunications equipment in 1992 according to International Telecommunications Union figures.

Some developing countries are cultivating their own design and manufacturing capabilities, particularly in Southeast Asia. The governments in both Hong Kong and Singapore are funding efforts to bring in design and manufacturing technology. Many countries in the same region are also getting assembly factories from Japanese-based companies. "Just as the U.S. was forced to go offshore for much of its manufacturing, thanks to the high Yen, Japanese manufactures are leaving Tokyo in droves to establish factories in Malaysia, Indonesia, China, etc.," says Hartshorn.

Both demand and competition is worldwide for RF telecomm devices. *RF*

1993 Global Regions – Exports for U.S. Electronics

Region	$ Millions	% change (92-93)	% of total
Asia	29,617	16	34.7
Europe - EU 12	22,409	1	26.3
Canada/Mexico	20,284	8	23.8
South America	4472	29	5.2
Middle East	2310	16	2.7
EFTA	2150	–5	2.5
Oceania	1874	–1	2.2
E. Europe	778	46	0.9
Africa	487	15	0.6
Central America	419	27	0.5
Caribbean	251	–1	0.3

EU 12 is composed of Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, and the UK.

EFTA is composed of Austria, Finland, Iceland, Norway, Sweden, and Switzerland.

From: *1994 Electronic Market Data Book*, EIA Marketing Services Dept., Electronic Industries Association.

Table 1. 1993 U.S. electronic exports by region.

Country	Subscribers	Market Penetration	System(s)
U.S.	18,566,700	7.28	AMPS, TDMA, NAMPS
Japan	2,744,000	2.20	J-TACS, N-TACS, NTT, TDMA, JDC
U.K.	2,177,200	3.77	TACS, GSM
Germany	1,961,700	2.44	C-Netz, GSM
Canada	1,433,300	5.23	AMPS, TDMA
Italy	1,375,700	2.38	RTMS, TACS 900, GSM
Australia	1,111,200	6.31	AMPS, TDMA, GSM
Sweden	925,300	10.76	NMT 450, NMT 900, GSM
China	846,600	0.07	TACS, AMPS, GSM, E-TDMA
France	653,700	1.14	RC 2000, NMT 450, GSM
Finland	633,700	12.67	NMT 450, NMT 900, GSM
S. Korea	570,500	1.29	AMPS
Taiwan	567,300	2.72	AMPS
Thailand	559,400	0.97	AMPS, NMT 450, NMT 900
Norway	503,300	11.79	NMT 450, NMT 900, GSM
Mexico	446,700	0.48	AMPS
Malaysia	428,000	2.32	NMT 450, TACS
Denmark	415, 700	8.06	NMT 450, NMT 900, GSM
Hong Kong	313,800	5.32	TACS, AMPS, GSM, TDMA
Spain	285,000	0.73	NMT 450, TACS
Total	36,618,700		

Compiled by: MTA-EMCI, 1130 Connecticut Avenue, NW, Suite 325, Washington, D.C. 20036, Tel. (202) 835-7800, FAX (202) 835-7811

Table 2. Top 20 international cellular markets.

What have you got to lose?

Want to lose a few ounces from your next PCS design?

Or reduce power consumption while extending the talk time on your next cellular phone design?

Or maybe add a few features to your next RF PCMCIA card without adding weight?

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We'll provide the right RFIC power amplifier for the job. Based on ITT's MSAG®-Lite technology, our power amplifiers deliver the 3V performance the marketplace demands with the ability to perform all the RF functions you need.

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So, forget bulky, low efficiency Si discretes and modules for your 3V applications and check out ITT's power amplifier RFICs.

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RF Design Wraps Up a 15-Year Anniversary Celebration!

Reflections and Comments from RF Companies Around the World

The RF Design *staff, and everyone in the Argus Business organization, are pleased to have you as a reader! Some of you have been receiving this magazine since it began, but whether this is the hundredth issue or the first one you've seen, we hope it gives you something interesting and useful. Our original goal remains the same today as it was at our founding —* RF Design *exists to deliver information to help you get the job done.*

Through the 1960s and 1970s, magazines for the electronics industry covered RF subjects quite well, along with power electronics, audio topics and instrumentation. In the late 1970s, the computer industry entered a phase of rapid growth. Early microprocessor ICs were beginning to be understood and put to use. Powerful desktop and hand-held calculators were quickly replacing slide rules, and mainframe computers were approaching supercomputer power. This was an exciting time in electronics, capturing the attention of engineers and the publications that served them.

As the major broad-based publications moved away from RF to address digital engineering, a void was created that was filled by RF Design at the very end of 1978. In November of 1993, we reached the 15-year mark without much hoopla. However, we have made up for that quiet moment, building our excitement through the past year, culminating in this special coverage. We'll soon be "Sweet Sixteen" and ready to go on for many more years.

As we conclude a year-long 15th Anniversary celebration, let us take a look at some *RF Design* issues of the past to see how the technology has developed, how the industry has changed directions, and how the engineer's job has changed.

January/February 1979
The Second Issue of *RF Design*

What was happening at the first of the year in 1979? Of course, as a new magazine, we were actively recruiting new subscribers, but some of the engineers who had seen our first issue wrote to tell us what they thought of the new magazine. A few of their comments were:

"...at last, here is a magazine which satisfies RF circuit designers working in the HF through UHF bands."

"...old standby journals like *EDN* and *Electronics* have capitulated entirely to the computer audience. I don't feel the we're close to abolishing RF communications."

"I'm certain you will be our primary publication for RF material."

Some of these early readers, and the company management who started *RF Design* would be quite interested to see that the rapid growth in the 1994 RF industry represents a merging of radio and computer technologies! Certainly, RF communications is far from being abolished.

Articles in the first issue of 1979 included "Meet the V-MOSFET Model" by Ed Oxner, then of Siliconix. Characteristics of the vertical MOSFET were just beginning to be well understood by the device designers, and that information needed to reach the circuit designers. The growth of power MOSFET technology evolved rapidly, and is a standard in today's RF industry, no longer an experimental technology.

The late Tom Litty published an article on "Microstrip RF Amplifier Design." This article would still be useful as a tutorial for new RF designers. However, 1979 engineers might be surprised to see an abundance of CAD tools and new microstrip substrate materials in 1994.

The cover of the issue and an accompanying article described "RF Linear Hybrid Amplifiers" from TRW. In 1979, there was a lot of attention to developing high performance products for the CATV industry, as cable system construction was accelerating rapidly around the country. Among the notes in the article were suggestions about using these broadband, medium power gain blocks in other RF applications like receivers, transmitters, and even fiber optic laser drivers.

A few of the new products highlighted in January 1979:

- 1-100 and 1-200 MHz directional couplers
- New low inductance value RF chokes; 0.022 through 0.100 μH
- A low cost digital capacitance meter
- A 22 GHz spectrum analyzer (priced at $47,500 in 1979 dollars!)
- "Microwave" power transistors providing 10 watts at 2 GHz, in class B or C operations
- EMI shielded backshells for D-subminiature connectors
- SAW filters (priced at $100 in 100 quantities)

C2

Penstock Acquired by Avnet, Inc.

Leading RF/Microwave distributor joins Electronics Marketing Group, retains name, independence, market focus.

By DOUGLAS R. DREW

GREAT NECK, N.Y. — Solidifying its position in the rapidly growing wireless communications market, Avnet, Inc. announced today that it has completed the acquisition of Penstock, Inc.

Penstock, the 39th largest industrial distributor in North America, is the United States' leading technical specialist distributor of microwave and radio frequency products and related value-added services.

Under the terms of the acquisition, the Sunnyvale, California-based Penstock will retain its name and remain a separate company, as part of Avnet's Electronics Marketing Group (EMG), currently the world's largest electronics distributor, with sales of more than $2.3 billion.

Sustained Sales Growth

Penstock's sales reached $45 million in the fiscal year ending this past March, an increase of 32% over the previous year, and were projected to exceed $57 million this year. But the privately-held company "wouldn't be able to reach the next level of growth" on its own, according to Bruce White, Penstock's founder and president.

"Avnet has presented Penstock with a golden opportunity," White said. "We'll be able to maintain our individual presence in the industry while having access to additional financial resources to grow the company in such a way as to benefit our customers, suppliers and employees.

"This alliance will allow us to stay focused in our niche communications market," he added, "using strong technical field sales engineers and providing significant inventory levels of quality products to our customers."

White remains president of Penstock, reporting to Roy Vallee, Avnet's president and chief operating officer.

Opportunities For Penstock

"The RF/Microwave market continues to grow dramatically," Vallee said. "We are excited about the potential opportunities for Penstock. They're as committed to quality as we are, so we're especially pleased to welcome them to the Avnet family."

Prior to the acquisition, Avnet EMG was comprised of five sales and marketing divisions; Allied Electronics, Time Electronics, Avnet International, Avnet Computer Group and Hamilton Hallmark.

> The alliance represents a major opportunity for both distributors.

By significantly expanding the support network of Penstock, the acquisition will enable both companies to offer more extensive services to their respective clients, according to industry analysts.

A Shared Priority

"Both Penstock and Avnet have always made their customers the number one priority and credit much of their success to this," Vallee said. "The proposed structure of this merger strongly reinforces that philosophy and neither company anticipates any 'shakedown' period since the fit is a perfectly logical one on all levels."

Sources familiar with the deal confirmed that no management changes are planned.

Traditionally a military supplier, Penstock entered the commercial arena six years ago and has increased its revenue by at least 30% every year since then. Although the company still generates about $11 million worth of military business annually, approximately 75% of its business now comes from commercial sales.

$2 Billion Commercial Market

In recent years, the military market has remained essentially static, while analysts estimate that the mushrooming commercial market for RF/microwave components has reached $2 billion.

Founded in 1975 and incorporated in 1984, Penstock's specialized product lines include such principal suppliers as Avantek, Comlinear, Hewlett-Packard, M/A-Com, QMI, Sawtek, SGS-Thomson, Siemens, Star Micronics and Toko America.

Financial terms of the acquisition, which was completed in just over four weeks, were not disclosed.

Stock Prices A...

Tradi...

Canada And United Stat...

California Eastern Laboratories (CEL) is the sales, marketing and engineering resource in North America for NEC's Compound Semiconductor Device Division (CSDD). More than just a rep or a distributor CEL is "something very different, something unique," says CEL President, Chairman, and CEO, Jerry Arden.

Sales and Engineering Independence
CEL develops its own strategic marketing and sales policies and responds to all domestic RFPs and RFQs. The company provides engineering and design assistance, maintains an extensive onshore inventory, sets pricing and extends credit.

Engineering Support and Application-Specific ICs
CEL's engineering facility provides customers with product characterization: measurements of S-parameters, noise, gain, and power characteristics, as well as circuit simulation, custom testing and product selection.

The NEC/CEL Design Center develops custom ICs to meet the needs of specific customer applications. Located at CEL headquarters in Santa Clara, the Design Center is staffed by engineers from both CEL and NEC. Fabrication is completed at NEC facilities in Japan, while performance evaluations and characterization are executed by CEL.

History
CEL was founded in 1959 as a representative for several Japanese semiconductor manufacturers. To make it easier for engineers to put the Japanese devices to work, CEL had to expand considerably the role of traditional sales representative. CEL built an extensive test and applications facility and also produced data sheets, catalogs and documentation in English.

The V-416, which was one of the first true microwave silicon transistors and which at the time had the lowest noise figure for any silicon transistor was one of the first successes CEL had with NEC products. By 1973, CEL was handling only NEC products, and at about the same time the V-244 was introduced. This device was the first commercially available GaAsFET, and CEL followed it a few years later with the first half-micron GaAsFET.

In 1978, the first issues of RF Design were appearing on engineers' desks, and CEL was selling the NE-710, part of the third generation of commercial GaAsFETs. Other hot items were the NE-645 and NE-021: general purpose silicon transistors that sold in the millions.

Since that time, the market for RF and microwave devices has expanded greatly. "Originally microwave devices were a highly specialized market niche, and there was little competition, " says Arden, "GaAs FETs were originally sold at three or four-hundred dollars apiece, and we couldn't ship enough of them. Now they're down to less than a dollar."


S-parameter measurement, circa 1978.

While the market has expanded to include more commercial microwave applications, CEL and NEC's product line has also expanded. The NEC/CEL product line now includes silicon MMICs such as prescalers, AGC and wideband amplifiers, frequency converters and application specific ICs, GaAs ICs such as prescalers, amplifiers, switches and frequency converters, along with their lines of small signal & power bipolar transistors, low noise GaAsFETs and power GaAsFETs.

California Eastern Laboratories, 4500 Patrick Henry Dr., Santa Clara, CA 95054-1817, Phone: (408) 988-3500, Fax: (408) 988-0279

Amplifier Research Corporation

Introduction
Why should you select Amplifier Research for your high power wideband RF amplifier requirements? The following synopsis on our background and capabilities will answer that question for you.

Company Background
Amplifier Research Corporation was founded and incorporated in November 1969 by Donald R. Shepherd and D.W. Roth. We develop and market high power, broadband RF amplifiers and associated equipment.

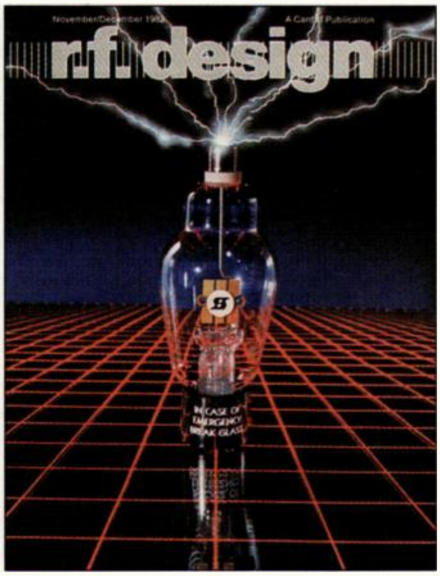
Mr. Shepherd, the President of the company, Received his B.S. in Electrical Engineering form Fairleigh-Dickinson University in 1961. He has an extensive background in the development of broadband RF equipment. Mr. Roth received his B.S. in Aeronautical Engineering from Tri-State University in 1958. His background was extensive in both the management of and mechanical engineering design for electrical development programs. In 1966 he received an M.S. in Engineering Management form Drexel University.

Before Amplifier Research Corporation, both Mr. Shepherd and Mr. Roth worked together very closely for four years. This work was in developing various types of high power, broadband equipment. From the founding until Mr. Roth's death in December 1988, that close working relationship continued.

Today, the company supplies amplifiers used in industrial applications, such as EMI Susceptibility testing, Nuclear Magnetic Resonance Studies, Ultrasonics, RF Plasma Generators, and General laboratory test equipment.

Facilities information
In June 1973, Amplifier research purchased a modern 12,000 square foot facility located at 160 School House Road, Souderton, Pa 18964. A major expansion program in 1984 took our facilities to 20,000 square feet, including air conditioned offices, production and warehouse space. In 1988, we renovated 4,000 square feet of space for our design and accounting departments.

The company presently has over eighty employees and follows the principles of Affirmative Action.



November/December 1982
Four Years After the Launch

In 1982, the military market was still the single largest place for RF product sales. Advertising in this issue often featured military themes, or identified the military focus of the products. The remaining ads were either of a general nature, or leaned toward mobile radio, instrumentation, or other active RF areas of the time. *Wireless communications* still meant Marconi sending the letter "S" across the Atlantic, and *portable communications* brought only images of a walkie-talkie, or maybe the fledgling cellular phone!

It's interesting to see which companies have changed over the years. In 1982, advertisers in *RF Design* included a few companies that have undergone major changes. Siliconix, featured on the cover, is still around, but no longer has anything significant to do with RF. Texscan is now part of Trilithic and some of their past products are no longer available. Acrian declared bankruptcy, although many of its products live on as part of several other companies which acquired the rights. Varian's Communications Transistor Corporation was another early advertiser that has disappeared from the RF scene, as has Sigmotek International, Adams-Russell (which is now part of M/A-COM), and RCA (split into many different pieces).

It is encouraging to see that most advertisers in this early issue of *RF Design* are still in business, including some that were small in 1982, but have grown dramatically into successful companies in 1994.

Editorial coverage in January 1982 featured design with power FETs and a discussion of ferrite rod loop antennas by Andy Przedpelski. Other authors that remain familiar were Bob Feeney and Dave Hertling of Georgia Tech. They provided a review of power gain specifications and their mathematical basis; and some of that material may still appear in the classes they teach at our RF Expo conferences.

Hot products in 1982 were:

- Discrete GaAs FET low noise amplifier transistors
- Power FETs and bipolars at HF, VHF and UHF
- Miniature packaged amplifiers and RF transformers
- Log amplifiers
- High-reliability mixer modules

Colby Instruments, Inc.

ELECTRONICS RESEARCH & DEVELOPMENT
1810 14TH STREET SANTA MONICA, CA 90404
(213) 450-0261 FAX: (213) 452-0027

When we started out in 1977, we decided to manufacture products for emerging markets and applications which require a high level of technical skill. What is a surprise to most of our customers, we only do R&D, and all manufacturing is subcontracted. Seventeen years ago this was rather unusual though today this idea is not so far fetched. This way we can concentrate on new product developments which we enjoy most.

Our first major product in 1979 was a 1000 MHz pulse generator and a number of clock drivers with risetimes below 200 ps. Over the years we have extended these products to 10 GHz with risetimes below 15 ps.

Then in 1989 we introduced a series of programmable delay lines and phase shifters with a resolution down to 0.25 ps (0.09°/GHz) and with a bandwidth from DC to 18 GHz. Unique to these products are that they are free from noise, phase noise, or time jitter, and exhibit extremely high accuracy and repeatability. There is little competition for these products.

Recently, we have made a decision to enter the RF & Communications scene which is very lively and highly competitive. The products under development at the present are a departure from the past, but will provide new opportunities for us. We are looking forward to this challenge!

Siegfried Knorr
President

Join us in Celebrating the 15th Anniversary of RF Design magazine!

comatlas

Comatlas sa is a French company specialized in the digital data transmission. The two major shareholders are VLSI Technology and SOREP. The basic objective is to design components, and equipment for the telecommunication market. The identity of **Comatlas** is the duality components/systems. All the developments need in general a strong preliminary system study, that **Comatlas** drives. The main skills developed are:

- channel coding: Viterbi, Reed-Solomon, BCH, Turbo-codes,...
- coded modulations: trellis coded modulations, block coded modulations,....
- digital demodulation: n-PSK and n-QAM digital modems, equalizers, differential demodulators, half-Nyquist filters, clock recovery, carrier recovery, direct sequence spread spectrum: digital matched filters, modems,...
- multicarriers: OFDM, ADSL,...

Important tools have been set-up, to improve the service. A complete top-down methodology is used, to speed-up the designs while keeping the quality of the developments at the top:

- system telecommunication software, for high level simulations,
- behavioral simulation, using VHDL,
- ASIC design environment, for ASIC and FPGA,
- hardware accelerator, to speed-up the simulations,
- printed circuit board software, for PC implementations.

The developments are custom designs. The applications where **Comatlas** is strongly involved are:

- digital TV transmission, either by cable, satellite and terrestrial,
- VSAT modems
- wireless data transmission modems.

Comatlas also offers a set of standard products. Some significant products available from stock are:

CAS 5053PC: low cost Viterbi decoder
CAS 5063PC: 2 Mbits Viterbi decoder
CAS 5073PC: 10 Mbits Viterbi decoder
CAS 6553: complete spread spectrum demodulator
CAS 5093PC: 40Mbits Turbo-codes decoder
CAS 7113PC: trellis coded modulation decoder
CAS 9053PC: AAL1_video Reed-Solomon decoder
CAS 5203PC: programmable Reed-Solomon decoder

Comatlas also introduces the first chip set fully compliant with the European digital TV recommendation (ETSI) available on the market:

CAS 5453PC: 60 Mbits FEC decoder
CAS 4123PC: 60 Mbits QPSK coherent demodulator

Other important developments are made for cable transmission, around blind equalization, n-QAM demodulation, with new and creative algorithms.

An important but unknown design win of **Comatlas** is the Reed-Solomon decoder used in the DirecTV set-top boxes. This illustrates that the customers are spread worldwide.

For more information, contact Mr. Alain DUBREUIL, general manager of **Comatlas**, BP 5, 35220, CHATEAUBOURG, France.

Phone: (33) 99 62 39 55, Fax:(33) 99 00 32 47, E-mail: dubreuil@comatlas.fr

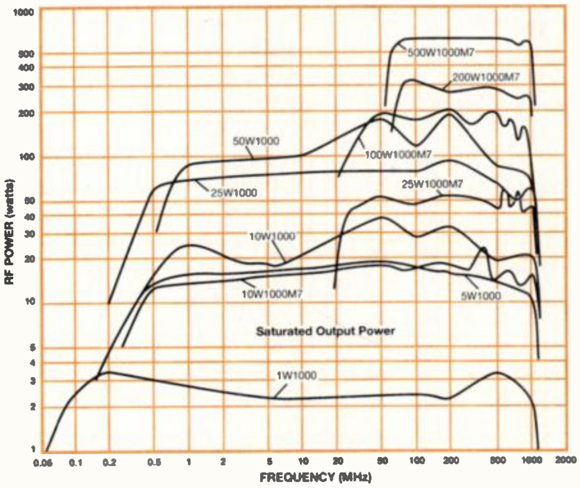
When it gets lonely out there at 1 GHz, you'll be glad you have all this power.

The only amplifier that can deliver 500 watts through that balky decade from 100 to 1,000 MHz is our new Model 500W1000M7. That's the majestic one on the left, with the front-panel bi-directional power meter, ALC, and a bagful of other controls that will let you actually *enjoy* automatic sweep testing in your lab.

The 500W1000M7 presently heads our well-known "W" Series of all-solid-state linear amplifiers that cover four crucial decades of bandwidth from 100 kHz to 1 GHz. Today, you may need only 1 watt (the little portable on the top), or 5, or 10, or 25, or 50, or even 100 or 200 watts *minimum*—all with that fantastic bandwidth instantly available without tuning or bandswitching—a combination of power and bandwidth that's comforting when you work the outer reaches of the rf spectrum. Wherever your power requirements are today, they're sure to go up. And one of these days you're going to want a 500W1000M7.

The "W" Series is part of a complete line of AR amplifiers offering rf power up to 10 kilowatts for rf susceptibility testing, nmr spectroscopy, plasma/fusion research, and a host of other test situations that demand rf power of unconditional stability—immunity to even the worst-case load mismatch, shorted or open cable, wild swings of VSWR—with no fear of oscillation, foldback, or system shutdown.

You might learn a lot from our free booklet, "Guide to Broadband Power Amplifiers." Send for a copy. Or call our toll-free number (800-933-8181), which will connect you directly to one of our applications engineers.



AMPLIFIER RESEARCH

160 School House Road
Souderton, PA 18964-9990 USA
TEL 215-723-8181 • FAX 215-723-5688

For engineering assistance, sales, and service throughout Europe, call EMV: Munich, 89-612-8054 • London, 908-566-556 • Paris, 1-64-61-63-29

INFO/CARD 19

5351

Philips Semiconductors is a division of Philips Electronics-one of the world's largest and most diversified manufacturers of electrical and electronics products. The semiconductor division designs, manufactures and markets its products worldwide, and is Europe's largest semiconductor manufacturer.

Philips Semiconductors emphasizes products and technologies used in four markets: wireless communications, multimedia, automotive, and consumer electronics. The semiconductor division is supported by Philips Research Laboratories, one of the world's largest privately funded research organizations, with facilities in five countries.

Organization

The organization known today as Philips Semiconductors is an amalgam of several semiconductor manufacturers, including the former Signetics (North America), Valvo (Germany), RTC (France), and Mullard (United Kingdom). The consolidation process was completed in January 1993. All four Philips Semiconductor operations have donated their unique strengths to the new unified division.

Creating a unified and streamlined semiconductor organization enabled Philips to leverage its in-house research capability, and make a strategic shift away from older logic families toward high performance, high margin products in fast-growing markets. The consolidation also permitted Philips to forge new industry alliances, such as its agreement with Texas Instruments to jointly develop advanced BiCMOS logic (ABT) and Futurebus+ product families. The semiconductor division benefits from the recognition and credibility of the Philips name-recognized throughout the world as a quality manufacturer.

A (Very) Brief History

The parent organization, Philips Electronics, was founded in 1891 in Eindhoven, the Netherlands. With its start in electric lighting, Philips pioneered and developed new consumer electronic industries such as radio and television. Philips was the first company to begin commercial production of light bulbs and x-ray machines, and more recently developed the audio cassette and the compact disc. In the past year, Philips introduced the CD-I, a compact disc-based device that turns the household television into an interactive machine that runs educational and entertainment software.

Today, Philips is the world's sixth largest electronics company, and is focused on four major IC market areas: computing, communications, consumer, and automotive. Each of these markets provides opportunities for Philips Semiconductors to take advantage of internal process capabilities, its relationships with other related Philips product divisions, and its global manufacturing resources.

Congratulations, RF design for 15 Years of Technical Leadership!

Synergy Microwave Corporation

SMC was founded in 1982 by Ulrich L. Rohde to provide the RF and microwave industry with high performance signal processing components. Its first high performance mixer was developed around stringent requirements for a Naval receiver, which had been manufactured by Cubic Communications in California and was sold in large volume.

While still located in Jersey City, NJ, SMC then developed a complete line of mixers, modulators, power splitters, and hybrid modules custom-made for high performance. These hybrid modules were the first of their kind to provide high integration and high temperature stability. In 1984, SMC moved to its present location in Paterson NJ, where it rapidly grew into a major player in its field. SMC soon demonstrated its innovative capabilities by introducing the first surface mount double-balanced mixer. While converting the standard PIN package to the new surface mount design, SMC was the first to also provide a high degree of EMI/RFI shielding in surface-mount package designs.

High volume manufacturing has been SMC's expertise, and over the years SMC has supplied specialty components to both commercial and military customers. Special manufacturing techniques have been developed which significantly lower manufacturing costs, improve yields, and accommodate market requirements. Most of SMC's components are specifically designed to be supplied in tape and reel to accommodate high volume manufacturing. It has been SMC's goal to offer these components at the lowest cost possible and still maintain the high performance and reliability SMC has come to be known for in the RF and microwave industry.

Along those lines, SMC obtained several fundamental patents in the area of packaging, specifically extending the range of the PIN package to several GHz. This patent was issued to SMC President Meta Rohde and Shankar Joshi, its Chief Engineer. Other key patents issued to SMC are single side-band (SSB) modulators using harmonic mixers and magnetic rods to achieve over 30 dB of sideband rejection at the personal communications (PCN) bands. In the past few years, SMC also introduced an ultra-wideband modulator with a 34:1 bandwidth and high performance image reject mixers capable of 50 dB image rejection in 10% bandwidths.

To accommodate the needs of the telecommunications industry, SMC developed a series of high performance VCOs and introduced the world's first low cost VCO for the 800 MHz range, which broke the 150 dB/Hz barrier at 800 KHz off the carrier. Additionally, SMC developed a symmetrical VCO design approach for which a patent is pending.

As a result of the high performance VCO line, SMC was able to secure a number of large US/European orders. Parallel to these technologies, SMC has developed a line of PIN packaged filters and even micro strip filters custom-tailored to meet the telecommunications needs. SMC continues its long history of providing novel solutions by responding to the requests of the cellular telephone industry and expanding wire based technology of high frequency mixers beyond the traditional 4GHz range. Today, SMC supplies to the industry a variety of surface-mount and standard packaging for the entire product line, which includes mixers, filters, power dividers, transformers, phase shifters, frequency doublers, directional couplers, modulators/demodulators, VCOs, amplifiers, phase detectors, and more.

IF YOU'RE LOOKING FOR NOISE COMPONENTS,

OR TEST EQUIPMENT,

ALL ROADS LEAD TO...

Noise Com. Broadband Noise Sources for Wireless, Space, Military and Commercial Applications.

Noise Com noise sources and noise subsystems are being used throughout the world to evaluate the performance of commercial and military, radar, satellite communications, and data transmission systems.

Noise Com has established a solid reputation for quality, performance, and product support that is among the most highly regarded in the industry. We have recently enhanced our facilities and equipment to increase the precision of our calibration, measurement, and testing capabilities and we hope that you will benefit from this.

Every Noise Com product is based on the generation of true white Gaussian noise, a result of years of research and testing to produce devices with outstanding stability and quality.

Noise Com routinely designs and manufactures custom components, subsystems, and turnkey systems with on-time deliveries. If you don't see a product here that meets your requirements, just ask for it—call a Noise Com representative for a prompt response.

A Noise Product For Every Application.

For more information and quick response, call NOISE COM, the experts in testing, at 201-261-8797.

Chips and Diodes

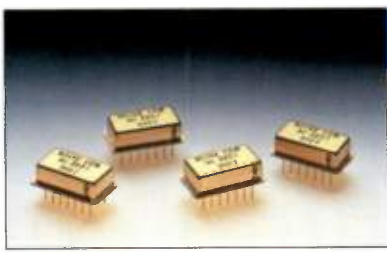
All Noise Com diodes deliver symmetrical white Gaussian noise and flat output power versus frequency. Noise Com diodes are available in a wide variety of package styles, and in special configurations on request.

TYPICAL STANDARD MODELS	
MODEL	FREQUENCY RANGE
NC 204	0.1 Hz – 500 MHz
NC 302	10 Hz – 3 GHz
NC 401	100 MHz – 18 GHz
NC 406	18 GHz – 110 GHz

Drop in Modules for BITE

The NC 500 series drop-in noise modules in TO-8 cans are an economical solution for built-in test requirements. These devices contain complete biasing networks and need no external components. Also available are TO-39 and surface mount packages.

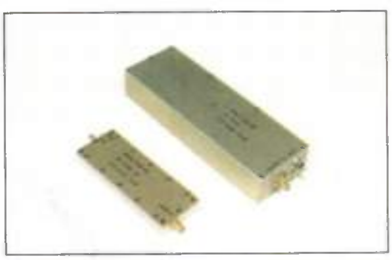
TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 501/15	0.2 MHz – 500 MHz	31 dB
NC 506/15	0.2 MHz – 5 GHz	31 dB
NC 511/15	0.2 MHz – 500 MHz	51 dB
NC 513/15	0.2 MHz – 2 GHz	51 dB



Broadband Amplified Modules

The NC 2000 series amplified noise modules are an excellent choice when a high level noise output is desired and the noise source is to be mounted on a circuit board. 24 pin packages are standard, 14 pins are available.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT
NC 2101	100 Hz – 20 kHz	0.15 Vrms
NC 2105	500 Hz – 10 MHz	0.15 Vrms
NC 2201	1 MHz – 100 MHz	+5 dBm
NC 2601	1 MHz – 2 GHz	-5 dBm



The NC 1000 series amplified noise modules produce white Gaussian noise from -14 dBm to +13 dBm at frequencies up to 6 GHz. They are designed for coaxial test systems, and are available with several bias voltages and connector options.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT
NC 1101A	10 Hz – 20 kHz	+13 dBm
NC 1107A	100 Hz– 100 MHz	+13 dBm
NC 1112B	20 MHz – 2 GHz	0 dBm
NC 1126A	2 GHz – 6 GHz	-14 dBm

Broadband Precision, Calibrated Coaxial

Noise Com's NC 346 series is designed for precision noise figure measurement applications. These products are available with coaxial or waveguide outputs. For OEM applications, the NC 3200 series provides high performance in a small ruggedized package.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 346A	0.01 GHz – 18 GHz	6 dB
NC 346B	0.01 GHz – 18 GHz	15 dB
NC 346D	0.01 GHz – 18 GHz	25 dB
NC 346Ka	0.1 GHz – 40 GHz	15 dB

Broadband Calibrated Millimeter-wave

The NC 5000 series noise sources feature outstanding stability and convenience in waveguide bands up to 110 GHz.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	WAVEGUIDE
NC 5142	18 GHz – 26.5 GHz	WR-42
NC 5128	26 GHz – 40 GHz	WR-28
NC 5115	50 GHz – 75 GHz	WR-15
NC 5110	75 GHz – 110 GHz	WR-10

Coaxial with Built-in Isolators

The NC 3400 series are precision calibrated noise sources for extreme accuracy and flatness enhanced by their low VSWR 1.25:1.

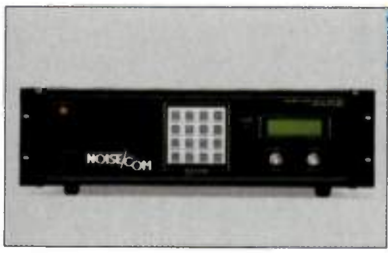
TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 3404	2 – 4 GHz	30–36
NC 3405	4 – 8 GHz	30–35
NC 3406	8 – 12 GHz	28–33
NC 3407	12 – 18 GHz	26–32

BER Testing Equipment

The UFX-BER accurately sets and displays Eb/No, C/N, C/No, or C/I between a user supplied signal and internally generated white Gaussian noise. The UFX-BER can be used for back to back or IF loop-back testing with extreme precision over a broad range of input or output power. Eb/No values can be entered directly from the front panel or by IEEE-488 bus.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	APPLICATION
UFX-BER-70	50 MHz – 90 MHz	General
UFX-BER-IBS/IDR	50 – 90; 100 – 180 MHz	IBS/IDR
UFX-BER-836	824 MHz – 849 MHz	CDMA
UFX-BER-1850	1800 MHz – 1900 MHz	DCS–1800

Amplifier Test Station



The UFX-NPR series instruments perform automatic distortion measurements in mobile telephone (CDMA and FDM) base stations, satellite communications systems, CATV, and other equipment operating in multi-signal environments. Some models are available with tunable measurement frequency or with multiple measurement frequencies.

TYPICAL STANDARD MODELS	
MODEL	FREQUENCY RANGE
UFX-NPR-70	50 MHz – 90 MHz
UFX-NPR-CATV	50 MHz – 1.0 GHz
UFX-NPR-1700	1.6 GHz – 1.9 GHz
UFX-NPR-2400	2.2 GHz – 2.6 GHz
UFX-NPR-11900	10.95 GHz – 12.8 GHz

Broadband Noise Generators

The NC 6000 and NC 8000 series noise generating instruments are designed for applications on the test bench or incorporated with other equipment to provide a wide variety of functions. Each instrument contains a precision noise source, amplification, and step attenuators to provide repeatable symmetrical white Gaussian noise with variable output power.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT POWER
NC 6107	100 Hz – 100 MHz	+13 dBm
NC 6110	100 Hz – 1500 MHz	+10 dBm
NC 6124	2 GHz – 4 GHz	-10 dBm
NC 8107	250 kHz – 100 MHz	+30 dBm

The new UFX-7000 series noise generating instruments are extremely easy to use, combining dedicated keys for control of operations and programming, with a large 4 x 20 character LCD display. Control of output power, filter settings, and attenuator step size for both the noise and the signal (for units with internal combiners) is performed from the front panel or remotely using the IEEE-488 interface.

TYPICAL STANDARD MODELS		
MODEL	FREQUENCY RANGE	OUTPUT POWER
UFX-7107	10 Hz – 100 MHz	+13 dBm
UFX-7108	100 Hz – 500 MHz	+10 dBm
UFX-7110	100 Hz – 1500 MHz	+10 dBm
UFX-7218	2 GHz – 18 GHz	-20 dBm
UFX-7909	1 MHz – 300 MHz	+30 dBm

NOISE/COM

Noise Com Inc.
E. 49 Midland Ave., Paramus, NJ 07652
Tel: 201-261-8797 • Fax: 201-261-8339

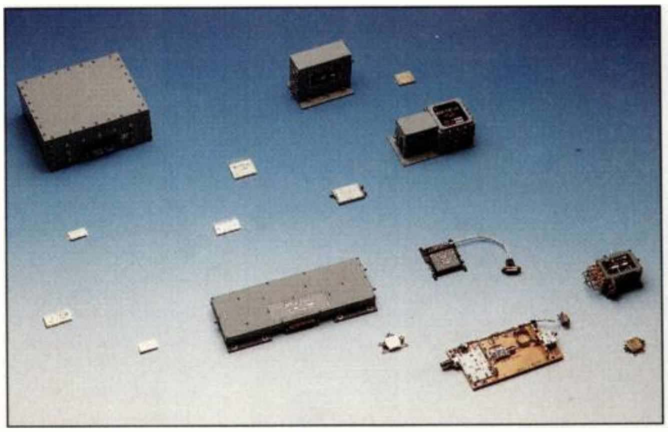
About Daico Industries

Daico Industries, Inc. is a privately held California corporation. Its 35,000 sq. ft. manufacturing plant is just 12 miles south of the Los Angeles International Airport.

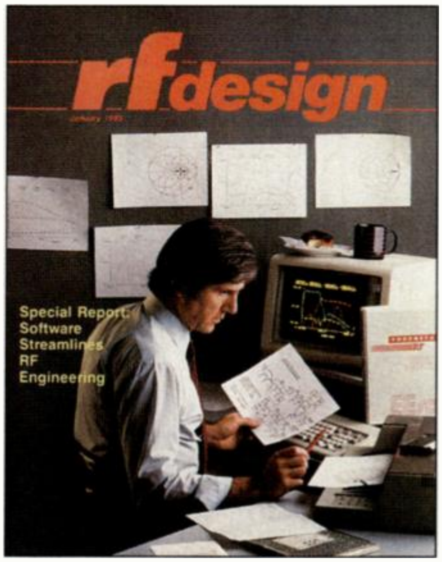
In the 28 year history they have concentrated on supplying the defense electronics, medical and high-end commercial industries with IF/RF and microwave control products. 20% of their product sales are to the Far East and Europe.

Daico's standard IF/RF and microwave products include switches from single-throw to fourty-throw with insertion losses as low as 0.2 dB and isolations as high as 120 dB at 5 GHz, digitally controlled attenuators with up to 8 bits, phase shifters, voltage variable attenuators and threshold detectors. These products serve as an impressive base for higher levels of integration.

Daico now offers High-Density Integration. By using thin film hybrid technology, GaAs MMICs and diodes (Schottky or PIN) together with amplifiers, mixers, limiters, couplers and power dividers, as well as CMOS, TTL or ECL logic devices, they are able to offer increased reliability and substantially reduced size. It is proven that these products offer a signicant cost reduction when compared to assemblies using conventional discrete packaged devices.



Daico's hybrids are designed by experienced RF Design Engineers using the latest CAE/CAD simulation and modeling software. Extensive circuit simulation and modeling, together with their innovative designs, provides a minimal size product with superior performance, while at the same time curtailing costs. Daico has demonstrated time and again that its name is synonymous with quality and value.



January 1985
Our first monthly issue

Initially, *RF Design* was published as a bimonthly publication. Except for a brief attempt at achieving monthly status in the first half of 1980, our magazine continued at six times a year through 1984. During 1984, the company management made a well-thought-out business decision to become a monthly magazine. A solid, loyal readership base had been established, and financial prospects looked good. The idea caught on, and *RF Design* has been monthly ever since.

To mark the occasion, a new look was established. The "tiger stripes" of the old logo were set aside, but the lower case text remained.

Another new venture in 1985 was the inaugural RF Technology Expo, held at the Disneyland Hotel in Anaheim, California. A good turnout was expected, but those expectations turned out to be too small! Hordes of engineers jammed the waiting lines to register, and the tutorial classes were expanded into adjacent rooms and standing-room-only crowds. Although the number of attendees actually increased over the following years, they were handled by implementing more efficient registration methods, mainly advance registration, to shorten the lines.

1985 also marked the beginning of the military industry boom of the Reagan administration. The advertising and new product announcements around this time emphasized high-reliability, mil-qualified components. Pulse modulators, amplifier modules, transistors, oscillators, switches and attenuators were all promoted with either space or military applications in mind.

Software was at the top of the "new RF technology" list in January 1985. EEsof provided our cover photo, Compact Software advertised its Super-Compact CAD tool, Communications Consulting Corp. (which later acquired Compact Software) promoted its Design Kit packages. Engineers were beginning to discover the PC, and one of our articles was a filter design program written in BASIC (including 2-1/2 pages of the program code listing!). However, we still had an article that included a routine for the popular HP-41 programmable calculator, which was probably more useful to RF engineers than the PC program.

The readers were still telling us to keep up the good work, too. As one letter writer said, "I would like to take a few moments to let you know how much I use and enjoy your magazine. Every issue has at least one article that has direct application to something I'm working on."

"Keep up the good work! I like* RF Design.*" — B. Chandler Shaw, October 1992

Pole/Zero Corporation

Pole/Zero Corporation was formed in 1989 by Gene Janning and his son, Joe, with the goal of providing the RF system designer with a new flexibility; readily available *digitally tuned* RF filter modules, useful for wide dynamic range receiver preselection, transmit cleanup filtering, or general purpose tunable filtering. Our goal was to turn these otherwise very expensive, custom engineered filters into standard, reasonably priced, "off the shelf" components, as easy to specify and use as amplifier and mixer modules. These miniature filter modules have been well received by the worldwide industry, and are currently available in frequency ranges from 1.5 MHz to 1 GHz, with RF power ratings up to 10 watts (soon to be 50 watts!)

Since its founding, Pole/Zero has rapidly expanded and now provides a broad range of services which complement its pre-eminent position in digitally tuned RF filters. We provide complete research, development, design and manufacturing of electronic products combining RF, digital, and microprocessor expertise. We are especially attuned to the application of new technology to the rapidly expanding worldwide consumer/industrial markets for specialized "niche" products. Current products now in development or production include:

- Commercial off the shelf (COTS) military subsystems
- RF remote monitoring and tagging devices (RFID)
- Complete receive/transmit COSITE solutions
- Spread spectrum data broadcasting systems with complex multipath equalization
- Micro-miniature RF receivers & transmitters
- Spectrally pure synthesizers and transmitters (S/N > 200 dBc/Hz)
- "Wireless" containment systems
- Noise reduction DSP processing

Pole/Zero has been described by some of our customers as an efficient "skunk works", noted for quick reaction, low cost solutions and the application of leading edge technology to complex requirements. We are housed in a modern facility with modern RF, digital, and CAD equipment. Our engineering staff has an extensive background in RF, digital, DSP, and microprocessor design. Our manufacturing personnel are trained to MIL-STD-454 qualifications and experienced in RF and digital circuit fabrication. All products are manufactured and thoroughly tested in Cincinnati, Ohio, which is fully equipped with modern computer controlled testing equipment.

M/A-COM — Driving Innovation and Integration in Wireless Components

M/A-COM offers manufacturers of wireless products unique advantages for the systems of today and the rapidly emerging applications of the near future.

Technology. For over 40 years, M/A-COM has expanded the frontiers of microwave technology. Beginning with semiconductor materials and diodes and now encompassing everything from ICs to antennas to connectors, M/A-COM continues to lead the industry in bringing the best RF and microwave technology to the marketplace. The company's investment in research and development and engineering support is now delivering a steady stream of new solutions for M/A-COM customers.

"Some of you have known and used M/A-COM products for years. Others are just now applying wireless technology to new communications products. No matter where you are coming from, one message should come through crystal clear: M/A-COM has the products and technology to give you a significant competitive advantage in our new wireless world."

—Allan L Rayfield, President and CEO

Integration. M/A-COM's vertical integration is unprecedented in the industry. Using both Si and GaAs technology and combining the best in active, passive and power components, M/A-COM is building a new generation of products which are smaller, more efficient, and lower cost. This integration provides cost-effective solutions and a one-stop-shop for almost any wireless application.

Worldwide locations. M/A-COM offers manufacturing and design support worldwide. With over 40 field sales offices spanning the globe, no matter where you are located, there is a M/A-COM team in place to help you with your wireless project.

High-volume manufacturing. M/A-COM employs advanced design and manufacturing processes to meet the high volume, high quality needs of the wireless industry including Design for Manufacturability and Continuous Flow Manufacturing.

Product availability. M/A-COM products are also widely available through a worldwide network of distributors. Most offer same-day shipment of standard products.

Microwave Technology, Inc.

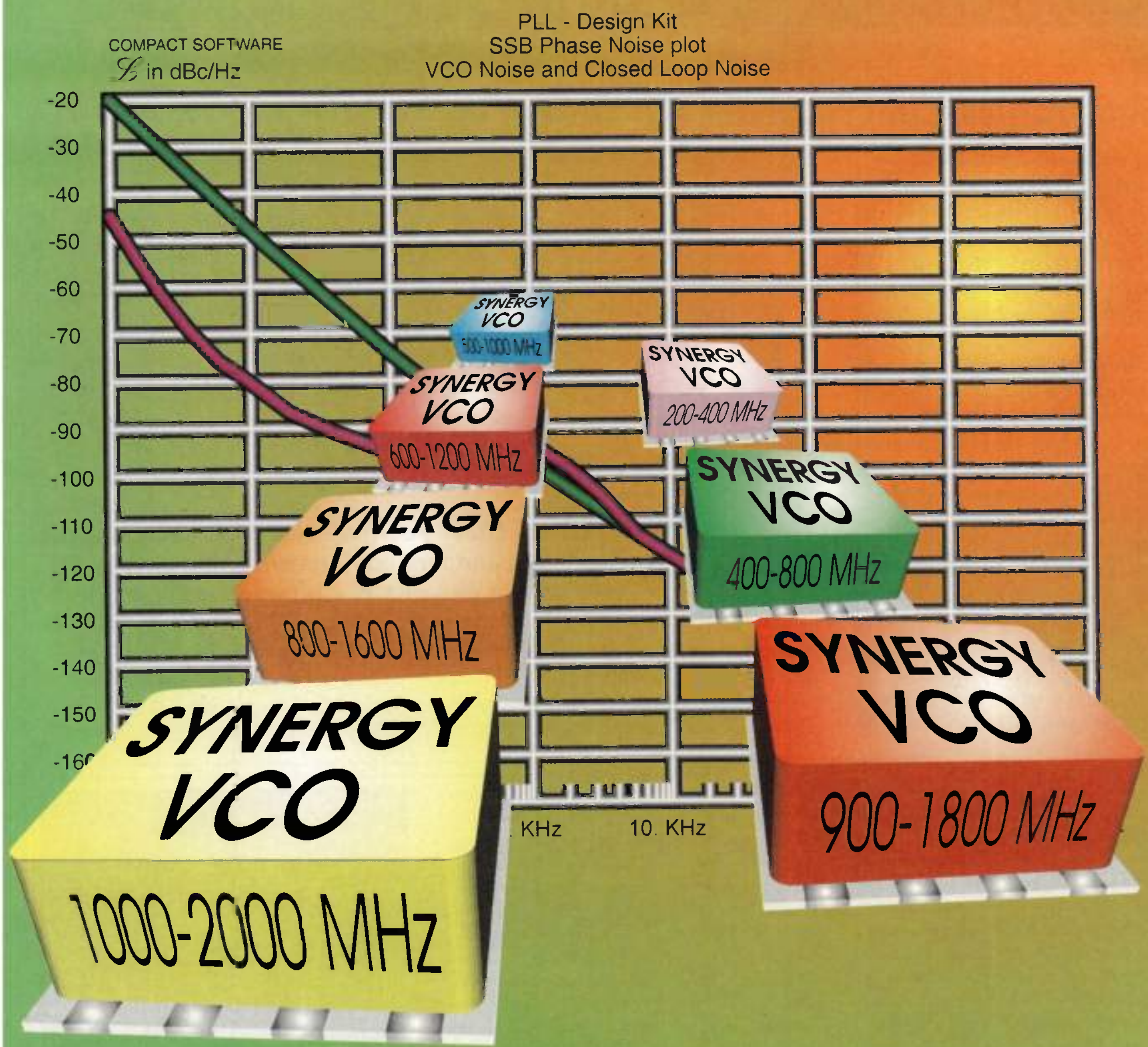
Located in California's Silicon Valley, Microwave Technology, Inc. (MwT) was founded in 1982 by technical pricipals with broad experience in gallium aresenide (GaAs) device design and fabrication.

Today MwT is the leading U.S. based merchant manufacturer of discrete gallium arsenide field effect transistors (FETs). These devices employ proprietary vapor phase epitaxial processes and quarter micron recessed gate technology, which result in highly linear, low phase noise devices with power outputs ranging from 10 milliwatts to 2 watts. Additionally, the Company has developed a proprietary high power (to 100 watts) RF silicon FET structure known as the Solid State Triode (SST) because of it triode-like current-voltage characteristics and its excellent linearity in common source configurations. These two complementary device types, sold as chips or in packages, find wide use in the amplification of signals from sub MHz to 40 GHz in the transmsission or reception of information in wireless telecommunications systems and in defense electronics applications.

Incorporating these devices MwT also produces and markets various standard modular amplifier products employing thin film hybrid microcircuit construction. Taking advantage of the low intermodulation distortion characteristics of MwT's GaAs FETs, the Company has recently introduced a line of small, internally matched surface mount amplifier products aimed at digitally modulated (high linearity) wireless telecommunications cellular base stations. The Company also sells higher level amplifier products for use in high linearity VSAT and commercial radio systems to 23 GHz and broadband defense radar warning receivers to 26 GHz.

The Company's 85 employees are committed to excellent customer service and strong applications support. This, coupled with its vertical manufacturing capabilities and its broad product lines, provides MwT uncommon flexibility in the microwave component marketplace.

VCO VCO VCO VCO VCO



VCO VCO VCO VCO VCO VCO

Now Available From 200-2000 MHz!

Including Coaxial Resonator Models for Specialized Bandwidths

Synergy's new product line of Voltage Controlled Oscillators covers the spectrum of 200 MHz to 2000 MHz. These low cost, high quality models exhibit extremely low phase noise along with linear transfer characteristics. These new Voltage Controlled Oscillators can be supplied in surface mount or plug-in package styles. Additional information and specifications are available from the Synergy Microwave Sales and Applications Department.

SYNERGY
MICROWAVE CORPORATION

Synergy Microwave Corporation
201 McLean Boulevard, Paterson, N.J. 07504 USA
Phone (201) 881-8800 or FAX (201) 881-8361

INFO/CARD 25

Giga-tronics Congratulates RF Design on its 15th Anniversary

In January of 1980, barely a year after RF Design's inaugural issue, Giga-tronics Incorporated began operations. Our initial product was a 50 MHz to 26 GHz synthesized signal generator designed for the U.S. Navy. In 1982, we introduced this product, and the Navy ordered several hundred.

Since then, Giga-tronics has expanded its product offering to include a line of narrow-band and wide-band synthesized signal generators and sweepers. In the early 1990s, we further expanded our product line to meet the needs of the growing commercial communications market. This includes acquiring the Power Measurements Division of Wavetek Corporation in 1992 and the Synthesized RF Signal Generator products of Fluke Corporation in 1993. At the same time, we introduced the third generation of synthesized microwave signal gnerators and sweepers, as well as a line of VXIbus products.

The Giga-tronics Model 1026, our first test and measurement instrument, has been the standard maintenance and calibration tool of the U.S. Navy for shipboard EW equipment since 1982.

Giga-tronics has evolved to meet changing needs while continuing to provide valuable products for our industry. Today, Giga-tronics is a $20-million company with a strong worldwide presence.

ingSOFT Ltd.

1988: A new company, ingSOFT Ltd., launches RFDesigner® software and introduces a Macintosh platform to RF design engineering. RFDesigner® combines its own calculation and graphing with the user's schematic and layout into an integrated design system. RFDesigner® is one of the first engineering software systems to utilize Macintosh's highly standardized and compatible 'plug and play' hardware/software environment.

Rather than competing with research oriented engineering workstations, RFDesigner® offers a complementing solution, addressing everyday, deadline-pressured, result-oriented design challenges. It is now possible to start a design investigation on Friday afternoon and, after a few analysis and optimization sessions, leave for the weekend with a graph printout and knowledge that the idea is real and workable.

1991: RFDesigner® software/hardware solution is awarded the Grand Prize for the RFDesign Magazine's first PC Software Contest. The RFDesigner® solution now includes a new ingSOFT package, RFSynthesist®, and several associated, highly-productive application programs covering a broad range of engineering activities, more than any other platform. The hardware is Macintosh SE/30, a popular small box model with fast execution and plug in engineering capabilities.

1994: RFDesigner® new version adds significant new features and the system solution block diagram (see the ingSOFT ad) keeps on growing. Another new product, RFLaplace™ meets the challenge of electro-magnetic field analysis in an easy to use high resolution graphics environment. With Macintosh based on 68040 and the first PowerPC microprocessors, the execution speed reaches the level of low end workstations, keeping all the benefits of a highly standardized versatile environment with hundreds of well developed general purpose applications that are the best in the field.

Future?? "Even more productive" in the words of the RFDesigner® developers who insist on combining custom RF circuit development with software development to ensure the ultimate software testing. New software will aim at communication system simulation combining time (SPICE) and frequency calculations for RF circuits, RF PCB layout and 3D electro-magnetic analysis. "And yes, ingSOFT will keep on being dedicated to delivering professional quality, versatile capability and price which encourages the 'one-per-engineer' personal hardware/software solution".

The workstations, even today, are neither "personal" nor "friendly" nor "easy to use". The development of a complex human interface and a variety of standardized engineering and non-engineering applications would be a waste of development dollars and would by its extensiveness and cost overshadow the engineering side of the same development. On the other side, the workstations are extremely powerful in the specialized tasks for which they have been designed. This is where ingSOFT developers see the ideal situation within an engineering department: workstations will always perform the high end tasks, leaving versatile small investigations, prototype CAD development, project coordination, and project documentation to the personal computer platforms such as Macintosh.

If workstation data formats for different levels of inputs and outputs are widely published and as standard ASCII text, data exchange between platforms at any level could be easily automated and thus solve communication problems at no extra cost and at an early date for everyone's benefit.

1991 RF Design Awards software contest winner Mike Ellis received a Macintosh computer and a package of ingSOFT's RFDesigner and RFSynthesist, plus additional untility programs.

June 1990
A New Look for *RF Design*

After 5-1/2 years, it was decided that the time had arrived to update our appearance. The cover above was the first of the new style to show up in our readers' mailboxes. In those 5-1/2 years, a lot happened in the RF world.

GaAs MMICs were in full bloom. In fact the market was in the midst of a shakeout as companies made go/no-go decisions on their GaAs development efforts. The market was good, but it just couldn't support so many different suppliers for this technology.

As the cover demonstrated, direct digital synthesis (DDS) was a major technology. This technology, a true merging of digital and RF techniques, had reached maturity, and was accepted as a legitimate design option for systems requiring the speed and phase-coherent switching that DDS could provide.

New items in June 1990 included a report on the soon-to-be-launched CRRES satellite, built to study the earth's magnetosphere and ionosphere. The FCC concluded the experimental status of the GTE Airphone aircraft telephone service, giving it permanent status by allocating 4 MHz in the 800-900 MHz range for regular telephone service. Business news covered the AVX/Kyocera marketing partnership, Zetex' entry into the U.S. market, having been formed after completing a buyout of Plessey's discrete semiconductors, and Metelics announced a new plant opening in the Philippines.

Technical articles in this issue included two analytical discussions, one on curve-fitting techniques, the other describing the use of MMIC foundry models in standard CAD simulators. Limitations of spectrum analyzer measurements were presented (an ongoing discussion, as evidenced by Morris Engelson's article in *this* issue). Notes on the bi-directional behavior of FETs and twisted-wire transmission lines rounded out the coverage of technical topics.

The editors' choices for featured New Products included: a synthesized signal generator from Leader Instruments, an RF radiation hazard monitor from Loral Microwave-Narda, modular microcircuit packages from Hewlett-Packard, an EMI/RFI filter sample kit from Murata Erie North America, and a 5 MHz 12-bit digital-to-analog converter from Burr-Brown Corp.

Compact Software

Compact software was founded in 1973 by Les Besser to provide the RF/Microwave community with automated analysis tools. The Compact simulator was the first commercial package that allowed RF/Microwave designers to model layout-related behavior and automatically optimize circuit parameters for best performance. Compact ran on IBM and DEC mainframes, accessed over time-share networks. The simulator ran in batch mode, producing printouts for analysis. Compact introduced AutoArt in 1976, the first automated layout too for RF/Microwave design.

In the late 1970's, Compact was sold to Comsat, who continued to offer the software as a time-share product. The original Compact code was maintained without significant enhancements.

Dr. Ulrich L. Rohde purchased Compact in 1985, and moved the company to its present location. Compact quickly established PC and Workstation versions of the simulator, which became the basis for the present product line.

in 1988 Compact became the first company to offer a commercial harmonic balance simulator for nonlinear circuit analysis. The harmonic balance technique combines frequency-domain linear analysis with nonlinear time-domain analysis, providing a steady-state solution up to 1000 times faster than traditional SPICE-based approaches. Compact's Microwave Harmonica simulator is based on a novel implementation that provides a usable dynamic range of up to 180 dB.

Compact introduced its Microwave Explorer #D electromagnetic in 1990. Microwave Explorer provides accurate modeling of EM coupling in MMICs layouts with arbitrary geometries. Today, Explorer is one of the few tools available that can model circuits in either an open (radiating) or closed (packaged) environment.

The Serenade product family was established during 1992/1993, providing an integrated design capture, analysis, and layout environment. 1993 also saw the introduction of Super Spice, which complements the frequency-domain tools by offering accurate simulation of microwave circuits including discontinuities and EM coupling effects.

Compact has a long history of providing novel solutions for analyzing the effect o noise in RF and microwave circuits. A noise correlation matrix was added to the Super-Compact simulator in 1988. in 1992 Compact was the first company to provide noise analysis of nonlinear circuits such as mixers and oscillators. The tradition continues today; where the upcoming 5.0 release of Microwave Harmonica will allow users to automatically optimize oscillator circuits for lowest phase noise.

Today, Compact is the only company that offers a broad range of RF and microwave design tools on both PCs running Microsoft Windows and on Engineering workstations. This allows users to start with PC-based tools and upgrade as their needs expand.

[RF Expo '86] "...its the best history that I have ever experienced in over 20 years...! " — Ed Oxner, April 1986

Faraday Technology

Faraday Technology was founded in 1984 in the UK to develop, design and manufacture filters and delay lines. Today, Faraday is a major supplier in the UK and we export our products around the world.

Faraday specializes in lumped element technology in the frequency range of 200 kHz to 1 GHz. Networks are constructed using discrete inductors, capacitors and resistors which result in high quality but physically small devices with good overall stability. Lowpass, bandpass, bandstop and high pass filters are produced with Buterworth, Tchebychev, linear phase, maximally flat, Gaussian and Cauer Tchebychev responses. Currently under development are active hybrid filters and the design of digital filters.

Product groups

- Antialiasing and reconstruction filters A full range of pre and post filters for ADC and DAC applications. Post filters incorporate sin x / x correction.
- Pulse shaping filters In a digital system bandlimiting and pulse shaping filters are used to minimize intersymbol interference and maximize operating range.
- IF filters for satellite links
- 70 MHz IF filters to satellite templates for "Fly Away" SNG systems.
- Phase matched filters For phased array antenna systems.
- Cable equalizers A full range of minimum loss amplitude equalizers either for baseband or IF.
- Group delay and amplitude manipulation Correction or pre-distortion networks up to 500 MHz.
- "Cable Clone" cable simulators
- Cable simulation to establish head height in digital video systems.
- Video filters and delay lines
- Active hybrid video filters
- A new range of actively equalized filters, fully buffered and tested.

Faraday has invested in state-of-the-art test equipment to ensure the highest standards. All products are 100% tested before shipment. We will meet specific design requirements including phase tracking, temperature compensation, high power and harsh environments. Design and development advice is freely available. Using specially written CAD technology and testing systems, Faraday has the flexibility to produce prototypes or large batches quickly and competitively.

Antenna Research Associates

Antenna Research Associates, Inc. is a manufacturer of antenna systems and sub-systems for both EMC test markets and communication surveillance and telecommunication areas. The company has been in business for thirty one years as a small, independent company. Five years ago, Antenna Research's emphasis changed from an engineering based approach to a marketing based approach under the guidance of Pradeep K. Wahi, President at CEO.

With its diversified markets, Antenna Research has had good success in the marketplace "Even when communication was going down EMC was doing well, and when EMC was down, communication was doing fine." according to Pradeep K. Wahi, President and CEO. Products for the EMC market include shielded fiberoptic cables and GTEM cells. For telecommunications, Antenna Research manufactures wide broadbase antennas and printed circuit antennas.

Antenna Research is looking toward the next five years anticipating enormous growth in the EMC market. "The new changes in EMC (FCC, Health Department, and the new European Standards) will spur a good bit of growth in that industry."

Antenna Research anticipates growth from 100-200% a year for the next few years. The company also has plans to penetrate further into the government contract market. "There is quite a positive outlook for us right now because of the marketing, planning and positioning we undertook in the past few years" states Wahi. "We have a new product line, new antenna. . .both of those things are ready to pay off now."

Antenna Research Associates, Inc.
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Beltsville, MD 20705-2088
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fax: (301)937-2796

Sprague-Goodman Electronics

Sprague-Goodman Electronics, Inc. was established in 1972, and has been under the same management since its founding. The company has experienced steady growth through the years, and now offers the world's broadest line of trimmer capacitors, inductors and microwave tuning elements. A growing network of manufacturer's representatives and stocking distributors market Sprague-Goodman products throughout the world.

In October, 1994, the company is moving its factory and offices to a new 15,000 square foot (1394 square meter) facility at 1700 Shames Drive, Westbury, New York 11590. (Telephone: (516) 334-8700, Fax: (516) 334-8771). The facility is convenient to all transportation facilities.

According to Jack Goodman, Chairman and Chief Executive Officer, "The new headquarters enables us us to integrate functions that were previously in four different locations. While the total space remains the same, the new layout is more efficient, and will allow us to operate with greater productivity." The plant will include a computer LAN (local area network) running manufacturing resource planning software, which will assist management in meeting the increased demand for Sprague-Goodman's products in RF and microwave wireless communication applications. Martin Markson, President and Chief Operating Officer, ststed that "Sprague-Goodman has been awarded preferred vendor status by many major electronic manufacturers. Quality control at the new location will continue to meet the requirements of MIL-I-45208. Production of the trimmer capacitors qualified to Military Specification MIL-C-14409 will not be interrupted; in fact, we are working to add additional items to the Qualified Products List (QPL) for this specification." The Facility will also be producing devices for commercial and industrial applications, such as GPS receivers and cellular telephones.

Elisra Microwave – Components Division

Elisra, Israel's EW House, has announced that its microwave components and microcircuits facilities will now operate within the framework of a unified Technology Center. Customers will benefit from access to a single address for the components that are the heart of today's high tech systems. The new Technology Center offers a full service, from design through production.

In addition to a full range of off-the-shelf product, the Technology Center draws on one of the finest engineering teams in the business to offer tailored solutions for systems with challenging constraints, whether the issue is weight, space, a harsh operating environment or special performance parameters.

Main Products — The Technology Center's microcircuits capability includes both thin and thick film products. The film products are characterized by superior high frequency performance and can be provided as small, high density modules. Thick film products feature attractive prices and are available as moderate to high density complex modules. Customers will be appreciative of the Technology Center's multichip module capability, which enables it to offer dense and complex multichip hybrids based on high temperature multilayer cofired ceramics. The input-output leads can be made for either through-hole or surface mount assembly.

The Technology Center's microwave capabilities are just as impressive, and range from filters, amplifiers, RF switches, frequency synthesizers through multicouplers, switch matrices, RF equipment, microprocessor controlled RF transmitters to the most sophisticated supercomponents.

State-of-the-art Facilities — The Microwave Components Division's modern facilities cover an area of 4,000 square meters. They are located in a suburb of Tel Aviv, Israel's main commercial city, near the country's international airport. The Division employs a staff of more than 200 microwave engineers, technicians, highly skilled production workers and marketing specialists.

Applications — Elisra Technology Center serves both defense and commercial markets. Its stringent QA standards enable it to provide solutions for the most discriminating customers. Typical applications include: telecommunications, aviation, the new geneartion of automotive products, control systems, computers, medical equipment and other industrial environment requiring high precision.

Elisra Technology Center
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Cougar Components

Cougar Components was founded "Silicon Valley" style in 1986 by Dan Cheadle, Sr. Mr. Cheadle had formed a leading cascadable amplifier product line within a large reputable company starting in 1973.

Cougar has moved three times since then into progressively larger facilities, and our latest move lead us to Sunnyvale, California into a remodeled 14,000 square foot facility. Obviously, our growth in sales is driving this advancement but the real key has been consistent new product development and exemplary quality and service. Our commitment to high performance can be seen in the journals and in our own literature. Our quality and servive is attested by several key customers such as Northrop, TRW, Harris, Texas Instruments, and Rockwell Collins.

We maintain a strong interest in military-related hardware and service but are actively pursuing commercial applications as well. Rather than take business from someone else, we prefer to grow the pie for everyone, which leads us back to new product development.

Our continued success - high performance products, unsurpassed quality, fair prices, exemplary service - rests in the hands of our staff. Our staff has been selectively assembled from many corporate and educational backgrounds. Our collective skill and knowledge base is our single most valuable asset and will project Cougar through the end of this century and beyond as a premier supplier in the RF/microwave industry.

If you're looking for noise products and test equipment, we've got you covered!

Noise Com is the source for noise generating components and instruments. Our products are used throughout the world to evaluate the performance of military and commercial radar, digital communications, and data transmission systems. Applications range from built-in calibration references to stand-alone additive white gaussian noise (AWGN) generators for the telecommunication industry. Noise/Com offers:

- Noise Diodes
- Amplified Noise Modules
- Coaxial Noise Sources
- Waveguide Noise Sources
- Calibration Service, Noise
- Noise Generators (AWGN)

Noise/Com has established a solid reputation for quality, performance, and product support that is among the most highly regarded in the industry.

Wireless International Corp. manufactures instruments for wireless and telecommunication performance testing. This test equipment fulfills the need for emulation of a data communication channel from antenna to antenna or from transmitter to receiver. Test equipment from WIC's includes:

- Multipath Fading Channel Emulators
- Precision Eb/No Generators
- Amplifier NPR Test Stations
- Communication Channel Analyzers
- BER Testers
- VXI Modules

WIC's comprehensive range of instruments is targeted at the evaluation of modern digital mobile, cellular, satellite, wireless modem, PBX, LAN and HDTV communication systems employing CDPD, CDMA, TDMA, burst, GSM, frequency hopping, and advanced coding techniques.

Wireless Telecom Group,Inc. designs, develops, manufactures, and markets test equipment. Wireless Telecom Group is a public company traded on the American Stock Exchange under the ticker symbol "WTT". The Company was founded in 1985 under the name Noise Com. Noise Com became a publically held company in 1991 and previously traded on the American Stock Exchange under the symbol "NOI".

The Company designs, develops, manufactures, and markets test equipment used for a wide variety of purposes. Noise Com and Wireless International Corp. form the two parts of Wireless Telecom Group. Each have become leaders in their fields: markets serving the wireless and telecommunications industry.

Goals

Our goal is to continue our history of growth and profitability by remaining a leader in the markets we serve.

Facilities

Wireless Telecom Group occupies a 12,000 ft2 modern facility in New Jersey. It has a variety of capabilities, including a 150 ft2 Class 10,000 clean room for hybrid microelectronics assemblies, computer-aided mechanical design, PC board layout systems supplemented by circuit simulation and software emulation. The Company has in-house environmental screening facilities including temperature cycling, thermal and mechanical shock testing, random and sinusoidal vibration, gross and fine leak tests.

The People

We have assembled a group of dedicated, knowledgable, creative people who have a wide range of backgrounds in test and measurement of wireless and digital telecommunications.

Products

Wireless Telecom Group's average annual growth rate has exceeded 25% over the last 5 years. This growth was generated from the sales of Noise Com products. These devices produce a random electrical signal with a gaussian (normal) probability distribution that is useful for test and calibration of larger electronic systems.

Noise sources and generators are used in a variety of ways including the testing of digital telecommunications and computer subsystems. These devices are also used to calibrate cable television equipment, in electronic warfare and in performance verification of scientific equipment.

To continue and potentially increase our growth, Wireless International Corp. has developed new products. Our multipath fading channel emulators, Eb/No generators and bit error rate testers have been well received by our customers. These productsare used in satellite and cellular communications and indoor\outdoor wireless data (LAN) transmission. The Company is continuing the development of additional products that cater specifically to large commercial markets most notably the wireless and telecommunications markets.

Quality

Wireless Telecom Group assures the quality of its products by maintaining a modern inspection system (ISO-9001 certification is anticipated in the near future). In addition we have in-house certified instructors, inspectors, and assemblers for the MIL-STD-2000 workmanship standard. Electro static discharge (ESD) protection is maintained at all levels throughout the production. Wireless Telecom Group's EMI shielded calibration department has standards traceable to NIST.

Customers

Wireless Telecom Group has a very large customer base. These customers include commercial electronic equipment manufacturers, telecommunication providers, universities, cellular mobile telephone manufacturers and operators, computer companies, as well as major defense contractors, and military and non-military government agencies. No one customer dominates the Company's sales.

Marketing

Wireless Telecom Group markets its products through aggressive and innovative advertising in trade publications and through a network of more than 30 national and international sales representatives. In 1994, Wireless Telecom Group, further expanded its advertising campaign. This effort includes five front cover presentations of new products, three of these accompanied with articles solely featuring the Company's products. A series of two-page four color ads, the "shoe campaign", was inserted in five international magazines during 1994. The Company also announced Wireless International Corp's new multipath fading emulator instrument in a cover feature in January 1994 *RF Design* magazine.

Service

All of Wireless Telecom Group's products benefit from comprehensive in-house facilities. These capabilities combined with service-minded technical personnel allow us to manufacture highly reliable products, including complete test systems, in an extremely short time. In fact 20% of our products are shipped on the day we receive the order and 50% are shipped within 10 days. These efforts have been commended in writing by some of the largest and most critical system manufacturers in the world.

Wireless Telecom Group has established a solid reputation for quality, performance, and product support that is among one of the most highly regarded in the industry. In recognition of our efforts, we received the 1993 "Administrator's Award for Excellence" from the U.S. Small Business Administration for our outstanding contribution and services.

For additional information or product literature call Wireless Telecom Group at (201) 261-8797.

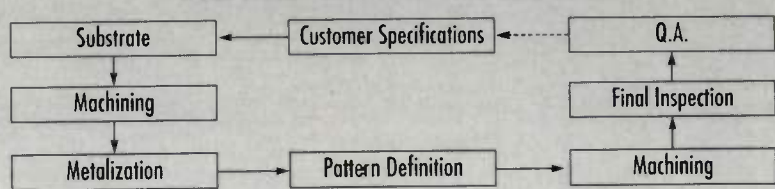
ATC THIN FILM PRODUCTS AND SERVICES

ATC Advanced Technology Center - Jacksonville, Florida

ATC brings a new standard of responsiveness and quality to thin film technology products and services. Custom metalization and patterned substrates are offered to address a broad spectrum of deposition and hybrid circuit fabrication requirements. Custom metalization consists of sputtered and electroplated coatings made to specifications. Products may include via holes and odd shaped substrates in a wide choice of ceramics and dielectric materials. Three-target, batch sputtering systems with load-locks are utilized for producing the most consistent film quality. Etched or pattern-plated substrates are also made to specifications. Designs may include metalized or solid via holes, cross overs and air bridges.

ATC's experienced engineering staff is available to provide assistance in choosing the proper substrates and metalization systems at the inception of a project. They will also assist in troubleshooting a customer's process if difficulties are encountered. The traditional ATC Quality Assurance Program will meet most existing military and aerospace requirements. MIL-STD-883 is used as a guide for 100% visual inspection in our in-process procedures. MIL-STD-105 sampling is used for final QA Inspection.

THIN FILM PROCESSES AND SERVICES



SPUTTERED AND ELECTROPLATED COATINGS

MATERIALS COATED: Alumina • Beryllia • Dielectrics • Ferrites • Quartz • Sapphire • Other

BARRIER LAYERS: Titanium/Tungsten (TiW) • Palladium (Pd)

ADHESION LAYERS: Chromium (Cr) • Titanium (Ti) • Titanium/Tungsten (TiW) • Nickel/Chromium (NiCr)

CONDUCTIVE LAYERS: Copper (Cu) • Gold (Au)

RESISTIVE LAYERS: Tantalum Nitride (TaN) • Nickel/Chromium (NiCr)

CUSTOM SERVICES

PATTERNED SUBSTRATES: Pattern Plating • Wet Chemical Etch-Back • Dry Etch (Ion beam milling)

SUBSTRATE MACHINING: Laser • Precision Diamond Saw • Ultrasonic

ATC RESPONSIVENESS

FACTORY ENGINEERING SUPPORT: Direct consultation from experienced thin film technology experts is available as required. This is the same high level of support that ATC customers traditionally receive.

SALES SUPPORT: Typical quotes are usually provided by the factory within 24 hours. Contact your authorized ATC Thin Film Products representative or call direct for additional information and quotations:

(516) 547-5700

AMERICAN TECHNICAL CERAMICS, ONE NORDEN LANE,
HUNTINGTON STATION, N.Y. 11746-2102 - FAX (516) 547-5748

American Technical Ceramics

INFO/CARD 2

Times Microwave Systems

Times Microwave Systems (TMS) was founded in 1945 under the name Times Wire and Cable, specializing in the manufacture of coaxial cables for military applications and the emerging cable television industry. Soon after, the company assumed a leadership role in promoting rigorous Mil-C-17 coaxial cable standards, and as a result holds more than twice as many Mil-C-17 qualifications today as its nearest competitor.

In the early 1960's, TMS entered the microwave cable assembly market through their work with General Dynamics on the F-111 aircraft program. TMS solved their flight operation interconnection problems and was instrumental in establishing an industry-wide military standard for assemblies. This relationship expanded to include long term relationships with all major airframe contractors and electronic system houses.

Times Microwave Systems commits its full resources solely to the design and manufacture of RF cables and microwave cable assemblies. As a result, we offer the broadest range of engineered RF cable and microwave cable assembly products in the high frequency industry.

In response to a smaller military market, we have remained responsive to our customers' needs. For example, we recently introduced the M8 Multi-Port Interconnect: a lightweight, smaller size microwave cable interface offering improved electrical performance without compromising mechanical integrity. The M8 is currently in use in the F-22 program.

Toward an increased presence in commercial markets, Times manufactures high performance cables and assemblies for collision avoidance systems used in commercial aircraft. Such systems are installed on airframes manufactured by McDonnell Douglas and Boeing in the US, and British Aerospace and Fokker in Europe.

Radiating cable presents another opportunity for our cable expertise. Our radiating cable functions as an antenna in enclosed environments such as tunnels, subway systems, and mines. Our unique triaxial construction affords several performance advantages. Most significantly, our radiating cable has reduced sensitivity to the environment and can be directly mounted against a conductive surface without affecting the coupling or attenuation values, unlike competitive designs.

The newest addition to our commercial product line is our economical LMR flexible communications cable. LMR cables are well suited for mobile and fixed antenna feeders, base station jumpers, and other applications requiring low loss cables. They offer lower loss and better flexibility at substantially lower cost than corrugated copper cables.

Times Microwave Systems
. . .a better connection

The company **TELE QUARZ** from Neckarbischofsheim, Germany decided on a policy of playing to strength on the market some time ago: not just with modem technology, but above all, with motivated employees.

Knut Kruger, Chairman of TELE QUARZ GROUP, said in a public company presentation "Everything which can be heard now about customer orientation and employee management as part of the lean production discussion should be a matter of course."

This self-evident truth has historical roots. When Knut Kruger founded TELE QUARZ in 1974, absolute customer orientation and flexibility were the only recipe for survival in the market against large rivals. At the time, special crystals were used predominantly in radio equipment. This demanded enormous flexibility on the part of suppliers, something which posed problems for larger companies. "The excuse put forward by the crystal suppliers at that time was that they needed between 6 and 10 weeks for production. It was clear to me right from the start that purely organizational reasons were the cause of this," remembers Kruger.

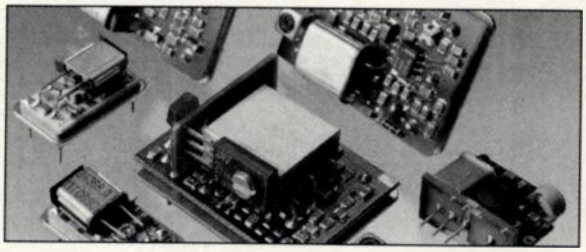
Flexibility suddenly took on a different meaning owing to the enormous market growth in the 70s and 80s. Quantities of 5000 for special crystals were then not unusual.

As one step, a plant for large quantities of crystals was built in the open countryside in Ternitz, Austria, in 1985 to complement the production center in Neckarbischofsheim. This trades independently as EURO QUARZ GmbH, but forms a works unit with Neckarbischofsheim.

The Customer Calls the Tune

Albrecht Bohnet, General Manager: "We had to make the processes more rational. In other words, we planned new production technology and also developed our own machines and processes."

Alongside the quartz crystals themselves, subassembly production for quartz filters and oscillators has been set up during the last few years. With the product range nicely rounded off in this way, TELE QUARZ thus occupies all the important segments on the European market today, starting with consumer electronics and computers, through telecommunications to automotive electronics (e.g. in ABS and injection electronics) and high-reliability technology (e.g. aerospace).



Flexible production planning according to ISO 9000 philosophy and qualified people guarantee for a successful cooperation with the customers.

In the case of just in time orders- TELE QUARZ serves suppliers to the automotive industry-Corresponding measures can be taken in good time of the basis of overall agreements. Production is controlled by means of a 14-day advance schedule, whereby a small buffer stock is kept for safety reasons.

The intermeshing of all departments and divisions proves the high importance attached to organization and employees. The company management makes sure that deeds follow words. For example, company boss Kruger goes through the works at least once daily and discusses problems and solutions with the employees. "It must be clear that the management takes care of things. It is less a question of correcting the work done on the shop-floor but how important it is to work out joint suggestions," comments Kruger.

And this goes hand in hand with a shift in responsibility. Bohnet: "The people at shop-floor level have to deal directly with the problems. The more responsibility they accept, the better it is for all concerned." Such a process is not possible overnight. Indeed, a good deal of time is needed to instill the necessary quality awareness and to make it an integral part of day-to-day work.

Motivation to achieve better quality is not just a catchword. It is measurable at TELE QUARZ. They are now the leading European manufacturer for quartz crystal products.

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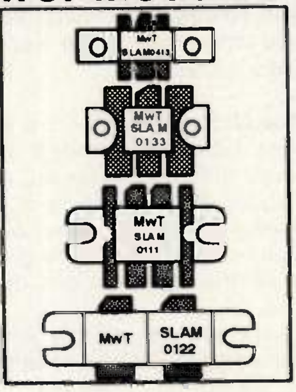
Power Mods							
SLAM0111	2-32	25	55	14	6	28	2.5
SLAM0122	2-32	50	59	12	6	40	4.0
SLAM0133	2-32	10	52	13	6	32	1.0
SLAM0413	2-50	12	54	13	6	32	1.5
SLAM0513	5-150	12	52	12	6	28	1.25
Receiver Mods							
SLAM0131R	1-50	4	53	14	4	18	1.25
SLAM0158R	1-50	2	48	13	4	15	0.5



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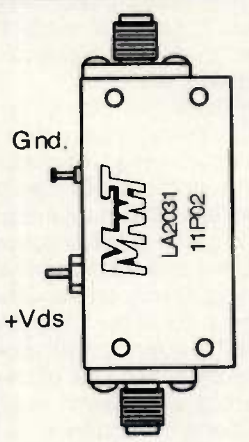
LA-2031-21P02	2-32	25	55	25	6	28	3.5
LA-2031-21P03	2-32	20	53	25	6	20	2.75
LA-2041-51P02	2-40	50	59	24	6	40	5.0
LA-2012-21P01	2-100	20	54	25	6	28	2.15
LA-1222-11S01	100-200	12	52	23	6	28	1.5
Receiver Amps							
RA-2012-50P02	2-100	5	53	24	4	20	2.0
RA-2051-40P01	2-50	4	52	12	4	15	1.5
RA-2031-20P02	2-32	2	47	24	4	15	0.6
RA-5012-50P01	5-100	5	50	20	4	15	1.25
RA-1142-50P02	10-400	5	48	38	4	15	1.5



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Quick Measurement of Unloaded Q Using a Network Analyzer

By Ajay Asija and Anand Gundavajhala
Harris Corporation

A quick way of measuring the unloaded Q, (Q_0), of a resonator is described. The method is based on measurement of both magnitude and phase of the input reflection coefficient and can be programmed to work from an automated network analyzer. Measured values of Q_0 using this method agree closely with those found by other known methods.

The Q of a resonator is a measure of the ratio of the energy stored and energy dissapated by the resonator. Unloaded Q is a measure of the energy dissipated in the resonator, while loaded Q is a measure of the energy dissipated in both the resonator and the external load.

There are essentially two ways of measuring the Q of a resonator. The frequency-domain method consists of observing the frequency response of the resonator close to its resonant frequency, either by the reflected signal or by the transmitted signal. The time-domain method consists of subjecting the resonator to an input signal and observing its transient response.

The usual methods of measuring the Q_0 of a resonator have their own unique set of problems. The most common method employed to measure Q_0 of a resonator is the transmission method. The resonator is lightly coupled by a pair of probes and the transmitted signal is observed directly on the network analyzer. The ratio of the resonant frequency to the frequency half-power points (points on either side of the resonance that are 3 dB down in magnitude from the resonant frequency) is calculated. Although this method is useful in measuring the loaded Q of the resonator, it can give large errors when used for measuring unloaded Q. To reduce this error, one must decrease the amount of coupling that loads the resonator. However, doing this decreases the amount of power transmitted, which increases the measurement errors of the network analyzer.

Another method of measuring Q_0 uses input VSWR values around the resonant frequency [1], [2]. This method is more accurate but gives large errors when VSWR at the resonant frequency is large.

A potentially more accurate method for measuring Q_0 involves the measurement of both magnitude and phase of the reflected signal [3,4]. The expressions for finding Q_0 are obtained by deriving a relation between Γ_R, the reflection coefficient at resonance, Γ_d the reflection coefficient far from resonance, and Γ_1, and Γ_2, the reflection coefficients at two points close to resonance. The method described in [4] is time consuming and requires the use of a transparent template that fits the display screen of the network analyzer. This paper is based on the results of [4] which are further manipulated into a form that can be read directly by an automated network analyzer. The entire procedure can be controlled by a short computer program that prompts the user for inputs.

Theory

Consider the circuit model of a resonator around its resonant frequency as shown in Figure 1. The procedure follows the approach from [4]. The input impedance Z_i and the reflection coefficient Γ_i of the circuit close to its resonant frequency are given as:

$$Z_i = R_e + jX_e + \frac{R_0}{1 + jQ_0\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)} \quad (1)$$

$$\Gamma_i = \frac{Z_i - R_c}{Z_i + R_c} \quad (2)$$

where,

$$X_e = X_1(1+\delta)$$
$$\delta = \frac{\omega - \omega_0}{\omega_0}$$
$$X_1 = \omega_0 L_e \quad (3)$$
$$Q_0 = \frac{R_0}{\omega_0 L_0}$$

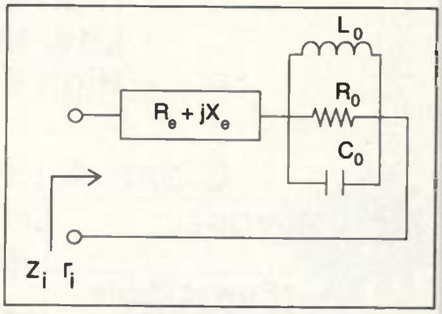

Figure 1. Model of resonator close to resonance.

When the coupling mechanism is lossless, R_e can be neglected. Also since the frequency detuning parameter $\delta << 1$, we can write:

$$\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \approx 2\delta \quad (4)$$

Defining,

$$Z_s = R_e + jX_e$$
$$Z_f = \frac{R_0}{1 + j2Q_0\delta} \quad (5)$$

we get the input reflection coefficient as:

$$\Gamma_i = \frac{Z_f - Z_s^*}{Z_f + Z_s} \quad (6)$$

Far away from resonance, the coupling coefficient becomes zero and the input impedance consists of only the first term in (1). The corresponding reflection coefficient at this detuned point, Γ_d, is given by:

$$\Gamma_d = -\frac{Z_s^*}{Z_s} \quad (7)$$

Using (6) and (7) we can derive a function $\Gamma(\omega)$ given as:

$$\Gamma(\omega) = \Gamma_i - \Gamma_d = \frac{2e^{-j2\tan^{-1}x_1}}{\left(1+\frac{1}{\beta}\right)(1 + j2Q_L\delta_L)} \quad (8)$$

In the above equation,

$$x_1 = \frac{X_1}{R_c} \tag{9}$$

and,

$$\delta_L = \frac{\omega - \omega_L}{\omega_0} = \delta - \frac{x_1\beta}{2Q_0} \tag{10}$$

The loaded Q, Q_L and the coupling coefficient, β are related as:

$$Q_L = \frac{Q_0}{1+\beta} \tag{11}$$

where the coupling coefficient defined according to [4] is:

$$\beta = \frac{R_0}{R_c} \cdot \frac{1}{1+x_1^2} \tag{12}$$

The function $\Gamma(\omega)$ defines a circle on a Smith Chart. Figure 2a shows a typical case for the overcoupled response ($\beta > 1$) and Figure 2b shows a typical case for the undercoupled response ($\beta < 1$).

From (8) we can calculate the value of Q_L as:

$$Q_L = -\frac{\tan\phi_L}{2\delta_L} \tag{13}$$

Let points P_1 and P_2 at frequencies f_1 and f_2, respectively, be the two points corresponding to an angle ϕ_L. Then (13) can be written as:

$$Q_L = \frac{f_L}{f_1 - f_2} \cdot \tan\phi_L \tag{14}$$

Let the reflection coefficient at P_1 and P_2 be defined as:

$$\Gamma_1 = ce^{j\phi_1} \qquad \Gamma_2 = ce^{j\phi_2} \tag{15}$$

To find Q_L, the quantities c, ϕ_1 and ϕ_2 have to be determined first. The input reflection coefficient at resonance, Γ_R, defined as:

$$\Gamma_R = (\text{at}\,\omega = \omega_L) = se^{j\psi} \tag{16}$$

can easily be read from the network analyzer as the frequency point with the smallest reflection coefficient. The lengths a, a_1, and d are calculated as shown in Figure 2. For any value of ϕ_L, the length c, defined in Figure 2 can be calculated as:

$$c = \sqrt{a^2 + a_1^2 - 2aa_1\cos 2\phi_L} \tag{17}$$

The value of c establishes the magnitude of reflection coefficient at points P_1 and P_2. The value of ϕ_1 and ϕ_2 can be found from Figure 2 as,

$$\phi_1 = \psi + \psi^P \pm 180^\circ = \psi + \psi^P \tag{18}$$

$$\phi_2 = \psi - \psi^P \pm 180^\circ = \psi - \psi^P \tag{19}$$

In the above equations, ψ^P can be found by a simple trigonometric relation,

$$\psi^P = 2\tan^{-1}\frac{r}{t-a} \tag{20}$$

where,

$$r = \sqrt{\frac{(t-a)(t-a_1)(t-c)}{t}} \tag{21}$$

and,

$$t = \frac{a + a_1 + c}{2} \tag{22}$$

To find Q_0 consider the function $\Gamma(\omega)$ at resonance when $\delta_L = 0$. The magni-

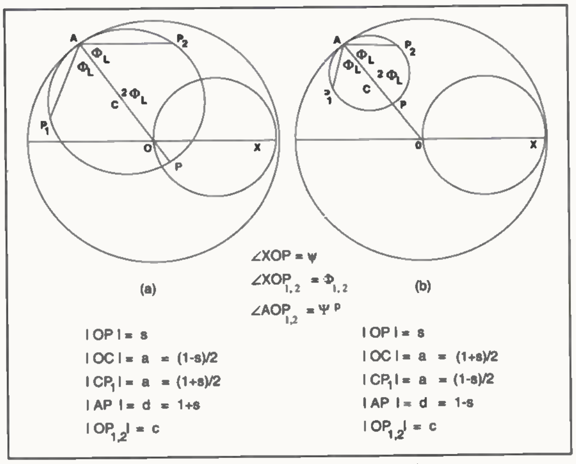

Figure 2. Frequency response of resonator: (a) overcoupled, and (b) undercoupled case.

tude of $\Gamma(\omega)$ becomes:

$$|\Gamma(\omega)| = d = \frac{2}{1+\frac{1}{\beta}} \qquad (23)$$

d, and thus β, can be found from Figure 2. Q_0 is then found from (11) .

Results

A program has been written that incorporates the above results. It runs using an HP 9826 computer connected to a HP 8753C Network Analyzer. The program calculates both unloaded and loaded Q and the coupling coefficient. It automatically distinguishes between overcoupled and undercoupled cases. It does this by comparing the angle of the reflection coefficient at resonance to the angle of reflection coefficient far away from resonance and determining if they are in or out of phase (i.e., lie on the same or opposite halves of the Smith Chart). The response is undercoupled if they are in phase and overcoupled if they are out of phase.

ϕ_L	Q_0
10	2568
20	2566
30	2570
40	2569
50	2565
60	2564
70	2558
80	2527

Table 1. Unloaded Q versus measurement angle for helical resonator, TEM mode, f_0 = 219.59 MHz.

ϕ_L	Q_0
10	8103
20	8110
30	8063
40	8007
50	7899
60	7679

Table 2. Unloaded Q versus measurement angle for dielectric resonator, TE_{01} mode, f_0 = 3.377 GHz.

Table 1 shows the variation of Q_0 versus the measurement angle ϕ_L for an RF cavity while Table 2 shows the variation of Q_0 versus the measurement angle ϕ_L for a microwave cavity. The two tables show good repeatability of Q_0 as angle ϕ_L is varied. Note that the accuracy of the results decreases as ϕ_L gets closer to 90°. This occurs because the input impedance parallel resonant model of the resonator breaks down as one moves far away from the resonant frequency. The accuracy also decreases for values of ϕ_L less than 10° because at such small values of ϕ_L the frequency resolution accuracy and the dynamic

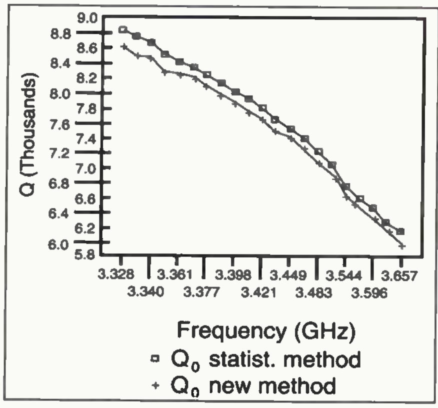

Figure 3. Comparison of measured Q_0 of a tunable microwave cavity, for TE_{01} mode.

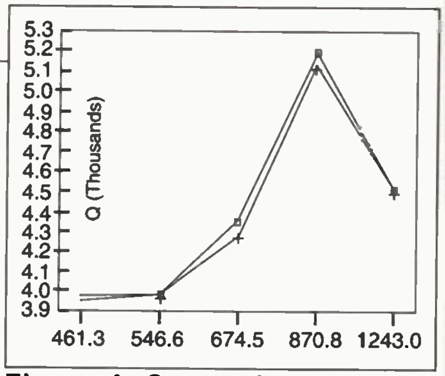

Figure 4. Comparison of measured Q_0 of a tunable microwave cavity, for the TEM mode, using two different methods.

range accuracy of the network analyzer magnify the error. It has been the authors' experience that the most accurate results are obtained for values of ϕ_L between 20° and 30°.

Figure 3 shows a comparison of Q_0 values obtained by two different methods for the TE_{01} mode of a tunable aluminum cavity loaded with a Murata Erie Resomics DRD163UD072 dielectric resonator (ε_r = 37.7) mounted on a fused quartz (ε_r = 3.78) support. In the first method, Q_0 is obtained by a statistical least square fitting of measured reflection coefficient data points to a fractional linear transformation [5]. The second method uses the approach described in this paper for ϕ_L = 30. The results agree very closely. The Q_0 values obtained by the method described here are always on the lower side. This may be because coupling mechanism losses have been factored out in the statistical method to yield higher values of Q_0.

Figure 4 shows a comparison of Q_0 values, obtained by two different methods for a TEM resonator. The first method uses values of input VSWR around resonant frequency to calculate Q_0 [1], while the second method uses the approach described in this paper for ϕ_L = 25°. The resonant structure consists of a 2.1×2.1 inch square cavity with a cylindrical inner resonator of 0.625 inch diameter. Each frequency point represents an inner resonator of different length, resonant at its quarter wavelength frequency. The two methods show excellent agreement with each other.

Conclusions

A new automated method of measuring unloaded and loaded Q of a resonator is presented. The method is easy to implement and works well for both undercoupled and overcoupled cases, automatically distinguishing between the two. The formulas presented here are directly incorporated into a computer program that interfaces with a network analyzer. Measured Q_0 values show good repeatability as the angle ϕ_L is varied for frequencies both in the RF region (Table I) and in the microwave region (Table II). The method also shows very close agreement with other known methods of measuring Q_0 in both RF and microwave regions.

Acknowledgement

The authors wish to acknowledge Prof. Darko Kajfez from the University of Mississippi for providing valuable guidance.

The HP-BASIC program noted in this article is available from Argus Direct Marketing — see page 88. ***RF***

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About the Authors

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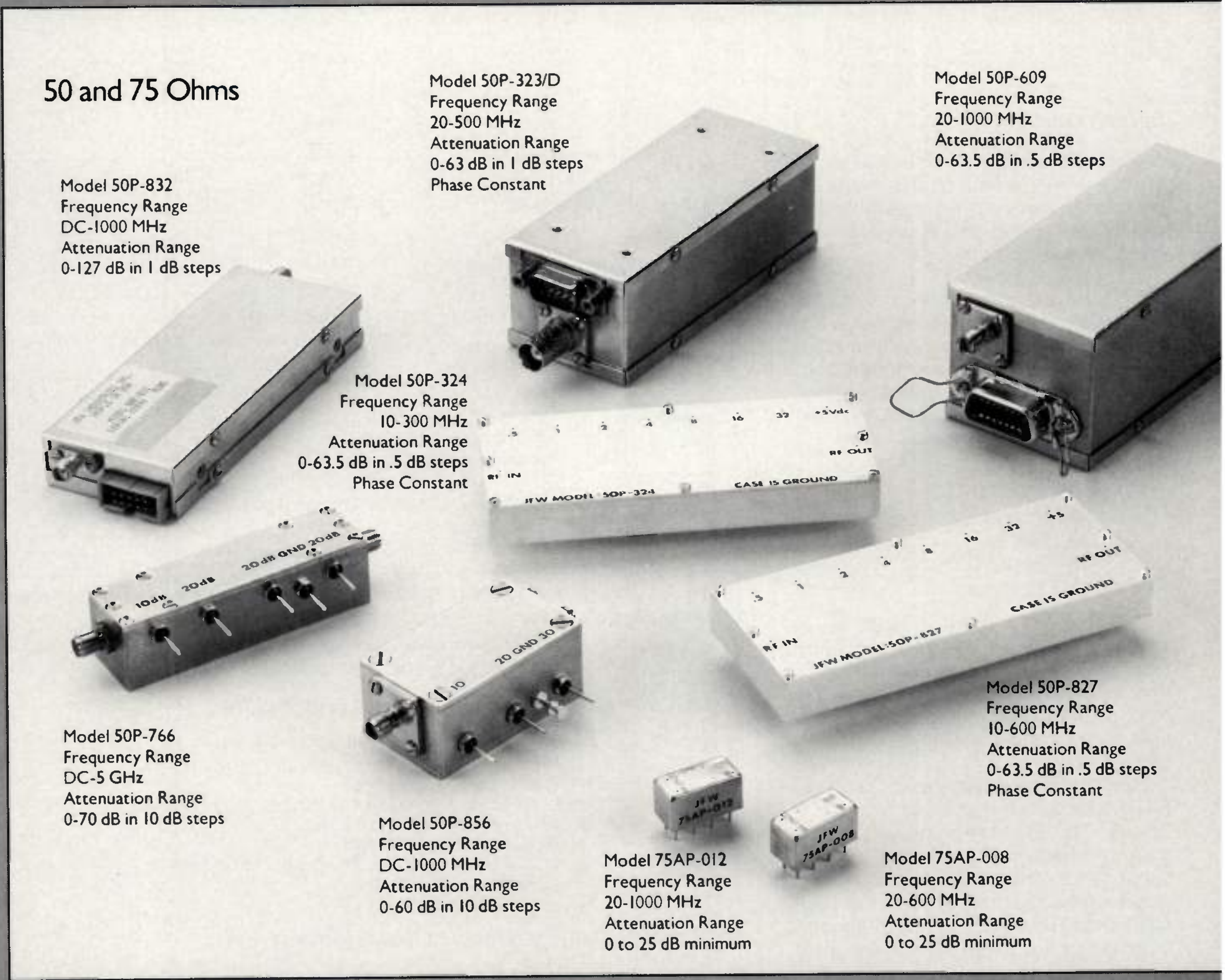

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INFO/CARD 36

Dual Resonance Measurements Evaluate Unknown Coils

By John Dunn

A coil with unknown properties can be inexpensively tested to determine its inductance and equivalent parallel self capacitance using only a dip-oscillator and a frequency counter.

First, the unknown coil is connected in parallel with two different values of known capacitance and the resulting resonant frequencies are measured. The unknown coil's own values of inductance and parallel capacitance are then found using these two equations:

$$L = \frac{F_1^{-2} - F_2^{-2}}{4\pi^2(C1 - C2)} \quad (1)$$

$$C = \frac{F_2^2 \cdot C2 - F_1^2 \cdot C1}{F_1^2 - F_2^2} \quad (2)$$

Note that F_1 is the resonant frequency measured when the unknown coil is in parallel with capacitor C1, and F_2 is the resonant frequency measured when the unknown coil is in parallel with capacitor C2.

Table 1 shows a program in QuickBASIC 4.0 for carrying out these two calculations. The examples shown are the actual inductances and parallel self capacitances obtained for a particular slug tuned coil at its two extreme slug positions. The two resulting resonant frequencies for these values are also shown. *RF*

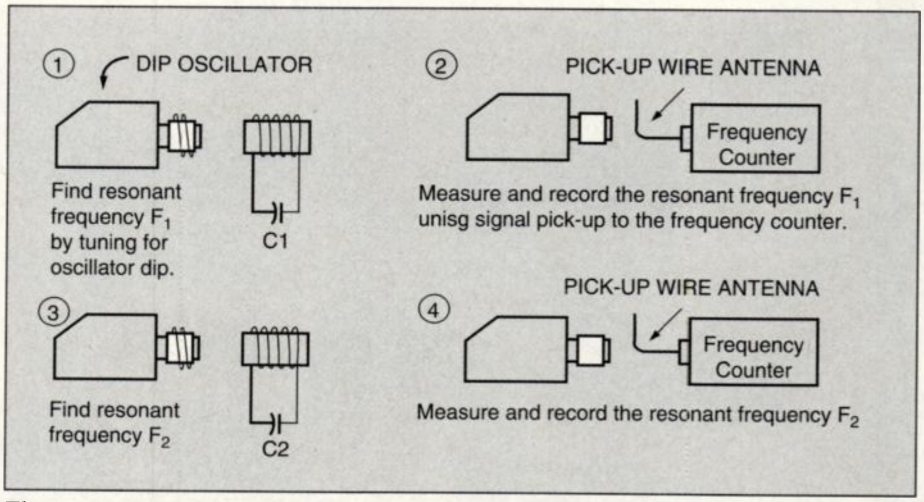

Figure 1. Diagram showing steps for coil inductance and self-capacitance measurements.

```
10 CLS : PRINT "GRID DIP OSCILLATOR DETERMINATION OF UNKNOWN L AND C:"
20 PI = 3.14159265#: PRINT
30 INPUT "WHAT ARE THE TWO FREQUENCIES IN MHz ";FA, FB
40 F1 = FA * 1000000!: F2 = FB * 1000000!
60 INPUT "WHAT ARE THE TWO CAPACITANCES IN pF "; CA, CB
70 C1 = CA * 1E-12: C2 = CB * 1E-12: IF CA < CB THEN C1 = CB * 1E-12
80 IF CA < CB THEN C2 = CA * 1E-12
90 L = 1000000! * (1 / F1 ^ 2 - 1 / F2 ^ 2) / 4 / PI ^ ^ 2 / (C1-C2)
100 C = 1E+12  * (F2 ^ 2 *C2 - F1 ^ 2 * C1) / (F1 ^ 2 - F2 ^ 2)
110 SRF = 1 / 2 / PI / SQR(L * C * 1E-18) / 1000000!
120 PRINT : PRINT "L ="; L; "uHy", "C ="; C; "pF", "F ="; SRF; "MHz": PRINT
130 PRINT "          -------": PRINT : GOTO 20
140 END

GRID DIP OSCILLATOR DETERMINATION OF UNKNOWN L AND C:

WHAT ARE THE TWO FREQUENCIES IN MHz ? 3.404, 4.898
WHAT ARE THE TWO CAPACITANCES IN pF ?  82,   39

L = 26.28382 uHy    C = 1.171141 pF    F = 28.68609 MHz

---------

WHAT ARE THE TWO FREQUENCIES IN MHz ? 7.371, 5.130
WHAT ARE THE TWO CAPACITANCES IN pF ?  82,   39

L = 11.54173 uHy    C = 1.393972 pF    F = 39.67872 MHz

---------
WHAT ARE THE TWO FREQUENCIES IN MHz ?
```

Table 1. Program listing and sample runs.

About the Author

John Dunn received a BSEE from the Polytechnic University in Brooklyn, NY, a MSEE from New York University, and has completed other graduate courses at Northeastern University. He can be reached at 181 Marion Ave., Merrick, NY 11566.

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INFO/CARD 37

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Spread Spectrum Chip Set Targets Cordless Phones

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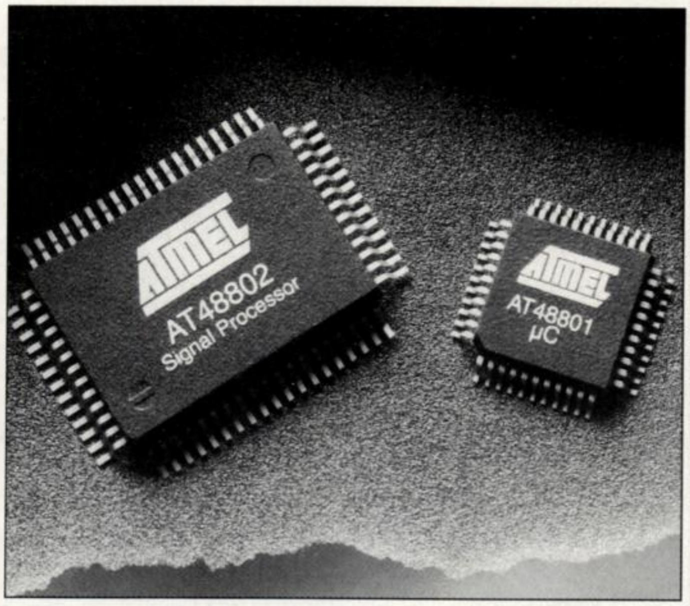
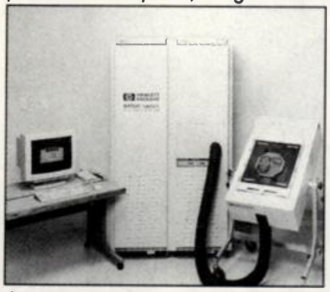


RFIC Test System

The HP 84000 Series RFIC test systems lower manufacturing-test costs by increasing throughput, speeding parts changeover and improving repeatability. The series provides complete, single-insertion 0.5- to 5-second test times for all combinations of common RFIC functions used in wireless communications, including amplifiers, up- and down-converting mixers, modulators, demodulators, switches and VCOs. In addition to measuring RF functions, the systems measure DC parameters and can be configured with digital parametric unit measurement capabilities. Frequency coverage is from 10 to 3000 MHz, extendable to 18 GHz. The HP 84000 Series RFIC measurement offers pre-defined test plans, and test plans can be written in C++. The software runs on an HP 9000 Series 700 workstation. The series uses a state-of-the-art VXI platform. Pricing for the HP 84000 Series RFIC test systems is based on configuration.



Hewlett-Packard Co.
INFO/CARD #220

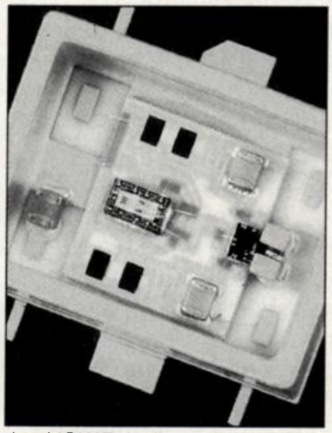
Coaxial In-Line Amplifiers

MITEQ introduces a line of coaxial in-line amplifiers available in either the entire 0.1 to 20 GHz range, or optimized in octave and multioctave bands. Designated the AFSX Series, these amplifiers readily fit into coaxial cable assemblies, receiving antenna systems, and any test and measurement system without the usual mounting problems. These hermetically sealed and weatherproofed units can be biased through the output, thereby eliminating cumbersome wiring problems. These amplifiers can be used as drivers or gain blocks in test instrumentation, mounted directly behind the antenna in satellite and radar systems, or can be used a slow-noise gain equalizers in receiving cables to receiver front ends, effectively providing a zero-loss cable.

MITEQ
INFO/CARD #221

Pulse Modulator/Switch

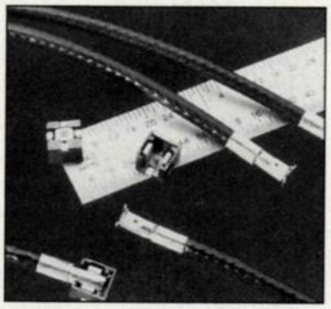
Hybrid-Tek is pleased to announce the addition of HTI P/N HTGS104, a surface mount SPST absorptive GaAs switch, to their RF control components product line. The device operates over a frequency range of 10 to 2000 MHz. This part features fast switching speed of 10 nsec and low power consumption of less than 1 mA at +5 V. At 1000 MHz, the VSWR is less than 1.4:1, insertion loss is less than 1.3 dB, and isolation is greater than 40 dB. At 2000 MHz, the VSWR is less than 1.8:1, insertion loss is less than 1.4 dB, and isolation is greater than 25 dB. The HTGS104 is available in a hermetic surface mount package or a low cost PC mount package.



Hybrid-Tek, Inc.
INFO/CARD #222

Microminiature Coax Connectors

High-density, high-performance microminiature coax connectors from AMP are well-suited for cellular telephone, base station, security system, test, telecommunications and telephone switching, and medical equipment. The plug and receptacle offer a low-profile of 0.145-inches (3.7 mm) when terminated to standard RG178, RG188, RG196 and RG316 cable. The receptacle, a surface-mount version for printed circuit board applications, is tape and reel packaged for automated pick-and-place equipment. The connectors offer a VSWR of 1.2 at 2 GHz, with a 100-cycle durability rating. Complementary application tooling is available from AMP, ranging from pneumatic tocling for volume applications, to hand tooling for limited volume and prototype applications. Pricing is $1.20 per line in quantities of 50,000.



AMP Incorporated
INFO/CARD #223

AMPLIFIERS

Digital Cellular Base Station Receive Amplifier

Celeritek has announced a solid state amplifier designed for digital cellular base station receiver applications operating in the 824 to 849 MHz frequency range. The high dynamic range receiver amplifier provides a very low-noise input of 1.5 dB, while maintaining a high intercept point of +49 dBm. The amplifier consumes 2.0 A at 24 VDC and measures less than 8.25 x 5 x 1 inches.

Celeritek, Inc.
INFO/CARD #227

Ultra-Low Noise

Model VMA 1722C-235 offers a 0.7 dB noise figure across 1.7 to 2.2 GHz and has 32 dB gain, ripple of ±0.7 dB and a +23 dBm third order intercept point. It measures 1 × 1 × 0.22 inches. It operates from +15 V, draws 130 mA and comes with SMA-F connectors.
Veritech Microwave, Inc.
INFO/CARD #228

4W MMIC Amplifier

Stanford Microdevices has introduced a family of GaAs MMIC amplifiers covering 1500 to 2500 MHz. At supply voltage of 9 V, model SMM-280-2 has 2.5 dB of gain and 33 dBm of output power from 1.7 to 2.3 GHz. Model SMM-280-4 also has 25 dB gain with 36 dBm output power from 1.7 to 2.3 GHz. Output third order intercept point is +42 dBm for the "-2" and +45 dBm for the "-4". Pricing for model SMM-280-2 is $195 in 1000 piece quantities.
Stanford Microdevices Inc.
INFO/CARD #229

200 W, S-Band Amp.

Power Systems Technology announces the availability of an S-band, 200 W, solid-state power amplifier for ground-based satellite telemetry. The amplifier operates class C and delivers a full 200 W over the 2025 to 2120 MHz frequency range. This amplifier, model CHCD29218-200/2956B can be controlled and monitored remotely via an integral IEEE-488 interface bus.
Power Systems Technology, Inc.
INFO/CARD #230

Blanking 120 W UHF Amp.

An amplifier from LCF Enterprises has an output power of 120 W CW and operates from 290 to 320 MHz. The amplifier has 15 μs typical bias enable and disable time. The unit delivers a minimum of 35 dB gain and operates from a 24 or 28 VDC supply with ultra-high efficiency, and measures 4.84 x 2.0 x 1.0 inches, excluding feet and connectors.
LCF Enterprises
INFO/CARD #231

Single-Channel Amplifier

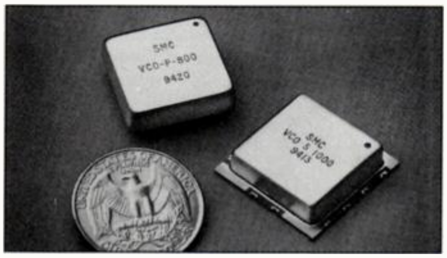
A 50 watt single channel amplifier for the 869-894 MHz band is announced by Microwave Power Devices. Applications include AMPS cellular base stations and cellular digital packet data (CDPD). P_{in} is 0 dBm, efficiency is greater than 35%, and power level can be controlled over 28 dB in 4 dB steps with TTL control logic.
Microwave Power Devices, Inc.
Info/Card #240

INFO/CARD 41

SIGNAL SOURCES

Octave BW VCOs

Synergy Microwave has introduced a line of voltage controlled oscillators covering 200 to 2000 MHz in nine different octave bandwidth models. Available in surface mount or



plug-in packages, these VCOs exhibit excellent phase noise characteristics. At 10 kHz offset from the carrier, phase noise is better than –90 dBc/Hz for a 500 MHz carrier, and –100 dBc/Hz for a 1200 MHz carrier. Output signal level is typically +13 dBm with a supply bias voltage of +12 VDC, consuming less than half a watt of power.
Synergy Microwave Corp.
INFO/CARD #232

SAW Oscillators

The CMS1000 series of SAW VCOs from C-MAC Quartz Crystals provides a standard product solution for use in high bit rate telecommunications applications including SDH/SONET and ATM. The series is available in a range of standard frequencies covering 155.52 to 2488.32 MHz. The C-MAC oscillators may be specified to operate from –5.2 to +12 V supplies, and are housed in hermetically sealed metal cases.
C-MAC Quartz Crystals Ltd.
INFO/CARD #233

Digitally Compensated Oscillators

Conner-Winfield announces a family of digitally compensated crystal filters. This family covers a frequency range of 100 kHz through 50 MHz. Each unit operates from a +5 VDC supply and typically draws 40 mA. The output is HCMOS compatible, maximum rise and fall times are 6 ns, and typically symmetry is 50/50 ±2%. Stability is ±2 parts in 10^{-7} five seconds after power on, and ±2 x 10^{-7} over 0 to +70 °C. Units are housed in a 24-pin, hermetically sealed package. Initial aging rate is 1ppm per year maximum.
Connor-Winfield
INFO/CARD #234

Octave Plus Tuned VCO

ESC 401-70 is a miniature voltage controlled oscillator (0.8 inches square) that covers 75 to 200 MHz with a tuning voltage of 0.2 to 20 VDC. This frequency range is accomplished in one continuous sweep, without frequency interruptions, spurs, subharmonic, or mixing products. Typical phase noise is –104 dB/Hz at 10 kHz offset, and –110 dB/Hz at 25 kHz offset. Standard power supply requirements are 45 mA at +12 VDC.
Electronics Surveillance Components, Inc.
INFO/CARD #235

SIGNAL PROCESSING COMPONENTS

Power Dividers/Combiners

Micro Mart introduces a new line of power dividers/combiners directed toward the standard telecommunication bands. Typical specs for model P405 (4-way) covering 3.6 to 4.25 GHz with type N connectors, include 20 dB return loss and isolation, 0.6 dB insertion loss and amplitude balance of ±0.2 dB.
Micro Mart, Inc.
INFO/CARD #236

Product Spotlight: Resistors and Capacitors

GKG Series Capacitors

Sprague-Goodman Electronics, Inc. offers a taped, radial leaded version of the GKG series 4×4.5 mm miniature ceramic trimmer capacitors. The new series is designed for automatic insertion in high volume lead-through-hole assemblies, and is ideal for consumer and industrial applications requiring a rugged trimmer capacitor at an economical price. Seven models are available in capacitance ranges including 1.4-3.0 pF, 2.0-6.0 pF, 3.0-10.0 pF, 4.5-20.0 pF, 6.5-30.0 pF, 8.5-40.0 pF and 8.5-50.0 pF.
Sprague-Goodman
INFO/CARD #224

WAMT Microwave Termination Chips

Mini-Systems, Inc. introduces the WAMT series microwave termination chips, specifically designed to enhance RF performance and to offer maximum flexibility in microwave applications through half-wrap terminations. Sizes range from 0.040 × 0.020 to 0.100 × 0.050 in., with values from 2 Ω to 1 kΩ. They can be assembled into strip line applications using wire bonding, ribbon bonding, or soldered flip chip methods.
Mini-Systems
INFO/CARD #225

Chip Attenuator

The 4100 series of chip attenuators offers RF designers high performance at low cost. Frequency range is DC to 3 GHz, with VSWR of 1.25:1. They are available in standard attenuation values of 3, 6, 10, and 20 dB. Chip dimensions are 0.126 × 0.063 × 0.024 inches. Price is $0.99 each.
ST Olektron Corp.
INFO/CARD #226

Surface Mount Coupler

Anaren Microwave has developed surface mount hybrid couplers selling for $2 each in large quantities. Model 1D1304-3 is a

stripline 90° hybrid coupler operating at 830 to 960 MHz (with other frequency bands available). The unit has maximum insertion loss of 0.4 dB, minimum isolation of 20 dB, maximum VSWR of 1.2:1, and maximum amplitude and phase imbalances of ±0.3 dB and 3°, respectively. Power handling is 100 W average/CW. The coupler measures 0.56 x 0.35 inches.
Anaren Microwave, Inc.
INFO/CARD #239

I&Q Demodulator

Mini-Circuits' MIQA-70D I&Q demodulator offers excellent amplitude and phase unbalance figures (0.15 dB typ. and 0.7 dB typ., respectively) making it ideal for communications and radar applications. Frequency range is from 66 to 73 MHz (RF & LO), with I&Q frequency range from DC to 5 MHz. Impedance is 50 Ω on all ports, with typical 1 dB compression point at the RF input of 4 dBm.
Mini-Circuits
INFO/CARD #238

UHF Bandreject Filter

4DN380-244/262 is K&L's latest version of the UHF range dielectric resonator bandrejects. This module, located immediately following the transmitter, eliminates two bands centered at 244 and 262 MHz by -45 dBc. Using dielectric resonators, the unit offers maximum insertion loss of 1.75 dB, sharp filter skirts and relatively small size. The unit can sustain 25 W CW and measures 5.75 x 3.25 x 1.570 inches.
K&L Microwave, Inc.
INFO/CARD #237

Threshold Detectors

A family of threshold detectors from Daico Industries provide precision power level detection and output throughout the frequency range of 10 to 4000 MHz. The tiny, thin-film detectors feature a threshold dynamic range of -30 to -10 dBm with adjustable threshold levels. The minimum input flatness is ±1.0 dB, minimum temperature stability is ±1.5 dB, and maximum hysteresis is 1.2 dB. The device has TTL-compatible output and operates from +5 VDC, drawing only 10 mA.
Daico Industries, Inc.
INFO/CARD #241

TEST EQUIPMENT

Waveform Digitizer

The DA60 waveform digitizer board from Signatec has 12-bit resolution and captures 60 million samples per second on a single channel, or 30 million samples per second on two simultaneous channels. The seven-inch-

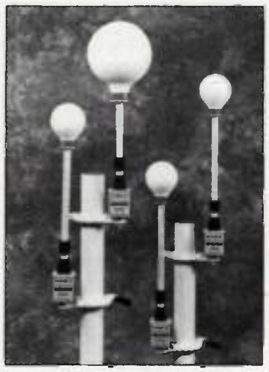
long, ISA bus compatible card can store 512k samples in on-board memory. The DA60 is priced at $4900 each with quantity discounts and OEM pricing available.
Signatec, Inc.
INFO/CARD #242

Programmable Filter

Synetcom Digital announces the SD2000A, a two-channel programmable filter using digital signal processing to design and implement brick-wall, linear phase digital filters. Bandwidth is DC to 100 kHz. Lowpass, bandpass, highpass, bandstop and special purpose filter types are all supported. Digital filters with up to 255 taps per channel can be implemented, and channels can be cascaded. SD2000A sells for $4995, which includes free firmware upgrades for one year.
Synetcom Digital Inc.
INFO/CARD #243

E- and H-Field Probes

Four new isotropic field probes add low- and high-intensity electric and magnetic field measurements to Amplifier Research's ultra-broadband field monitor systems. Model FP2103 senses as low as 15.0 mA/m and up to 3 A/m over 5 to 300 MHz; model FP2130 senses high intensity H-fields from 0.15 to 30 A/m over 0.3 to 30 MHz. Model FP2031 senses very low intensity E-fields (0.15 to 30 V/m) over 0.5 to 1500 MHz; model FP2033 senses high-intensity E-fields (15.0 to 3000 V/m) over 0.5 to 5000 MHz.



Amplifier Research
INFO/CARD #244

Arbitrary Waveform Generator

The PCI-311 and PCI-312 arbitrary waveform generators occupy one expansion slot in a PC and offer 12-bit output DACs with update rates to 50 Msps, 32 kilo-sample memory on each channel, memory segmentation with looping and linking, and 12 V_{pp} output into 50 Ω. The PCI-311 is a single channel generator, and the PCI-312 is a dual channel generator. The PCI-311 sells for $1495 and the PCI-312 sells for $1995.
PC Instruments Inc.
INFO/CARD #245

MMIC Test Probes

The ACP40 series probes from Cascade Microtech are high-performance, on-wafer probing tools for the demanding MMIC test environment. These new probes utilize the unique AirCoplanar™ tip design to achieve excellent electrical and mechanical characteristics up to 50 GHz in coax. The standard coaxial interface to the ACP40 is through a 2.92 mm connector for operation to 40 GHz. Worst case insertion loss is less than 1 dB to 10 GHz for all pitches.
Cascade Microtech, Inc.
INFO/CARD #246

SEMICONDUCTORS

3V MMIC Amp

The NEC UPC2749T silicon MMIC amplifier from California Eastern Labs delivers 16 dB gain (typical) and 4 dB noise at 1900 MHz while drawing only 6 mA, typical. The UPC2749T operates at 3 V, so it's ideal for battery powered products, and the miniature 6-pin TO6 package will help reduce any

design's size and weight. The amplifier is available packaged in bulk or on tape and reel.
California Eastern Laboratories, Inc.
INFO/CARD #247

Zero-Bias Schottky Diodes

Hewlett-Packard has introduced a series of low-cost, surface-mount, zero-bias Schottky-barrier diodes. These devices are designed to meet the requirements of RF identification and RF tagging systems operating in the de-facto-standard 915, 2450, and 5800 MHz bands. Basic performance of these P-type diodes include 0.3 pF maximum capacitance at 1.0 GHz, tangential sensitivity of -57 dBm at 2.45 GHz, and voltage sensitivity of 30 mV/W at 2.45 GHz. The diodes are available singly and in pairs. A single diode in an SOT-23 package is priced at $0.80 each in 10k to 25k quantities.
Hewlett-Packard Co.
INFO/CARD #248

Noise Diodes

Noise Com has introduced the model NC302LBL noise diode for wireless applications such as built-in calibration references in signal strength meters. The device has a 30 to 35 dB excess noise ratio, and covers the 10 Hz to 3 GHz with white Gaussian noise when biased at 8 mA from a supply voltage larger than 12 VDC. The NC302LBL is available in a surface mount, hermetically sealed ceramic package. Price is $5.95 in 10,000 piece quantities.
Noise Com, Inc.
INFO/CARD #249

Transceiver Chip Set

TriQuint Semiconductor has announced the availability of its RFIC, two-chip transceiver solution to cost-sensitive, high-performance 2.4 GHz wireless applications. The tranceiver chip set is ideally suited for space-limited, quick time-to-market applications in the 2.400-2.483 GHz ISM frequency band. The TQ9205 amplifier/switch front-end has a LNA receive amplifier with 3.5 dBm noise figure, and a 100 mW output power amplifier. The TQ9206 RF up/down converter, has an on-chip VCO, +14 dBm third order intercept point for receive, and +12 dBm 1 dB compression point for transmit. Unit price for the TQ9205 in 10,000-piece quantities is $9.77. Unit price for the TQ9206 in 10,000-piece quantities is $10.42. Production quantities for the TQ9205 and samples of the TQ9206 are available now.
TriQuint Semiconductor
INFO/CARD #250

Improve Measurement Accuracy With Bandwidth Related Factors In Spectrum Analysis

By Morris Engelson
Tektronix

This article explains how to avoid the errors in spectrum analyzer measurements that arise when incorrect assumptions are made regarding filter passband shape. While such errors are often small, they can be significant when maximum accuracy is necessary.

Spectrum analyzer measurement accuracy is significantly affected by the characteristics of its resolution bandwidth filter. The ability to separate (resolve) individual sinewave components, instrument random noise bandwidth, and the impulse bandwidth are all determined by the resolution filter. Frequently the filter shape is approximated by a Gaussian response for ease of computation. This is acceptable for many applications. But spectrum analyzer resolution filters are in fact not Gaussian, and the assumption introduces unacceptable errors where higher measurement accuracy is needed.

Most spectrum analyzers use four section, synchronously-tuned, single-resonator filters for the resolution circuit. The relationships for such filters, while different than those for Gaussian-shaped filters, are well known. Therefore, it is possible to compare results, and provide correction factors between actual filters and a Gaussian shape approximation.

The Gaussian Filter

The *IEEE Standard Dictionary of Electrical and Electronic Terms* states that a Gaussian filter is, "a polynomial filter whose magnitude-frequency response approximates the ideal Gaussian response... The ideal Gaussian response is given by: $|H(j\omega)| = \exp[-0.3466\,(\omega/\omega_c)^2)$, where ω_c = 3 dB frequency." In other words, the Gaussian filter has a e^{-x^2} shape, where x is fractional frequency shift. Thus, for an amplitude difference of 3 dB, where voltage is down to 0.707, x^2 is 0.3466 and x = 0.5887.

We can compute the three primary resolution filter based measurement factors from the Gaussian shape equation.

Resolution bandwidth is a measure of how close two equal amplitude signals can be in frequency and still be recognized as two separate signals. There are two conventions for defining the resolution bandwidth: the 3 dB and the 6 dB bandwidths. For the Gaussian shape, the ratio between the two definitions is $\sqrt{2} = 1.414$.

Resolution shape factor is the ratio of 60 dB down bandwidth to the resolution bandwidth. The shape factor determines how well a small signal will be resolved and recognized next to a large signal. At 60 dB the voltage amplitude is reduced by a factor of 1000 and x = 2.63. The bandwidth ratio $B_{60}/B_3 = 2.63/0.589 = 4.46$, and the shape factor using a 6 dB resolution bandwidth is 3.15.

The *effective random noise bandwidth* is the average frequency width of the power, or voltage squared area under the filter. For the Gaussian filter we get a normalized bandwidth of:

$$x = \int_0^\infty e^{-2x^2}\,dx = 0.627$$

The correction factor to the 3 dB resolution bandwidth is 0.627/0.589 = 1.065.

Accurate pulsed signal measurements

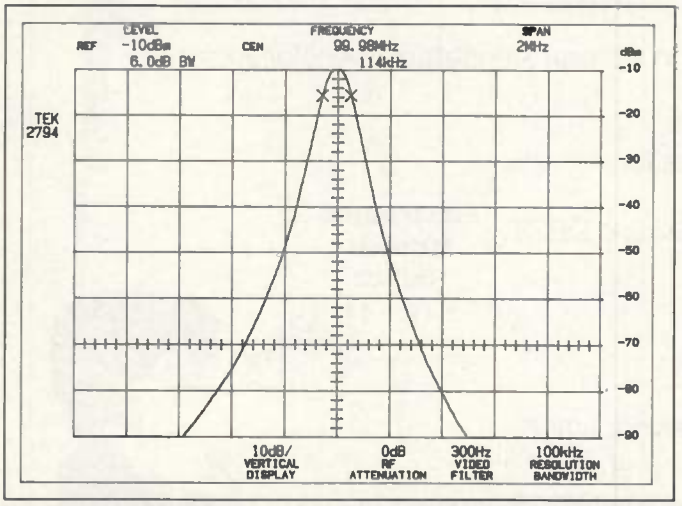


Figure 1. 100 kHz specified resolution bandwidth filter measures 114 kHz at 6 dB.

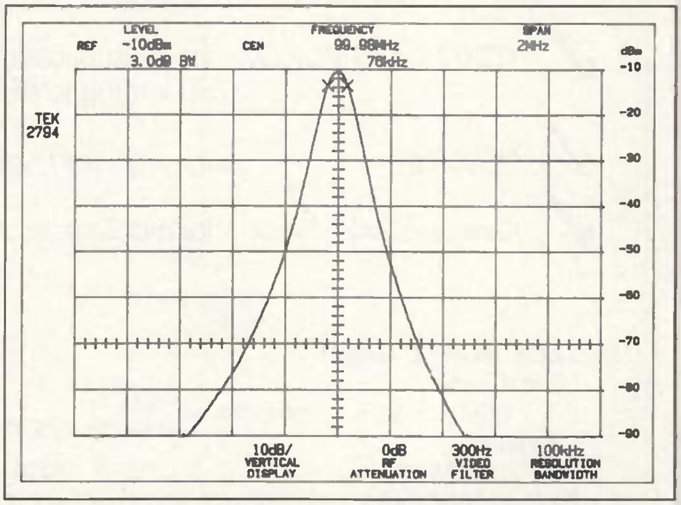
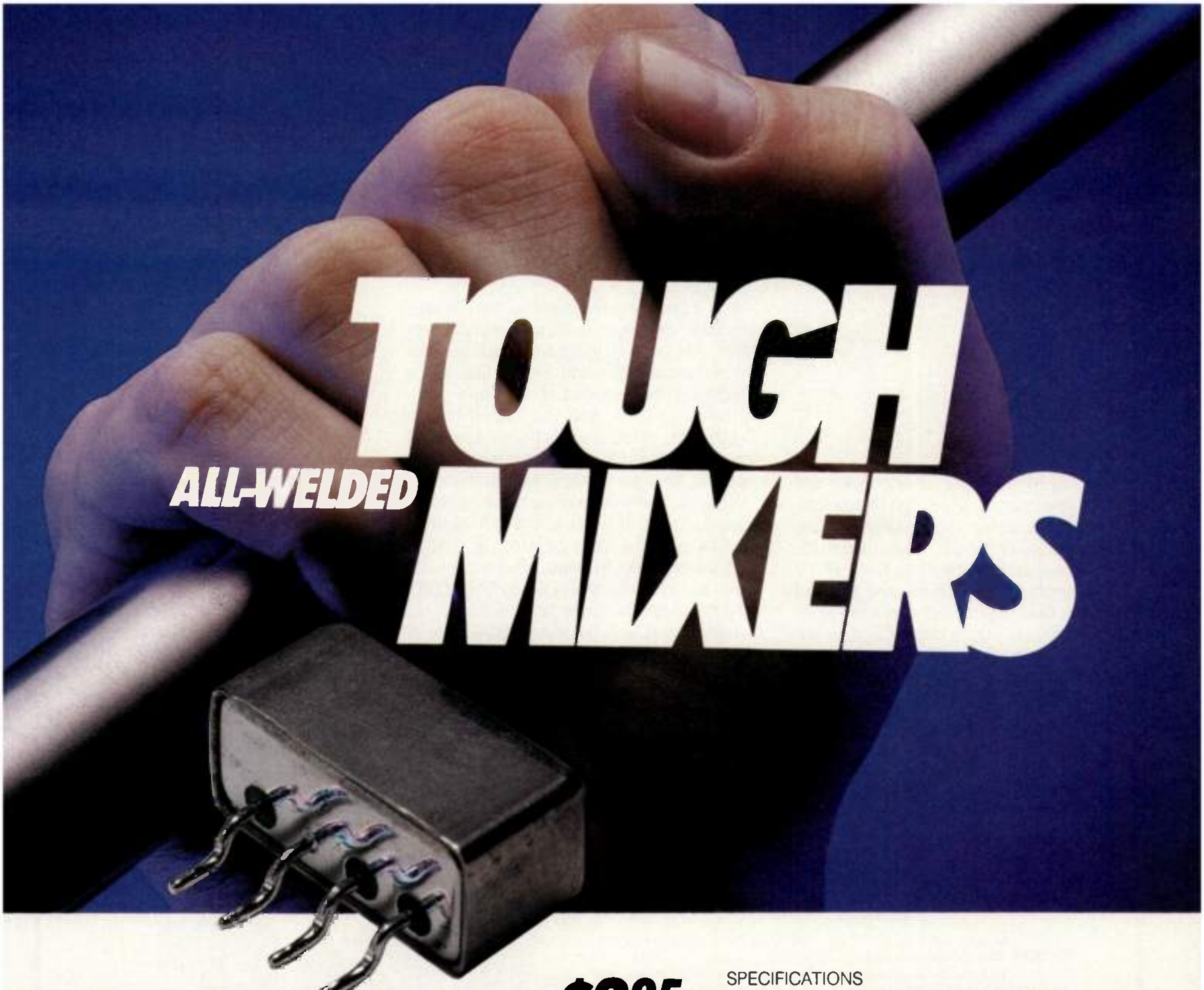


Figure 2. Same as figure 1. The 3 dB bandwidth is measured at 76 kHz.



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Available with LO drive levels from +7 to +17dBm, performance features include very low conversion loss flat over the entire band, high isolation (L-R, L-I), and well-matched VSWR at all ports.

All-welded internal and external construction is used to assemble and package the TUF-unit in its tiny 0.5 by 0.2 by 0.25 in. metal case, for plug-in or surface-mount* assembly.

TUF-Ultra-Rel™ mixers are guaranteed for five years and boast unprecedented "skinny" sigma (δ) unit-to-unit repeatability as shown in the Table.

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with extra long life due to unique HP monolithic diode construction, 300°C high temp. storage, 1000 cycles thermal shock, vibration, acceleration, and mechanical shock exceeding MIL requirements.

SPECIFICATIONS

Model	LO Power (dBm)	Freq. LO/RF (MHz)	■ Conv. Loss (dB) $\bar{X}$	Conv. Loss (dB) δ	Isol. L-R (dB)	Price,$ Ea. 10 qty
TUF-3	7	0.15-400	4.98	0.34	46	5.95
TUF-3LH	10		4.8	0.37	51	7.95
TUF-3MH	13		5.0	0.33	46	8.95
TUF-3H	17		5.0	0.33	50	10.95
TUF-1	7	2-600	5.82	0.19	42	3.95
TUF-1LH	10		6.0	0.17	50	5.95
TUF-1MH	13		6.3	0.12	50	6.95
TUF-1H	17		5.9	0.18	50	8.95
TUF-2	7	50-1000	5.73	0.30	47	4.95
TUF-2LH	10		5.2	0.3	44	6.95
TUF-2MH	13		6.0	0.25	47	7.95
TUF-2H	17		6.2	0.22	47	9.95
TUF-5	7	20-1500	6.58	0.40	42	8.95
TUF-5LH	10		6.9	0.27	42	10.95
TUF-5MH	13		7.0	0.25	41	11.95
TUF-5H	17		7.5	0.17	50	13.95
TUF-860	7	860-1050	6.2	0.37	35	8.95
TUF-860LH	10		6.3	0.27	35	10.95
TUF-860MH	13		6.8	0.32	35	11.95
TUF-860H	17		6.8	0.31	38	13.95
TUF-11A	7	1400-1900	6.83	0.30	33	14.95
TUF-11ALH	10		7.0	0.20	36	16.95
TUF-11AMH	13		7.4	0.20	33	17.95
TUF-11AH	17		7.3	0.28	35	19.95

*To specify surface-mount models, add SM after P/N shown.
■ $\bar{X}$ = Average conversion loss at upper end of midband ($f_u/2$)
δ = Sigma or standard deviation

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require a knowledge of the *impulse bandwidth*. It has been found [2] that for a Gaussian filter the impulse to 3 dB bandwidth ratio is:

$$\frac{1}{\sqrt{2}}\sqrt{\frac{\pi}{\mathrm{Log}_e 2}} = 1.505$$

This is usually given as 1.5 or 3/2 in the literature.

Real Filters

A variety of resolution filter shapes are used in spectrum analyzers. Different filters are sometimes used depending on the application. Thus, EMI measurements in accordance with CISPR 16 requirements will use a square shaped filter. The vast majority of spectrum analyzers, however, use a cascade of single resonator filters synchronously tuned to the same frequency. The filter voltage transfer function shape is given by:

$$\left(\sqrt{1+x^2}\right)^n$$

where x is the fractional frequency offset and n is the number of sections in the synchronous cascade. Usually n = 4, and that number that will be used in this discussion.

It is interesting to note that the Gaussian filter and four-section synchronous filter are part of the same family. The synchronous filter acquires a Gaussian shape as the number of sections goes to infinity. This, and the fact that the Gaussian shape equations are well known, are major reasons why some use the Gaussian shape approximation.

The fractional frequency offset, x, for a four-section filter at the 3 dB points, (1.414 voltage ratio points), is 0.435. The 60 dB down x-value, where the voltage ratio is 1000, is x = 5.53. The 60 dB to 3 dB shape factor is 12.7. 3

Letting the voltage ratio equal 2 for 6 dB and 1.414 at 3 dB, the bandwidth ratio comes to B_6/B_3 = 0.644/0.435 = 1.48.

The normalized fractional bandwidth under the power response is x = 0.49087. The 3 dB normalized fractional bandwidth is x = 0.43498. This makes the ratio of the random noise bandwidth correction factor to the 3 dB bandwidth B_n/B_3 = 0.49087/0.43498 = 1.1285, usually approximated as 1.13.

Finally, impulse bandwidth calculations for a four-section synchronous filter [2] show a ratio of 1.094 versus the 6 dB bandwidth, and (1.094)(1.48) = 1.62 for the 3 dB bandwidth.

The transfer function shape of actual filters is usually sufficiently close to theoretical that measurements should not be necessary, though a measurement will improve accuracy somewhat. The big problem is in using the specified bandwidth as if it were the actual bandwidth. Figure 1 shows the shape of a filter specified to be 100 kHz at the 6 dB points. The actual 6 dB bandwidth is 114 kHz, and the 3 dB bandwidth is 76 kHz as shown in figure 2. The 6 vs 3 dB bandwidth ratio is 114/76 = 1.5, which is very close to the expected value of 1.48. But the bandwidth value is off by 14%, because the bandwidth is specified to an accuracy of only 20%. Hence, for

INFO/CARD 40

good measurement accuracy, it is useful to measure the actual bandwidth rather than relying on the specified value.

Measurement Error Correction

The following steps will reduce measurement errors:

1) Determine the actual 3 dB or 6 dB bandwidth rather than using the value specified. This will remove 20% of measurement uncertainty. For random signals this represents a difference of 10Log(1.2) = 0.8 dB, and for pulsed signals the accuracy will improve by 20Log(1.2) = 1.6 dB.

2) Use the actual random noise to resolution bandwidth ratio rather than the Gaussian filter approximation. For the usual four-section synchronous filter the multiplier to the 3 dB bandwidth is 1.13 rather than 1.06 for the Gaussian filter. This will improve measurement accuracy by 10Log(1.13/1.06) = 0.3 dB.

3) Use the actual impulse bandwidth, which is 1.6 times the 3 dB bandwidth for four-section synchronous filters, rather than the usual Gaussian approximation of 1.5. Accuracy will improve by 20Log(1.6/1.5) = 0.6 dB. *RF*

References

1. *IEEE Standard Dictionary of Electrical and Electronics Terms.*
2. ANSI/IEEE Std. 100-1977, pg 283.
3. Engelson, *Modern Spectrum Analyzer Measurements*, JMS, 1991, chapter 7.

About the Author

Morris Engelson is the former chief engineer at Tektronix and is currently associated with Tektronix on a consulting basis. He is a Fellow of the IEEE for contributions to spectrum analysis and is the author of several books on this topic. He is a NARTE certified EMC engineer. He is currently director at the Portland, Oregon-based consulting firm of JMS. He can be reached at Tektronix at (503) 627-4823, and at JMS at (503) 292-7035.

RF FET Amplifier Modules Exhibit High IP3 Without Feedforward

By A. I. Cogan, K. Socknanan, MicroWave Technology, Inc.
and L. B. Max, Independent Consultant

The limited frequency spectrum available for voice and data communications has rapidly become overcrowded. System conversion to digital or multicarrier modulation and new power applications compound the problem. As a result, linear RF applications in the power amplification area have seen a significant increase in performance requirements, and equipment manufacturers have had to reduce signal distortion and spurious frequency generation to the lowest practical levels.

The best linear amplifying devices available to fabricate the "best linear amplifier" must be used. Then, if the resulting performance levels are not adequate, an appropriate signal processing, feedforward or feedback technique must be used to enhance the active device's intrinsic performance. The "more linear" the active device, the simpler the required linearization efforts, [1].

Solid State Triodes™, or SSTs™ are power FETs which were recently shown to extend the bounds of solid state linear power amplification [2, 3, 4] and represent a viable alternative to BJTs and MOSFETs in linear RF applications.

Design simplicity has become extremely attractive to the RF designer and this has resulted in an increased availability of easier to use components such as pre-matched RF gain blocks [4].

SSTs are used to fabricate pre-matched class A linear gain blocks, called SST Linear Amplifier Modules (SLAMs). Examples of SLAM power amplifiers and low-noise, high-intercept SLAM amplifiers are presented in this paper.

SLAM RF Power Amplifiers.

SST biasing requirements are similar to those of GaAs FETs and are well suited for incorporation in SLAM gain modules, whose basic building block is shown in Figure 1a. The FET is self-biased and uses a 50 Ω resistor for the gate DC return. The I-V characteristic is shown in Figure 1b.

The drain current voltage drop across the source resistor sets the FET class A operating point. The source resistor also provides negative feedback, which improves the gain block linearity and temperature stability.

Figure 2 underscores the SLAM circuit simplicity: only two DC-blocking capacitors and an RF choke are needed. Added benefits of this pre-matched single stage amplifier include single power supply operation and intrinsic temperature compensation. The gain/thermal-derating factor is under 0.01 dB/°C.

Both the SST chip and the biasing resistors are mounted inside a conventional RF power transistor package, providing the user with an easy to use, self-contained RF gain block. The values of the SLAM's internal components are selected to minimize or even eliminate the need for impedance matching.

By terminating the SLAM input and output with 50 Ω loads, class A linear power amplifiers, covering the frequency range from DC through 100 MHz can easily be fabricated, with power outputs ranging from 5 W through 50 W or more.

The frequency response of a 10 W single-ended SLAM amplifier is shown in Figure 3, with the IMD3 data shown in Figure 4. The calculated IP3 is 53 dBm, which is 13 dB above the P_{1dB} level of 40 dBm, illustrating the SLAM's superior linear performance. RF SLAM amplifiers with IP3 to P_{1dB} differences as high as 15 dB were fabricated. The self-biased SLAM reduced sensitivity to power sup-

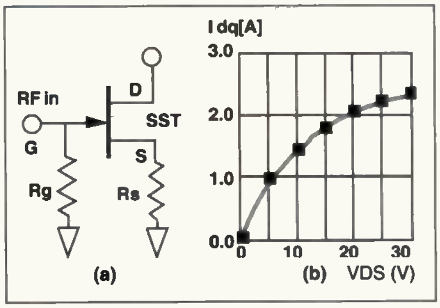

Figure 1. Self-biased SLAM: a) circuit, b) I-V characteristics.

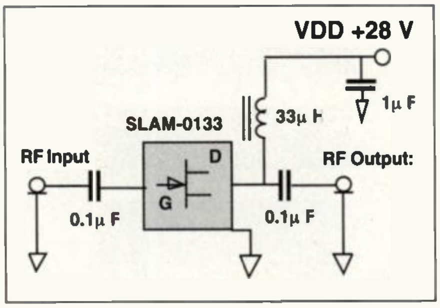

Figure 2. HF/VHF SLAM amplifier circuit diagram.

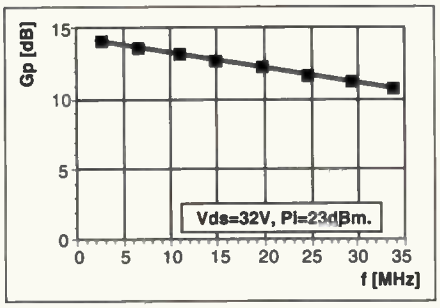

Figure 3. Typical G_p vs. frequency.

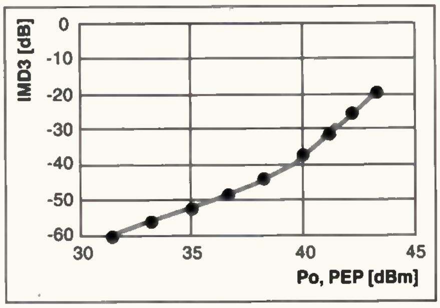

Figure 4. Typical IMD3 vs. P_{out}.

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- **QuERC,** a bias analysis electrical rules checker.
- **QuicKic,** a fast, error-free netlist-driven layout editor that checks process design rules, connectivity,and interconnect parasitics as the layout is being accomplished.

All processes are available for full custom work. C-Pi/SHPi and GST-1 have QuickChip arrays in various configurations to meet your requirements.

NAME	NPN BV_{CEO} (V)	NPN f_T (GHz)	PNP BV_{CEO} (V)	PNP f_T (GHz)	JFET	DIGITAL DENSITY (GATES)	ISOLATION	METAL LAYERS	THIN FILM RESISTORS	SCHOTTKY DIODE
SHPi	8	9	9	0.1	YES	3K	OXIDE	2	YES	YES
C-Pi	9.5	9	10.5	5.5	YES	3K	OXIDE	2	YES	YES
GST-1	5.5	13	—	0.1	NO	20K	TRENCH	3	YES	YES
GST-2	4.5	27	—	0.1	NO	60K	TRENCH	3	YES	YES

- **C-Pi** is a recessed-oxide-isolated high-speed complementary bipolar process optimized for analog signal acquisition, amplification, and sourcing. Without the vertical PNP option, C-Pi is designated as **SHPi**.
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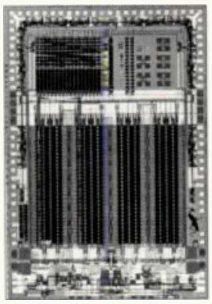

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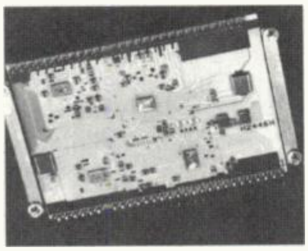

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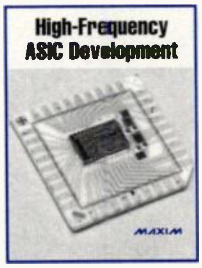

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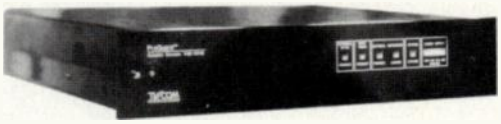

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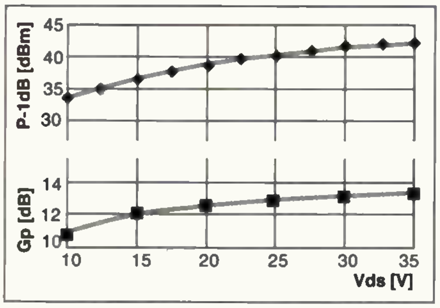

Figure 5. G_p and P_{1dB} vs. V_{ds} for the 10 W SLAM.

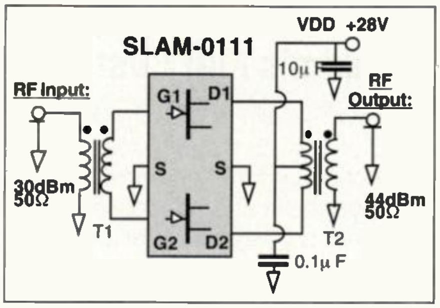

Figure 6. SLAM-0111 2 MHz to 32 MHz amplifier circuit.

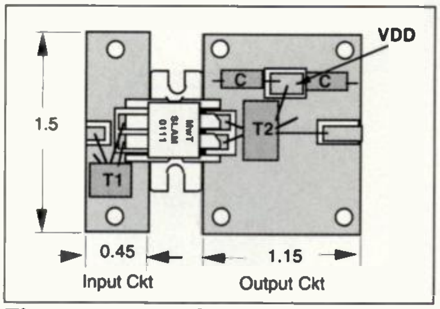

Figure 7. 25 W SLAM amplifier circuit layout.

ply variations for both power gain and P_{1dB} are illustrated in Figure 5.

SLAMs can also be used in a push-pull configuration. This type of SLAM has the added advantage of improved IP2 performance. Figure 6 shows a 25 W, 2 to 32 MHz push-pull SLAM circuit. Only two simple balun transformers and two DC blocking capacitors are required. The printed circuit layout and component placement are shown in Figure 7. The SLAM linear performance is maintained over a broad frequency range. Figure 8 shows the IMD3 figures from 4 MHz through 100 MHz for the 25 W SLAM.

The circuit examples shown rely on the internal matching elements, while externally terminating the circuit into 50 ohms. The operating frequency can be expanded by adding external input and output matching elements. Figure 9 shows the S21 and the Maximum Stable Power Gain (MSG) for the 25 W push-pull SLAM. S21 is the amplifier power gain when terminated into 50 Ω, without external matching. As shown, much higher power gains can be approached by using external matching elements.

One simple matched circuit is illustrated in Figure 10, where a 25 W SLAM uses coaxial cable transformers and two variable capacitors to improve the input and output matching. The resulting frequency response is shown in Figure 11. The 100 MHz IMD3 data in Figure 8 was obtained with this circuit.

Currently available SLAMs can be matched to operate at frequencies up to

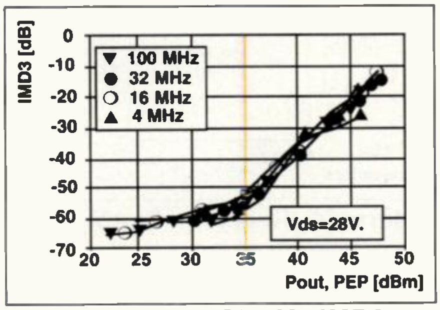

Figure 8. 25 W SLAM: IMD3 vs. frequency.

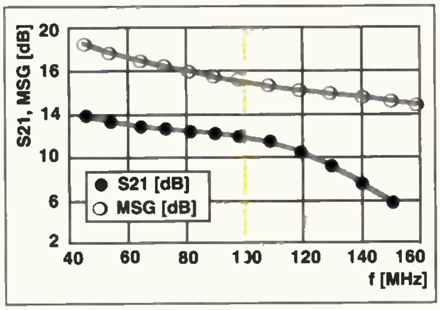

Figure 9. 25 W SLAM: MSG G_p vs. frequency.

250 MHz. Figure 12 shows the frequency response of a 5 MHz to 175 MHz broadband 10 W push-pull SLAM amplifier.

Typical applications for power SLAMs include ultralinear class A final amplifiers, class A drivers for high power class AB linear amplifiers, class A correction amplifiers in feedforward linearized power amplifiers, etc.

High IP3 SLAM Amplifiers

Receiver front-end amplifiers must operate in multitone signal environments, under widely changing signal amplitudes. They operate over a very wide dynamic range, with low noise-figure and extremely good linearity. Various manufacturers meet such stringent requirements by using rather complex feed-forward techniques to improve linearity [6]. Tradeoffs are made between the amplifier RF performance, power consumption, complexity, and size.

MwT has developed a family of receiver SLAM amplifiers which offer superior linear RF performance from low power, small size modules. One of these modules, the SLAM 0158M, for instance, has an IP3 of 48 dBm, with a power gain of 17 dB to 30 MHz, while using only about 5 W of DC power when biased at 15 V. The IP2 level is better than 89 dBm. This SLAM has a supply voltage operating range of 10 V through 30 V. The noise-figure is less than 4 dB over both the entire frequency and voltage ranges.

A typical HF circuit example is shown in Figure 13. The two source resistors meet to form a virtual RF ground point which does not require RF bypassing. The input and output transformers, unlike the 50 Ω power SLAMs, are used to provide an adequate level of impedance matching. Figure 14 shows the connectorized SLAM 0158M housing, which measures only 1" × 1" × 0.25".

The SLAM-0158M spurious free dynamic range (SFDR) [6, 7] is 95 dB, while the dynamic range (DR) is 126 dB. As the P_{1dB} is 33 dBm, this amplifier exhibits a difference of over 15 dB between IP3 and the 1 dB compression level. This is a remarkably high differ-

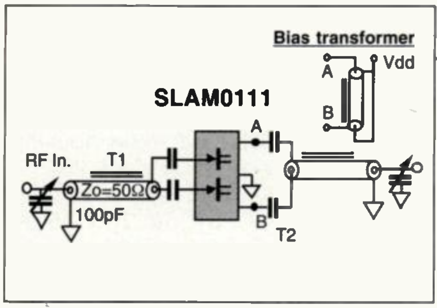

Figure 10. Broadband 1 MHz - 100 MHz amplifier.

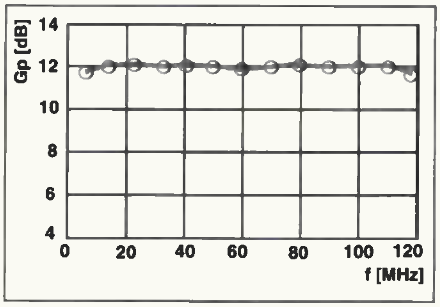

Figure 11. 1 MHz - 100 MHz SLAM amplifier Gp vs. frequency.

ence for such a simple circuit. Other receiver SLAMs, with IP3 figures higher than 53 dBm, were fabricated and tested at MwT [4].

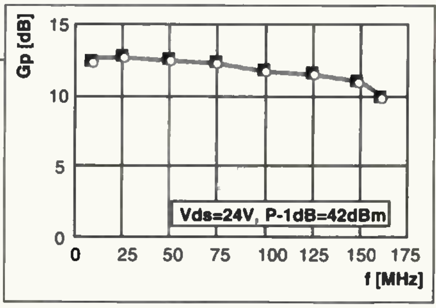

Figure 12. Broadband SLAM amplifier frequency response.

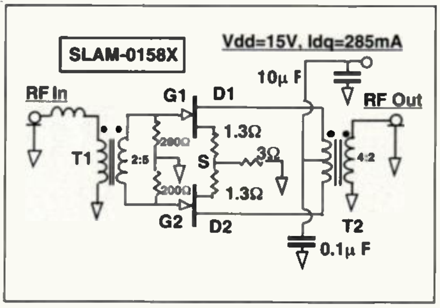

Figure 13. Receiver SLAM amplifier application circuit.

A comparison can be made between the MwT receiver SLAMs and products

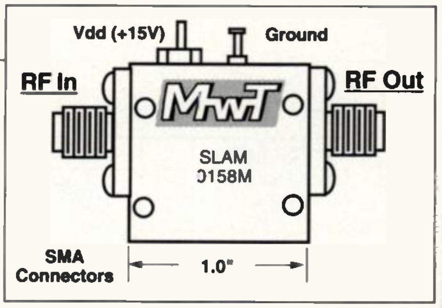

Figure 14. Receiver SLAM housing outline drawing.

with similar performance [6]; the MwT amplifiers are 14 to 20 times smaller, use less than one third the DC power, have a much wider dynamic range and an SFDR at least 5 dB better. The P_{1dB} SLAM 01 58M is higher by at least 5 dB and its noise-figure is 2 dB lower. Due to their simplicity, SLAM amplifiers offer reliability and cost advantages.

In addition to receiver front-ends, these SLAMs can be used in applications including IF amplifiers for digital receivers, antenna amplifiers, HF switch matrices, fiber optic cable laser driver amplifiers, VHF TV transmitters, lab amplifiers, etc.

The following list summarizes the SLAM's salient features:

- class A operation
- broadband operation
- high IP3
- high IP2 (push-pull)
- low noise
- wide dynamic linear range
- wide power supply range
- low DC power
- single power supply
- temperature self-compensated
- rugged
- small size
- low cost

Conclusions

The SST SLAMs are well suited for high performance linear RF applications up to 500 MHz. The examples described in this paper offer the RF amplifier designer an alternative to the widely used bipolar and MOS transistors.

SLAMs were shown to deliver superior linearity, and several examples of solutions utilizing SLAMs have been demonstrated [2, 4, 8].

Work is underway to expand the SST linear operation up to 1 GHz and thus bring the SST technology into the booming, lucrative cellular telephone and PCS markets, both in low and high power applications.

In addition to higher frequency operation, new devices will be available which will exhibit even better IMD3 figures and a wider dynamic range than present SSTs and SLAMs. *RF*

Acknowledgment

The authors acknowledge the critical contribution made at MwT by Neill Thornton, Toru Nakamura, and Precy Pacada. Masa Omori's support and guidance is gratefully appreciated.

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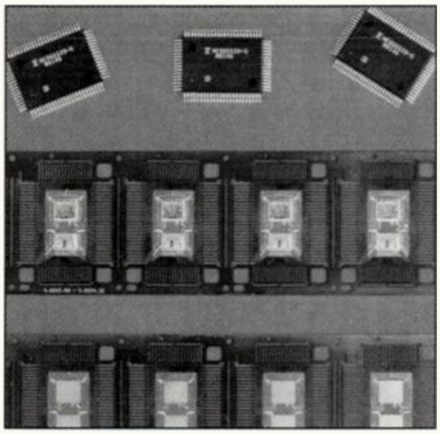
RFICs Exploding in Marketplace

Ideas from Harris Semiconductor

RFICs are approaching VLSI levels of integration. Harris Semiconductor today manufactures SSI- and MSI- level RFICs



Harris Semiconductors low-cost multi-chip packaging that will bring VLSI integration levels to RFICs. Harris uses this packaging today for telecom packages.

and will soon offer LSI and VLSI levels. Harris' SSI products are simple building blocks such as the HFA3096 differential amplifier (8 GHz f_T). MSI products are complete internally-matched devices such as the HFA3600, a 900-MHz LNA/Mixer that utilizes MMIC techniques, including spiral inductors. Harris' LSI RFIC products will integrate, transmit, and receive functions on one chip (LNA, mixer, up-converter, PA).

When achieved, VLSI integration will employ low-cost plastic-encapsulated multi-chip modules to attain high levels of signal isolation and to integrate mixed technologies (RF bipolar with mixed-signal BiCMOS) in small-footprint, low-profile, surface-mount packages. VLSI RFICs will enable development of extremely small wireless equipment for such high-volume applications as wireless LAN adapters in PCMCIA cards and personal communication system (PCS) handsets, and data terminals in shirt-pocket form factors.

Penstock's Perspective

Penstock (a division of Avnet) has been a focused RF/Microwave distributor since 1975. Initially the primary markets for RFICs were limited to defense programs, support test equipment, and an occasional radio requirement. With dramatic defense budget reductions and and explosion in commercial communication requirements, the demand for integrated RF semiconductors has blossomed.

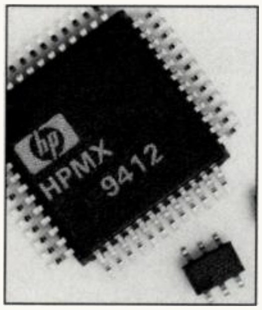
Computer manufacturers are scurrying to find integrated RF solutions to compress designs into space limited PCMCIA applications. Wireless LAN and WAN products, Gigabit/sec Fiber Optic systems and Personal Communication Systems (PCS) are a reality.

The automotive industry is demanding multifunction RFICs to satisfy the emerging auto toll tag, collision avoidance, and RF controlled cars in the future. Companies all over the country utilize RF technology to help you page

your kids, track your car, and curb your dog. Miniaturization of these designs require RFICs.

These devices require combinations of amplification, filtering, mixing, and LO. Products that were originally designed as application specific are now being introduced as standard products to help satisfy demand. Penstock currently has over $9 million of RF products in its inventory and anticipates increasing this level dramatically over the next year to meet our customers' needs. We anticipate that this market will continue to grow at a dramatic pace for at least the next five years.

Hewlett-Packard's Perspective



HP's mixed signal cellular transmitter IC.

The expanding market for RFICs is being fueled by the growth of consumer and industrial applications of wireless voice, data and video distribution systems. For high volume markets with segments that have common system approaches (e.g., DECT, GSM, DBS), integration of many functions is economically viable. For performance or flexibility reasons, RFICs that combine a small number of functions (such as LNAs and power amplifiers) are used in all markets.

HP is addressing the trend to smaller, low cost, low voltage RFICs from both directions on the integration scale. For multi-function RFICs, HP is producing a mixed signal cellular transmitter IC and will introduce a two-chip DECT solution. For the building block approach, HP is producing Silicon and GaAs RFIC amplifiers, mixers, and vector modulators, and will introduce in 1995 a family of the smallest surface-mount-packaged low voltage amplifier MMICs in the industry.

Atmel's Observations

The new PCS bands are reminiscent of the 1980's cellular rush. For the 900 MHz band, products from cordless phones to wireless stereos and security systems are launched daily. Many RFIC makers are quickly partnering with digital IC merchants to enter the new markets. Adaptive hardware, the corner of every portable and handheld digital system, is now providing the same availability to PCS makers. Atmel has produced a direct sequence spread spectrum (DSSS) chip set that is an easy encoding facility for virtually any audio-based, analog RF design.

Direct sequence spread spectrum, once exclusively for the military, is the best way to improve signal quality, eliminate crosstalk, and secure communications for traditional analog modulated designs. Atmel's DSSS is a drop-in pair of smart chips, the ATOU812/AT89C51. All the processor and algorithms needed to control a traditional RF design are contained in proprietary CMOS ICs, one pair at either end of the system.

Opinions from California Eastern Laboratories

Because of its long relationship with NEC, California Eastern Laboratories has a unique perspective on the RFIC industry. The company's projections are extremely favorable. Len Lea, CEL's Vice President of Sales and Marketing, expects the market to grow five-fold by the end of the century–over 30% a year. Two main factors will fuel this growth: the increase in spread spectrum applications, and the marriage of RF technology with digital applications.

"More and more, these companies are driving wireless connectivity," says Lea. "They're coming to us regularly for help with the RF side of their designs."

They're also coming with demands. According to Lea, "These customers want low voltage, low power consumption, high efficiency, higher levels of integration, and smaller packages. We're responding with our 3 Volt MMIC family, our 1 Volt 1mA ICs for pagers, and our miniature MCICs for cellular phones. We see these demands continuing to drive the need for MMIC technologies with f_{max} in excess of 40GHz."

The View From Analog Devices

The still-young RFIC market faces enormous growth, as both technical and market forces require that highly integrated systems replace traditional discrete solutions and design philosophies.

Firstly, new high-volume wireless applications drive the market with demands for less power, size and weight–difficult with discretes. Then, as new players with no RF design experience-telephone suppliers with cellular/cordless, computer companies with WLANs–find themselves developing complex systems at 2GHz, they desperately need complete solutions. Thirdly, the new digital standards demand greater sophistication and integration. Finally, silicon technology now allows this without penalty; single chip sub-systems integrating LNA, mixer, and more at 2GHz are now more feasible.

Analog Devices serves this market with skilled analog design and unrivaled mixed-signal expertise to deliver "Microphone to Antenna" solutions: IF ICs, RFICs, mixed signal ICs and DSPs, all designed for seamless interface and ultra low power operation, from an independent vendor. *RF*

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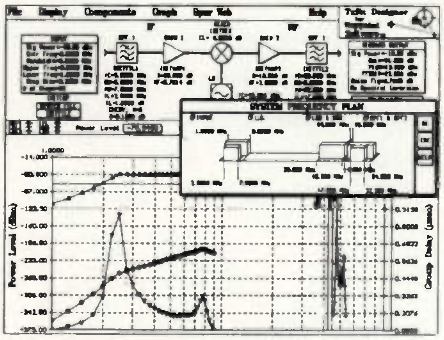

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CAREER OPPORTUNITIES

RF ENGINEER

ICTV is Silicon Valley's most exciting interactive TV startup. Our strategic partners are Cox Cable and IBM. We're looking for an RF engineer with 5+ years experience who will have design responsibility for ICTV compatible cable TV set-tops and headend products. Experience desired: Broadband datacom, circuit system design/analysis, NTSC TV modulators, "scrambling" circuits, BTSC stereo system encoders and familiarity with RF CAD simulation software. If your background is close, we offer top talent, state-of-the-art equipment and an opportunity to architect the first generation of interactive TV systems.

Please contact Renny Bejosa at 1-800-926-8398 or fax your resume to 408-986-9566.

INFO/CARD 73

CAREER OPPORTUNITIES

RF SOLID STATE P.A. DESIGN ENGINEERS

Harris, a $3 billion Fortune 200 Corporation, is seeking World Class candidates for an RF Solid State P.A. Design Engineer, at their Broadcast Division Headquarters, a worldwide supplier of radio and TV broadcast equipment and integrated systems, in QUINCY, IL.

This challenging position calls for a driven, RF engineer, with at least five years of experience in the design of linear, class A/AB, RF amplifier systems and circuits, power dividers and combiners, and control/monitor circuits for high power VHF/UHF application. Must be experienced in solid state design utilizing MOS FET's, and a champion of design for low cost, manufacturability, and high reliability. The desired candidate will have the skills to manage small project teams, as well as the capability of being a hands-on, individual contributor. This position requires a BSEE or equivalent experience; MSEE preferred.

Harris Corporation offers a competitive starting salary, with a comprehensive benefits package and opportunities for growth and advancement. If qualified please send resume (including salary history/requirements) in confidence to: William G. Kellner, Supervisor, Human Resources, Harris Corporation, Broadcast Division, Dept. PA, P.O. Box 4290, Quincy, IL 62305-4290.

HARRIS

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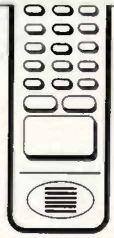

Wireless Networking Radio Engineering: Develop technical specifications for radio transceivers to be used for wireless LAN's. Assist in interface to other hardware/software product elements. You should have a BSEE with at least 10 years experience with radio transmitters/receivers, Modulation techniques and microwave radio circuits.

...YOUR CAREER

Spread Spectrum Design: Responsible for design development and test of RF circuits and systems for spread-spectrum wireless systems. Designed 1.8/2.4 GHz wideband frequency synthesizer and VCO and GaAS linear power amplifiers. Analyzed and simulated communications system performance. Assisted in producibility redesign and system integration.

Product Marketing Manager: Our client, a well known communications firm, seeks an experienced professional to perform classical marketing functions for a product line: i.e., develop short and long term business plan, determine marketplace, etc. Excellent compensation package along with executive benefits.

Manager, Commercial Products: Project engineering and management for development of GaAs MMIC chips and MMIC-based products. Products include phase-locked 2.5 GHz television converter for high volume production, monolithic telephone converter and power amplifier, integrated amplifier/switch for data communications; voltage controlled oscillator and converter for satellite communications; Frequencies ranged from 800 MHz to Ku-band.

RF Design Engineer: Design and develop various RF circuits (including but not limited to PA's, LNA's, mixers and filters). Perform subsystem and system level testing. BSEE/MSEE 5-7 years RF circuit design experience with proven track record of developing RF subsystems from concept through manufacturing introduction.

RFIC Design: MS or PhD in Electrical Engineering with minimum 5 years related experience preferred. The candidate should have a good knowledge and experience in Linear Bipolar High Frequency IC design and measurement techniques in design IC's like Amplifiers, Mixers, Oscillators, VCO's, Prescalers, Synthesizers, Limiting Amplifiers, etc. operating up to 2 GHz in Bipolar or BiCMOS technologies.

MMIC Design Engineer: Develop L/S band GaAs MMIC power amplifiers for commercial wireless communications. Requires: M.S. or BSEE, +2 years experience with GaAs MMIC design, simulation, packaging and test.

Director R&D: One of the three largest suppliers of Microwave Digital Radios in the U.S. Common carrier and cellular markets is seeking an RF and Microwave circuit design engineer with the following minimum qualifications: MSEE or BSEE, 10 years experience in Microwave circuit design such as microstrip circuits, low noise amplifiers, power amplifiers, mixers, oscillators and RF circuits, Commercial experience in cost effective design and knowledge of digital communication theory is desirable.

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Career Opportunities

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SUNBELT OPPORTUNITIES

Several of our growing commercial major electronic companies located in the southeast have asked us to identify candidates in the mid-level experience range.

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2) BSEE – RF Test Engineer – 50 MHz to 1 MHz. Spectrum analyzers, Network analyzers
3) BSEE – RF Circuit Design Engineer – Frequency Synthesizers
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RF ENGINEER LAB TECHNICIAN

High technology company located in Ocala, FL is seeking an experienced Rf technician to assist in the design and development of RF based products. A thorough understanding of analog and radio frequency circuits is essential. Applicant should have experience in operating RF test equipment and PC based programs.

Mail resume and salary requirements to:

Intellon Corp., Attn: Ms. Aschliman
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SENIOR WIRELESS ENGINEERS

MicroUnity Systems Engineering, Inc. is a well-financed startup company in the San Francisco Bay area. We are interested in adding experienced engineers to further strengthen our wireless team.

The selected candidates will play a key role in developing the wireless link architecture and driving harcware and software engineering for very innovative digital communications products, utilizing extremely advanced semiconductor and circuit technology.

Principals only. Please submit your resume, quoting the appropriate department code on the cover letter and envelope, to: MicroUnity Systems Engineering, Inc., Wireless Project Team, 255 Caspian Drive, Sunnyvale, CA 94089-1015.

Wireless System Design Engineer

We are seeking engineers with both theoretical and product experience in the design of digital communication links. A thorough understanding of transmitter and receiver architectures, modulation formats, access methods, packet protocols, propagation characteristics and link budgeting is required. Knowledge of handoff protocols in cellular systems would be an advantage. Dept. RFD/WS

RF Design Engineer

We are seeking engineers experienced in the design and construction of RF circuits from HF to UHF; a background including 2.4 GHz or 5.8 GHz ISM projects would be an advantage. Considerable practical experience with surface mount microstrip technology is necessary. Dept. RFD/RF

RF IC Design Engineer

We are seeking engineers experienced in linear high frequency integrated circuit design, who have applied their skills to the development of low-noise amplifiers, mixers or oscillators in silicon bipolar or BiCMOS technologies. Dept. RFD/RFIC

DSP Engineer

We are seeking engineers with both theoretical and product experience in signal processing for digital communications, who can lead modem design and implementation efforts across a variety of modulation schemes and physical media, and who are extremely familiar with architectural and algorithmic tradeoffs in this area. Strong software skills are an advantage. Dept. RFD/DSP

RF Test Development Engineer

We are seeking an RF test development engineer with the ability to enhance testability through design and improved testing techniques in development and volume situations. The candidate's experience should include RF fixturing and hardware as well as the use of DSP as a test tool in applications that include transmitters, receivers, up/down converters, filters and PLLs. RFD/RFT

microunity

INFO/CARD 80

Electronics Systems Supervisor position

in the National Superconducting Cyclotron Laboratory at Michigan State University. **Title:** Engr/Phys Aclr III/S. **Salary:** $35,595-$44,494/year commensurate with qualifications. **Duties:** Able to work with research engineers/scientists.Coordinate resources,develop/maintain/fabricate/repair complex electronic systems; Assist solving technical design problems; supervise 3 or more electronics technical support. Significant experience in troubleshooting/repairing complex high power RF equipment such as tuned vacuum tube based amplifiers, resonators, associated power supplies and electronics in the 1 to 110 Mhz and 25-250 kilowatt regime. **Required:** BS in Electronics Technology or equivalent combination of education and experience; five years experience in electronic equip. repair incl. fabrication/testing, use of specialized scientific equip., high power RF equipment and supervision. **Desired:** experience in staff training and budget management. Contact Michigan State University Employment office (517)432-1662 by 10/28/94. **Reference posting number S40039.** MSU is an affirmative action/equal opportunity employer.

INFO/CARD 81

ERICSSON GE MOBILE COMMUNICATIONS LAND MOBILE RADIO DIVISION in Lynchburg, Virginia has immediate openings for qualified senior level engineers for our RF Hardware design and systems. B.S.E.E. or M.S.E.E. required with 5-10 years Hardware design experience. Thorough knowledge of Land Mobile Radio a plus. Candidates must be proficient in design and test of one of the following RF modules; Power amplifier, receiver, synthesizer or system.

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ENGINEERING ■ ■ ■

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OCP Inc.

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CAREER OPPORTUNITIES

RF Engineer

NEC America, Inc. is a recognized leader in information technology and telecommunication. Due to growth in our Mobile Radio Division, we are seeking an experienced RF Engineer at our Dallas, Texas location.

Position is responsible for the design and development of NEC voice/data subscriber equipment for cellular telecommunication systems and related equipment.

Qualifications include BS degree in EE with 6+ years experience in 900 MHZ RF transmitter and receiver design at both system and circuit level. In-depth experience with analog and digital modulation and demodulation techniques and circuit implementation is required. Such experience includes system architectural design, component selection, hardware debugging and testing. Knowledge of cellular concepts and technologies (AMPS, GSM, TDMA, CDMA, RF Propagation, Antennas, delay spread, channel equalization, A/D conversion, AGC, and synchronization) are desirable.

For immediate consideration: FAX resume to: L. White, NECAM (214) 751-7051.

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SENIOR STAFF ENGINEER - WIRELESS COMMUNICATIONS – Outstanding opportunity for a qualified communications engineer whose expertise includes RF communication from 20-1200 MHz with a wide variety of modulation types of formats. Must have good balance between analytical capability and hands-on experience. Responsibilities may require working with customers to design requirements, writing proposals, detailing system architecture, system engineering, and self-directed IRAD tasks, as well as monitoring less experienced engineers. Prefer some experience with hand-held equipment including receivers, transmitters, spread spectrum systems, mobile satellite systems and DSP.

Send resume to: Xetron Corporation, 460 West Crescentville Road, Cincinnati, OH 45246. U.S. Citizenship required. EEO/AAE.

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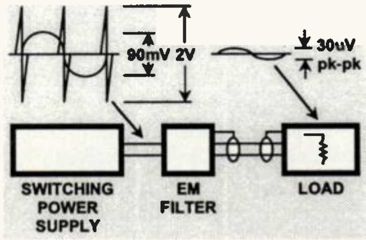

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255 Spectrum Probe 30 KHz to 2.5 MHz $279
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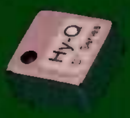

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RF design

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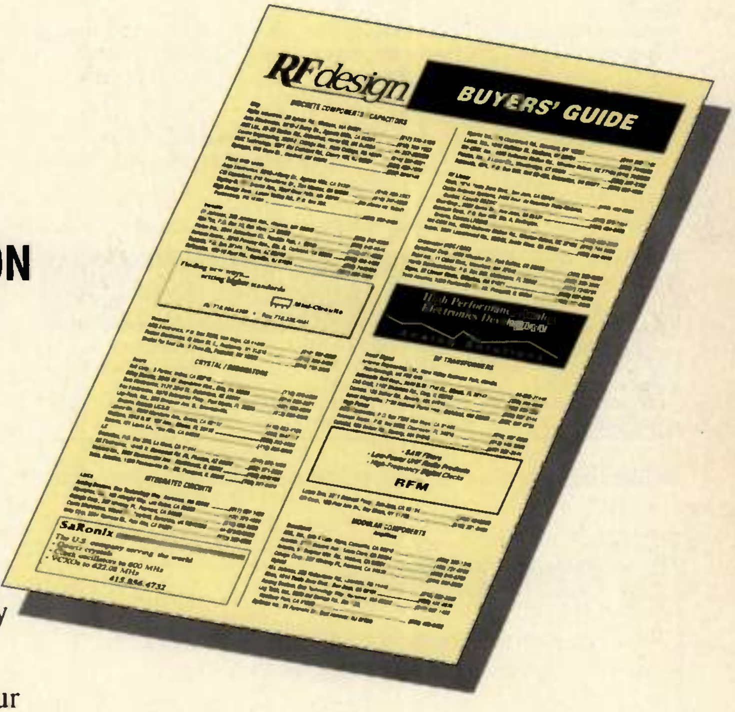

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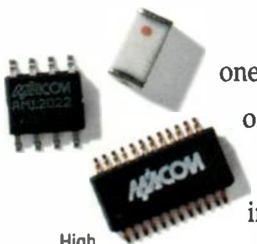

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