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engineering principles and practices

December 1994

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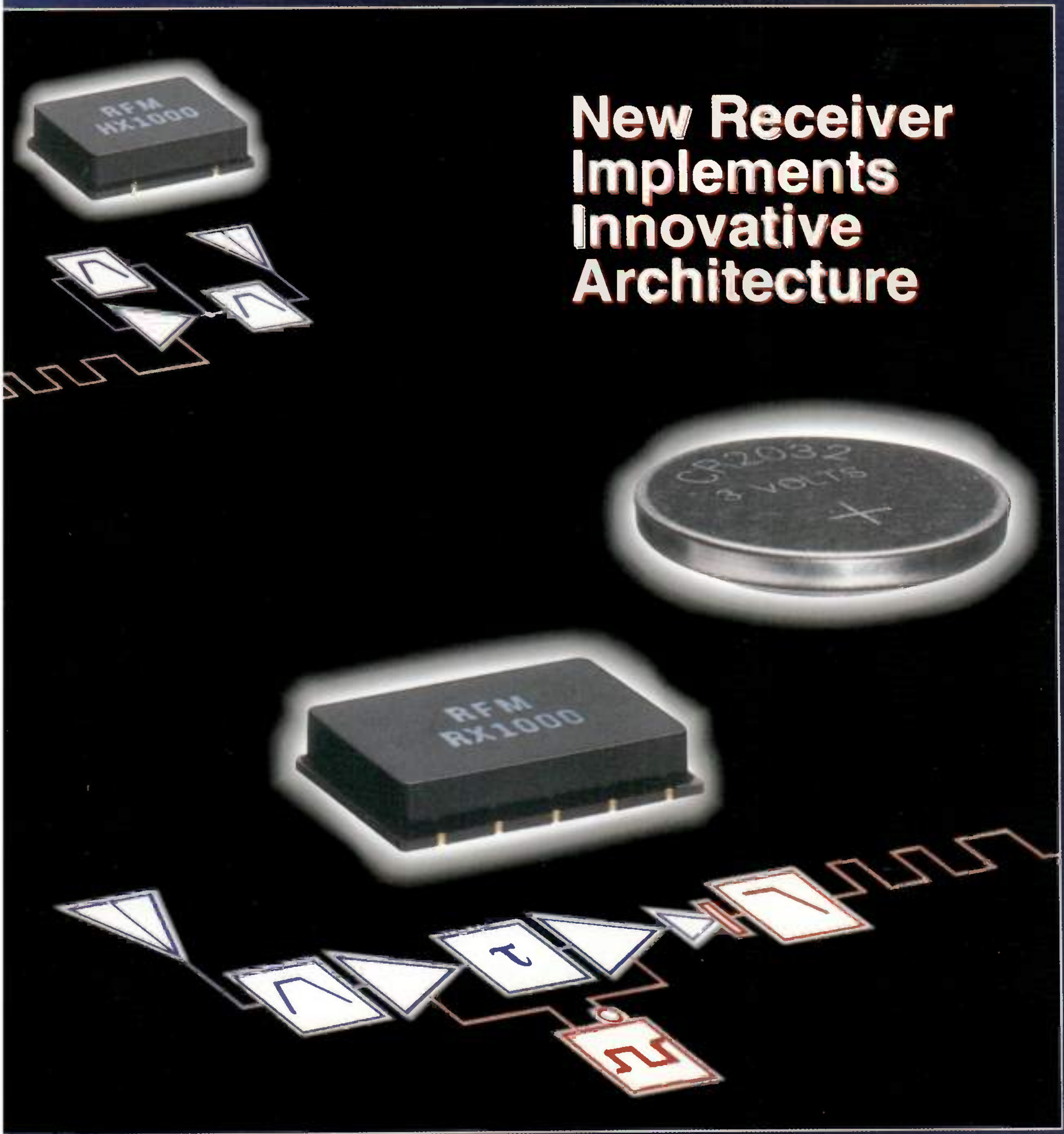

Plus –

Low Cost Doppler Detector

1993-1994 Article Index

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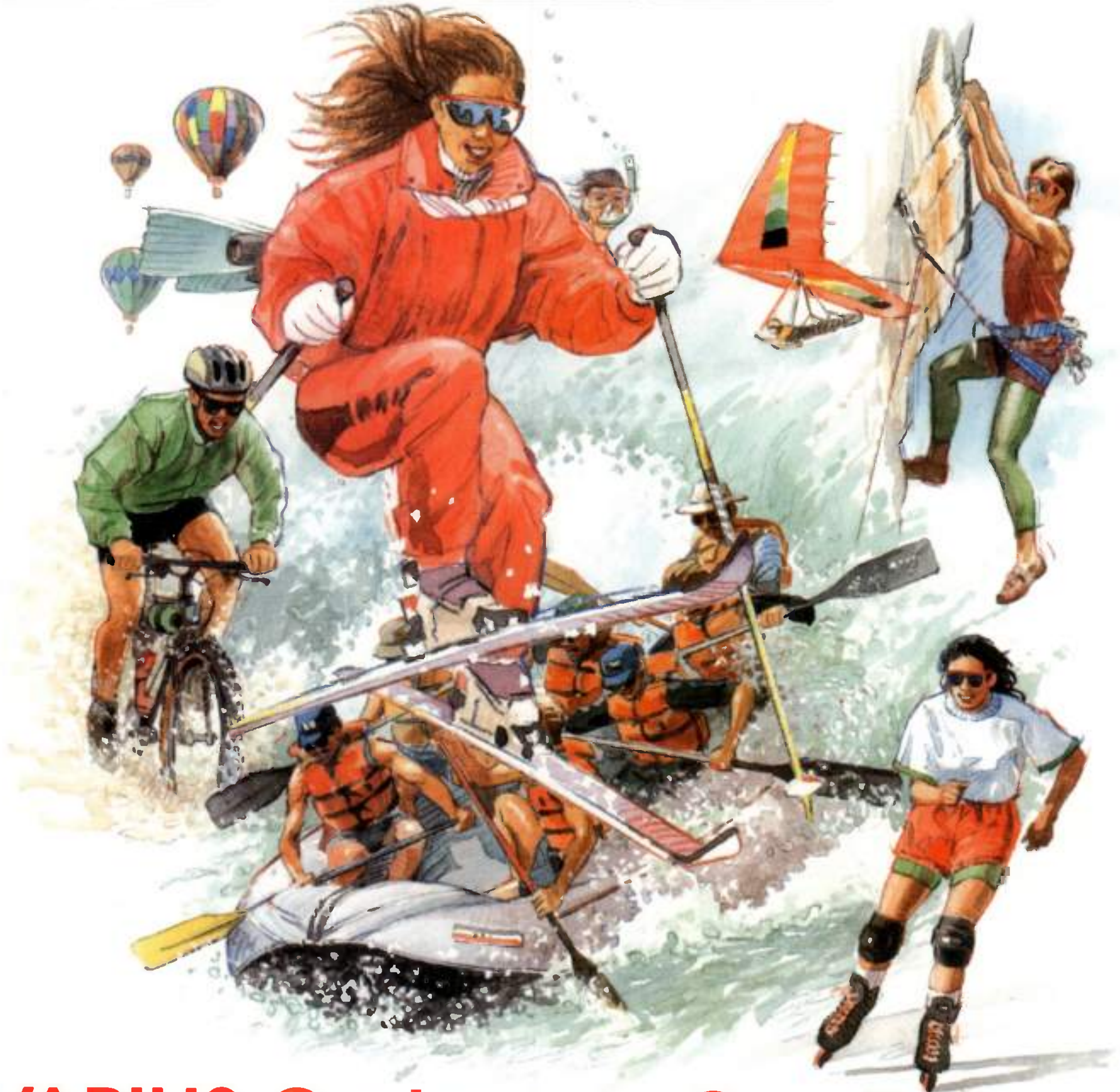

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INFO/CARD 1

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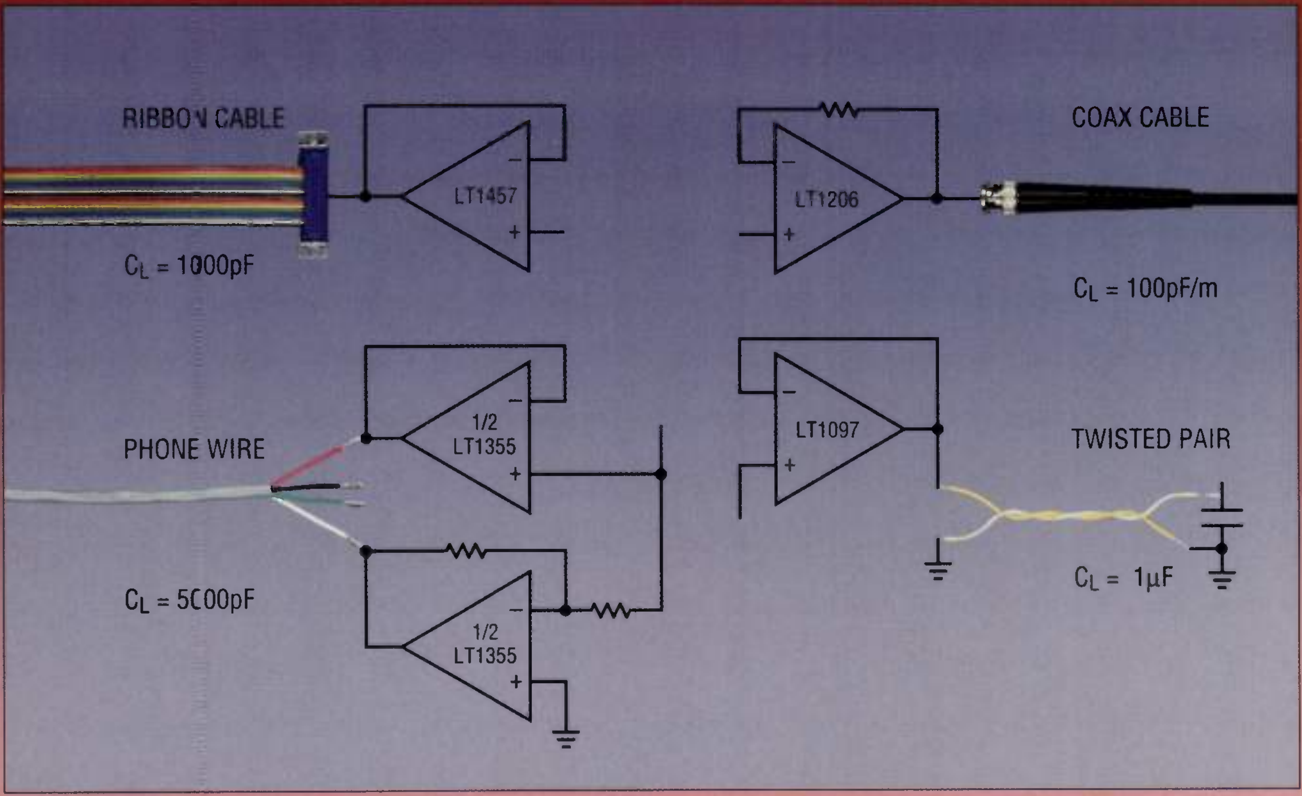

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The LT1206 with its 250mA minimum output current has enough drive to slew 10,000pF at 50V/µs. Precision instrumentation applications? The LTC1152 rail-to-rail input and rail-to-rail output zero drift op amp provides 10µV max offset as well as C-Load driving.

Part #	Max V_{OS}	Max I_B	Min I_{OUT}	Bandwidth	Slew Rate
LT1097*	60µV	350pA	5.7mA	700kHz	0.2V/µs
LT1152	10µV	100pA	4mA	1MHz	1V/µs
LT1206	10mV	5µA	250mA	60MHz	900V/µs
LT1220	1.0mV	300nA	24mA	45MHz	250V/µs
LT1224*	2.0mV	8µA	24mA	45MHz	400V/µs
LT1354*	800µV	300nA	30mA	12MHz	400V/µs
LT1357*	600µV	500nA	30mA	25MHz	600V/µs
LT1360*	1.0mV	1µA	40mA	50MHz	800V/µs
LT1363*	1.5mV	2µA	70mA	75MHz	1000V/µs
LT1457	800µV	75pA	10mA	1.7MHz	4V/µs

*Duals and Quads are available.

Specifications for the table shown are low cost grades in plastic DIP. Prices for our C-Load op amps start as low as $1.05 for the LT1097CN8. For details, contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035/408-432-1900. For literature only, call **1-800-4-LINEAR**.

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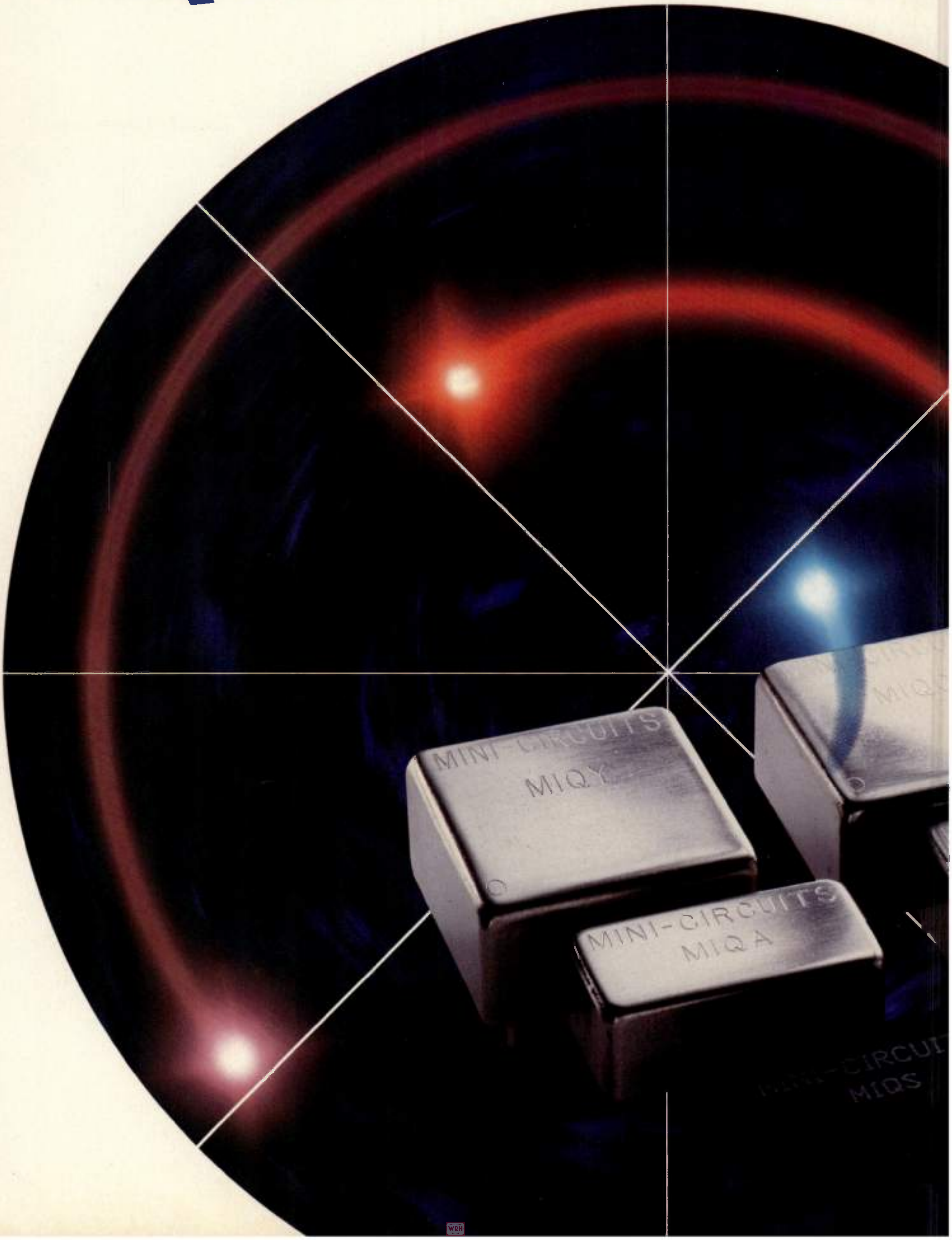

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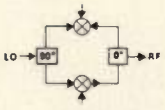
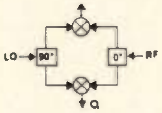


I/Q MODULATORS

MODEL NO	FREQ (MHz) f_L	f_U	CONV LOSS (dB) x	σ	CARRIER REJ (dBc) Typ	SIDEBAND REJ (dBc) Typ	HARM SUPPRESS (dBc) Typ 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
☐ MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
☐ MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95



I/Q DEMODULATORS

MODEL NO	FREQ (MHz) f_L	f_U	CONV LOSS (dB) x	σ	AMP UNBAL (dB) Typ	PHASE UNBAL (Deg.) Typ	HARM SUPPRESS (dBc) Typ 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
☐ MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
☐ MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
☐ MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95

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INFO/CARD 3

F 156 Rev B

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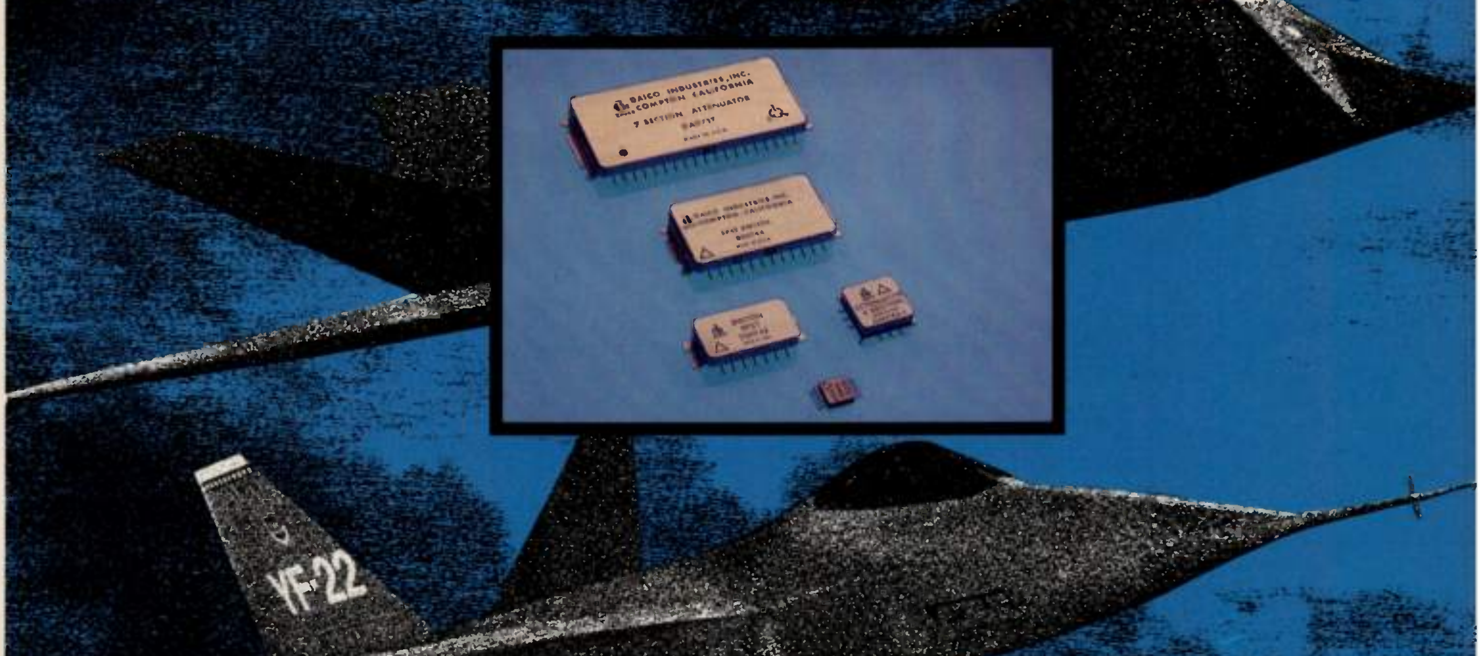

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Surface Mount Switches

Config	Freq MHz	IL dB	Iso dB	Switch Speed µSEC Max	Control	Package	Part No.
SPST	5-1000	0.7	45	0.035	TTL	12 Pin SMP	DSO799
SPST	10-2000	1.8	53	0.035	TTL	14 Pin SMP	DSO790
SP2T	DC-2000	0.6	25	0.003	-	SOIC 8	DSO702
SP2T	10-1000	0.7	32	0.050	TTL	12 Pin SMP	DSO712
SP2T	5-1000	1.6	58	0.070	TTL	14 Pin SMP	DSO742
SP2T	50-1100	1.4	48	0.150	TTL	10 Pin SMP	DSW25030
SP4T	10-1000	1.0	57	3.0	TTL	24 Pin SMP	DSO744
SP4T	50-500	1.1	52	1.0	TTL	24 Pin SMP	DSO778
SP5T	10-400	1.0	43	0.100	TTL	24 Pin SMP	DSO705

Surface Mount Bi-Phase Modulators

Freq MHz dB	LSB Range DEG	IL dB	Switch Speed µSEC Max	VSWR	Package	Part No.
10-500	0-180	1.0	0.070	1.4	12 Pin SMP	DBPO738

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Surface Mount Attenuators

# of Sections	Freq MHz	LSB Range dB	IL dB	Switch Speed µSEC Max	Control	Package	Part No.
1	20-700	10/10	1.0	0.035	TTL	12 Pin SMP	DAT15015
4	10-1000	1/15	1.9	0.030	TTL	12 Pin SMP	DAO784-1
5	300-1000	1/31	3.4	0.500	TTL	24 Pin SMP	DAO769
5	10-1000	2/62	5.6	0.050	TTL	24 Pin SMP	DAO757
6	10-1000	1/63	6.3	0.050	TTL	24 Pin SMP	DAO786
7	30-500	0.5/63	4.5	20.0	TTL	38 Pin SMP	DAO795
7	30-250	0.5/63.5	6.1	0.035	TTL	38 Pin SMP	DAO717
7	30-150	0.1/12.7	4.0	0.035	TTL	38 Pin SMP	DAO775
VCA	20-300	-/18	0.8	-	Analog	14 Pin SMP	DAO735

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RF design

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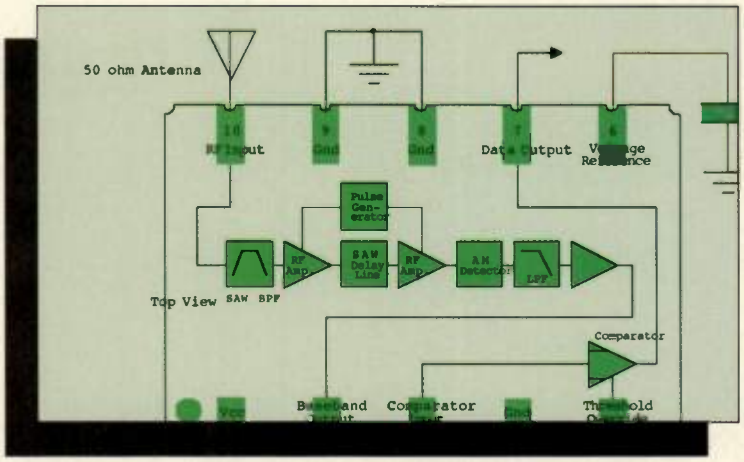

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RF editorial

My Wireless Gadget Christmas List

By Gary A. Breed
Editor

I think it's time to take advantage of the revolution in personal, portable, wireless technology. So, my list for Santa Claus this year will be loaded with RF devices! Here's what I need in my office and at home to make life easier:

A *wireless mouse* for my computer — The cord keeps getting stuck under the edge of my CPU, making me unintentionally (of course) misplace modifiers and split infinitives.

A *wireless headset* for my stereo system — This isn't for convenience, I need it to shut out the sounds of Nirvana, Nine Inch Nails, Screaming Trees and Crash Test Dummies coming from my kids' rooms.

For one of my neighbors, I'll get an *"invisible fence"* for his dog. A few weeks ago, she discovered that she's grown big enough to jump over the fence separating our yards.

How about a new spread spectrum, interference-free (?) *cordless telephone?* My neighborhood has so many 49 MHz phones that none of the channels is totally interference-free. Besides, some scanner enthusiasts are probably listening in on my calls (I'm not paranoid, of course).

A *cellular telephone* that I can afford to use — Maybe the new PCS services will cut the cost down from the monthly fee plus 50¢ a minute. A cellular phone would be just a personal convenience for me, not business-related.

I'm one of the lucky ones who doesn't have a freeway commute, but my insurance bills would be lower if the family car had an *anti-collision radar system* on board over the past few years!

While I'm at it, I better get a *radar detector*, too. With two children (OK, they're young adults) in college, we make a lot of trips up and down I-25.

For business, I could use a telephone that's part of a *wireless office system*; so I can carry it around the office. That way, your calls will reach me when I'm at the fax machine or lounging around on our sixth floor patio. You'll agree with this one if you've ever gotten dumped into my voice mail with no way out!

I should support the Colorado economy by getting a *DBS receiving system*. They're a lot cuter than the big C-band TVRO systems that are still common.

Maybe I should support my local *cable TV* company, too by finally putting in service (something less than 500 channels will do nicely, however).

We only have one five-mile stretch of toll road in the entire state, and it offers wireless *automatic toll collection*. I never use that road, so I think I'll leave that off my list.

I could also use a wireless *printer-sharing device* — at home, not at the office. When everyone is home from college, we have six computers in the household and only three printers. Plus, my notebook computers would be a lot more convenient if I could hit the "print" command while sitting on the couch or working in the electronics lab.

Finally, in the spirit of the original meaning of the word wireless, my *ham radio equipment* is falling far behind the state-of-the art. It might be time to wish for some new RF equipment there, too!

Seriously, although RF gadgets are on my list of fun things, I also hope that those who can't afford these expensive toys have a happy holiday season, too. You can help by contributing to the charitable group of your choice. Ho, Ho, Ho!

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710FC	10W CW	1-1000 MHz	40dB	$ 6,695
*727LC	10W CW	.006-1000 MHz	44dB	$ 7,950
713FC	15W CW	20-1000 MHz	42dB	$ 5,680
225LC	25W CW	.01-225 MHz	40dB	$ 3,295
*737LC	25W CW	.01-1000 MHz	45dB	$ 9,995
712FC	25W CW	200-1000 MHz	45dB	$ 6,950
714FC	30W CW	20-1000 MHz	45dB	$ 9,350
250LC	50W CW	.01-225 MHz	47dB	$ 5,550
715FC	50W CW	200-1000 MHz	47dB	$ 14,990
707FC	50W CW	400-1000 MHz	50dB	$ 10,990
716FC	50W CW	20-1000MHz	47dB	$ 17,950
*747LC	50W CW	.01-1000 MHz	47dB	$ 18,550
116FC	100W CW	.01-225 MHz	50dB	$ 9,500
709FC	100W CW	500-1000 MHz	50dB	$ 16,990
717FC	100W CW	200-1000 MHz	50dB	$ 19,500
718FC	100W CW	20-1000 MHz	50dB	$ 29,800
7100LC	100W CW	80-1000 MHz	50dB	$ 19,500
*757LC	100W CW	.01-1000 MHz	50dB	$ 29,950
122FC	250W CW	.01-225 MHz	55dB	$ 19,950
723FC	300W CW	500-1000 MHz	55dB	$ 29,995
LA500V	500W CW	10-100 MHz	56dB	$ 12,900
LA500UF	500W CW	100-500 MHz	57dB	$ 46,000
LA500G	500W CW	500-1000 MHz	57dB	$ 55,000
LA1000V	1000W CW	10-100 MHz	60dB	$ 22,500
LA1000UF	1000W CW	100-500 MHz	60dB	$ 75,000
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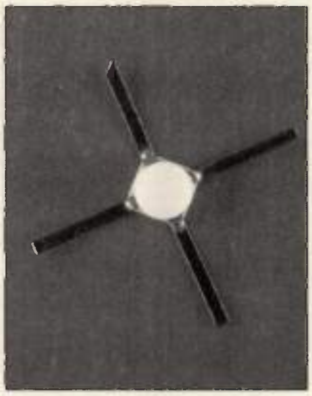

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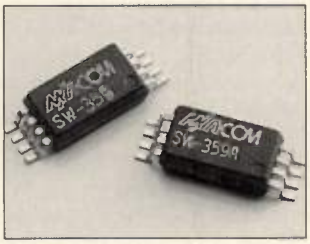

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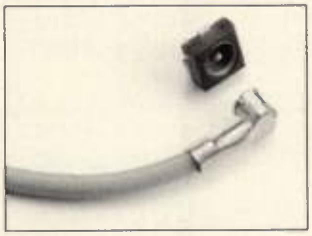

OSMT: Microwave Surface Mount Interconnect System

The OSMT has a mated height of 4.2 mm, and a VSWR of 1.2:1 at 2 GHz, and 1.4:1 max at 6 GHz. Applications include Cellular, GPS and WLAN. Plugs are supplied in tape and reel packages and cable jacks are available in pigtails or jumpers.

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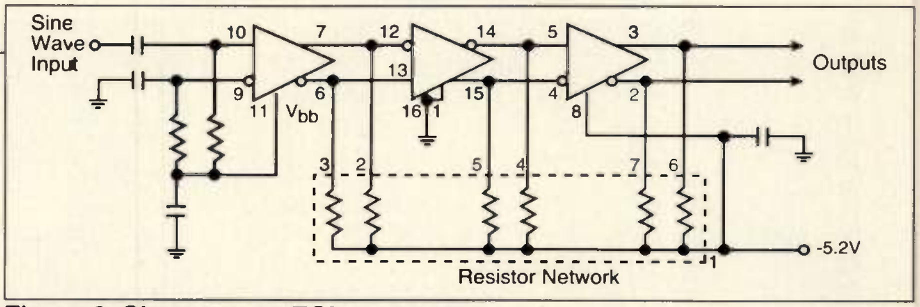

Figure 3. Sine wave to ECL converter.

More ECL for RF

Editor:

This is a comment on the letter by Pat Conway in the September issue of *RF Design* about the June issue which had a letter entitled "A Note on ECL for RF" by David Freeman. This letter was about the article on the analog use of ECL by R.N. Mutagi in the April issue.

Since 1980 I have been using line receivers for crystal oscillators, limiting amplifiers and 50 ohm output devices (with differential output devices is is easy to get +3 dBm with 20 dB return loss). I have seen several designs which use the same circuit for converting a sine wave as is shown in Mr Conway's letter (Figure 1). This will work fine in most applications, however, if the sine wave is small the offset is critical.

I have used the circuit shown in Figure 2 to balance the impedance and DC currents to the inputs. The circuit shown in Figure 3. uses this approach. because of the high DC gain, the offset in this circuit is critical. I have shipped thousands of these without any problems.

The circuit may be less prone to oscillation that the type which used filtered DC feedback. Of course grounding and layout play a big role in stability.

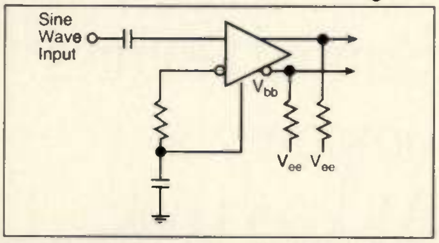

Figure 1. Unbalanced input circuit.

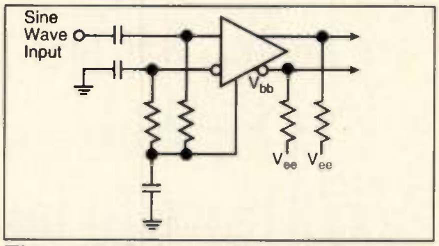

Figure 2. Balanced input circuit.

William Heathorn
Hewlett-Packard

Don't fade away

Rely on **Marconi 2050** digital and vector signal generator: the first **with built-in Rayleigh and Rician fading simulation.**

High buildings, cars, trees...they all cause fading problems for communications systems. The problem is that realistic testing means replicating real-world conditions: and that's always needed expensive, specialist equipment.

Now there's the new Marconi 2050 series. It's the first-ever generator with a built-in Rayleigh and Rician fading simulator, allowing receivers to be tested under realistically adverse conditions.

The 2050 series is highly versatile, with comprehensive IQ modulation facilities plus the ability to test new digital systems including TETRA and APCO 25.

Covering an exceptionally wide carrier frequency range - from 10 kHz to 5.4 GHz with the 2052 - it maintains a high standard of accuracy and stability. The flexible operator interface and large clear back-lit display, ensure simplicity of control and ease of use.

Choose a one-box solution for testing receivers: get the Marconi 2050 in focus.

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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	.1 to 1057 MHz	.01 to 1056 MHz	.1 to 2115 MHz	.1 to 2112 MHz
Switching speed	<85 ms	<100 ms	<85 ms	<100 ms
Spectral Purity*				
Spurious	<-100 dBc	<-100 dBc	<-94 dBc	<-94 dBc
Subharmonics	None	None	<-45 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*	+16 to -140 dBm	+17 to -140 dBm	+16 to -140 dBm	+13 to -140 dBm
Accuracy	±1 dB >-127 dBm	±1 dB >-127 dBm	±1 dB >-127 dBm	±1 dB >-127 dBm
Reverse Power Protection	50 Watts/50 Vdc	50 Watts/50 Vdc	25 Watts/25 Vdc	25 Watts/25 Vdc
Amplitude Modulation				
Depth	0–99.9%	0–99.9%	0–99.9%	0–99.9%
Distortion @ 30%	<2%	<1.5%	<2%	<1.5%
Frequency Modulation				
Max. Deviation*	3 MHz	4 MHz	3 MHz	8 MHz
Distortion	<2%	<1% @ 50% Dev.	<2%	<1% @ 50% Dev.
Phase Modulation				
Max. Deviation*	100 Rad.	40/400 Rad.	200 Rad.	80/800 Rad.
Pulse Modulation				
On/off	>40 dB	>40/60 dB	>40/80 dB	>80 dB
Rise/fall time	<400 ns	<15 ns (Typ 7.5 ns)	<400 ns	<15 ns (Typ 7.5 ns)
Minimum Pulse Width	<2 µs	<30 ns	<2 µs	<30 ns
Internal Modulation Source	20 Hz to 100 kHz	0.1 Hz to 200 kHz	20 Hz to 100 kHz	0.1 Hz to 200 kHz
Level Range	0 to 3 Vpk	0 to 4 Vpk	0 to 3 Vpk	0 to 4 Vpk
Waveforms	Sine	Sine/Sq/Tri/Pulse	Sine	Sine/Sq/Tri/Pulse
Programmable	Yes	Yes	Yes	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
4650 Norris Canyon Road
San Ramon, California 94583
Telephone: 800 726 4442 or
510 328 4650
Telefax: 510 328 4700

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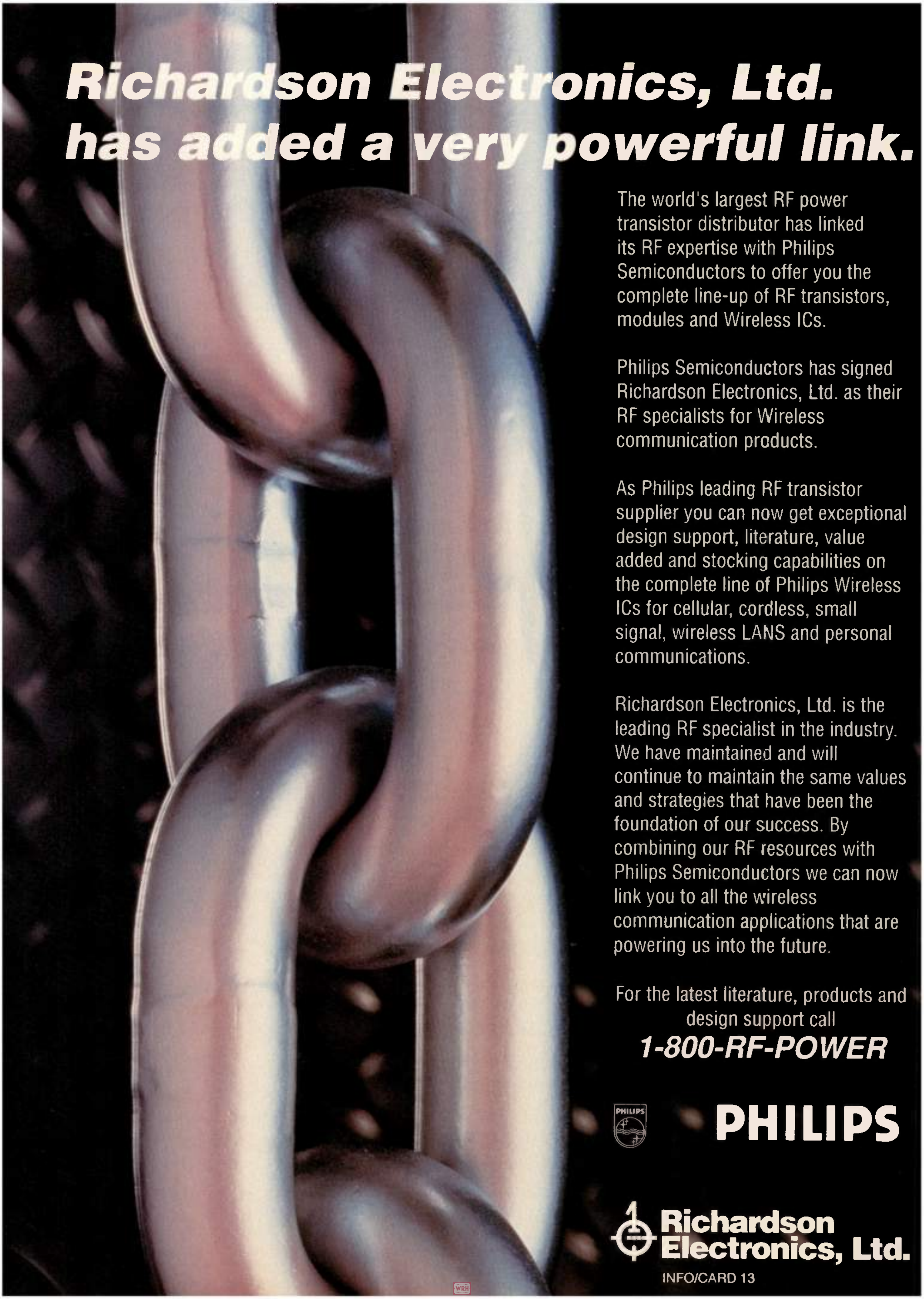
Richardson Electronics, Ltd.
has added a very powerful link.
The world's largest RF power transistor distributor has linked its RF expertise with Philips Semiconductors to offer you the complete line-up of RF transistors, modules and Wireless ICs.
Philips Semiconductors has signed Richardson Electronics, Ltd. as their RF specialists for Wireless communication products.
As Philips leading RF transistor supplier you can now get exceptional design support, literature, value added and stocking capabilities on the complete line of Philips Wireless ICs for cellular, cordless, small signal, wireless LANS and personal communications.
Richardson Electronics, Ltd. is the leading RF specialist in the industry. We have maintained and will continue to maintain the same values and strategies that have been the foundation of our success. By combining our RF resources with Philips Semiconductors we can now link you to all the wireless communication applications that are powering us into the future.
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Richardson Electronics, Ltd.
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RF calendar

January

5-6 **Plastics in Portable Electronics**
Las Vegas, NV
Information: Ms. Deborah Cawley, SPE, 14 Fairfield Drive, Brookfield, CT 06804. Tel: (203) 775–0471. Fax: (203) 775–8490.

16-18 **Second Annual Mobile Communications 95 Conference**
Dallas, TX
Information: Frost & Sullivan Conference Division, 26524 Golden Valley Rd., Suite 401, Santa Clarita, CA 91350. Tel: (800) 256–1076.

23-26 **ComNet 95**
Washington DC
Information: IDG World Expo, 111 Speen St., P.O. Box 9107, Framingham, MA 01701-9107. Tel: (800) 225–4695 or (508) 879–6700. Fax: (508) 872–8237.

26-27 **1995 Measurement Science Conference**
Anaheim, CA
Information: John Schultz, 1280 Bison Ave., Suite B9-530, Newport Beach, CA 92660. Tel: (909) 987–4673 ext 443. Fax: (909) 466–4177.

29-1 **RF Expo West**
San Diego, CA
Information: RF Expo West, Registration Coordinator, 6151 Powers Ferry Rd. NW, Atlanta, GA 30339. Tel: (800) 828–0420. Fax: (404) 618–0441.

29-1 **EMC/ESD International**
San Diego, CA
Information: EMC/ESD International, Registration Coordinator, 6151 Powers Ferry Rd. NW, Atlanta, GA 30339. Tel: (800) 828–0420. Fax: (404) 618–0441.

February

15-17 **IEEE Solid-State Circuits Conference**
San Francisco, CA
Information: Electronic Industries Association, EIA Components Group, 2001 Pennsylvania Avenue N.W., Washington, DC 20006-1813. Tel: (202) 457–4930.

27-1 **Second International Conference on Data Transmission**
London, UK
Information: DT 95 Secretariat, IEE Conference Services, Savoy Place, London WC2R 0BL, UK. Tel: 44–071–344 5478/5477. Fax: 44–071–497 3633.

March

8-15 **CeBIT 95 Hannover**
Hannover, Germany
Information: Mette Fisker Petersen, Project Manager, Hannover Fairs USA, Inc., 103 Carnegie Center, Princeton, NJ 08540. Tel: (609) 987–1202. Fax: (609) 987–0092.

RF courses

Rapid Prototyping: Technologies and Applications
January 23-25, 1995, 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.

Optimal Design of Engineering Systems
January 18-21, 1995, Lake Tahoe, CA
Chemical Vapor Deposition for Microelectronics
January 25-27, 1995, Monterey, CA
Avionics and Weapons Systems Flight Test
February 6-10, 1995, Washington, DC
Ground Vehicle Navigation Systems: GPS & IVHS
February 15-17, 1995, Dearborn, MI
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel: (818) 995–6335. Fax: (818) 995–2932.

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.

Wireless System Design
January 16-20, 1995, Los Altos, CA
Information: Besser Associates, 4600 El Camino Real, Suite 210, Los Altos, CA 94022. Tel: (415) 949–3300. Fax: (415) 949–4400.

DSP Without Tears
January 25-27, 1995, Long Beach, CA
February 8-10, 1995, Denver, CO
Information: Z Domain Technologies, Inc., 325 Pine Isle Court, Alpharetta, GA 30202. Tel: (800) 967–5034, (404) 587–4812. Fax: (404) 518–8368.

International Workshop on Semiconductor Characterization: Present Status and Future Needs
January 30-February 2, 1995, Gaithersburg, MD
Information: Jane Walters, B344 Technology Bldg., Gaithersburg, MD 20899-0001. Tel: (301) 975–2050. Fax: (301) 948–4081.

Digital Cellular Radio
January 17-20, 1995, Washington, DC
Digital Cellular Telecommunications
January 25-27, 1995, Washington, DC
Digital Cellular & PCS Communications: The Radio Interface
February 6-10, 1995, Washington, DC
Analog and Digital Cellular Networks: CDMA versus TDMA
March 6-8, 1995, Washington, DC
The Cellular Telephone System
March 27-29, 1995, 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.

Wireless Office Market to Grow Nearly 20-Fold

The US market for wireless office equipment will expand from $101 million in 1993 to $1.9 billion by the year 2000, at a 52 percent compound annual rate, projects "Wireless Office Markets: Anytime, Anywhere Communications", a new report from Frost and Sullivan. The already dominant wireless local area network segment will increase its share of total revenues from 68 percent in 1993 to 91 percent of the year 2000's much larger market, while the voice segment share – while growing healthily in absolute terms – will plummet from 23 percent to 8 percent and integrated voice/data equipment will fall from 10 percent to 2 percent in the same period. Manufacturing, distribution, higher education, healthcare, and hotels will lead the intra-building wireless LAN market. Large corporate campuses will follow suit toward the end of the decade. Wireless inter-building LAN equipment will also show strong growth, particularly once these match the speeds of today's wired LANs. Radio-frequency based wireless LANs will slightly outsell infrared units. Wireless vendors will give greater attention to offering LANs with varied protocols to cater to a broader base of networking customers.

Future Semiconductors May Use Electrostatic Glue

Researchers in NIST's Materials Science and Engineering Laboratory have patented a process that uses electrostatic charges as an adhesive for naturally acidic surfaces, like silicon oxide and some forms of gallium arsenide, which readily give up protons. The process involves bonding a single molecular layer of a basic chemical (one that takes up extra protons) to the silicon oxide. When the newly-processed silicon oxide and the gallium arsenide come together, the proton exchange creates two oppositely charged surfaces with an electrostatic pull between them. The top layer may be pulled up and repositioned – like a sticky yellow office note – without damaging the adhesive. The process works best with thin, smooth layers.

Call For Papers

The IEE announces a call for papers for the Sixth Annual Conference on Radio Receivers and Associated Systems, to be held September 26-28, 1995, at the University of Bath, UK. Paper topics include RF techniques, signal processing, performance optimization, application-specific receivers, and receiver components. Papers in other related fields, particularly those dealing with system topics and component advances which bear on receiver design, maintainability, and operation costs, will be considered. A 250 word minimum synopsis of the paper should be submitted by February 24, 1995. The selected authors will be asked to provide a full typescript of not more than five camera ready pages, including illustrations. Synopses should be sent to RRAS 95 Secretariat, IEE Conference Services, Savoy Place, London WC2R 0BL, United Kingdom, tel:+44–71–344–5477, fax: +44–71–497–3633, E-mail: conference @iee.org.uk.

Semiconductor Industry Sets Billing Record

The semiconductor industry established a new billings record of $3.16 billion, marking the second time this year that the $3 billion mark was exceeded, according to data collected by the World Semiconductor Trade Statistics and released by the Semiconductor Industry Association. The September book-to-bill ratio of 1.03 for the North American market translates into the tenth consecutive month that the industry surpassed the 1.00 break even mark. A 1.03 bill-to-book ratio means that for every $100 worth of products shipped (billed), manufacturers received $103 of new orders (bookings). The ratio is computed by dividing three-month average bookings and billings. The September book to bill ratio reflected the historical trend as it declined for the ninth consecutive September. The September ratio has been below the 1.00 break even mark six times in the last ten years. September billings were $2.82 billion, a 1.4 percent increase from August's $2.78 billion. Billings increased 31.6 percent over the September 1993 figure of $2.14 billion. 1994 North American market bookings were virtually unchanged for September, at $2.91 billion, although September bookings were 33.5 percent higher than the $2.18 billion recorded in September 1993.

Messiah Engineering Program Accreditation

Messiah College announced the accreditation of its Bachelor of Science in Engineering degree by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. For more information, contact Carl A. Erikson, Jr., Assistant Professor of Engineering, Messiah College, Grantham, PA 17027, tel: (717) 766–2511, fax: (717) 691–6002, E-mail: erikson@mcis.messiah.edu.

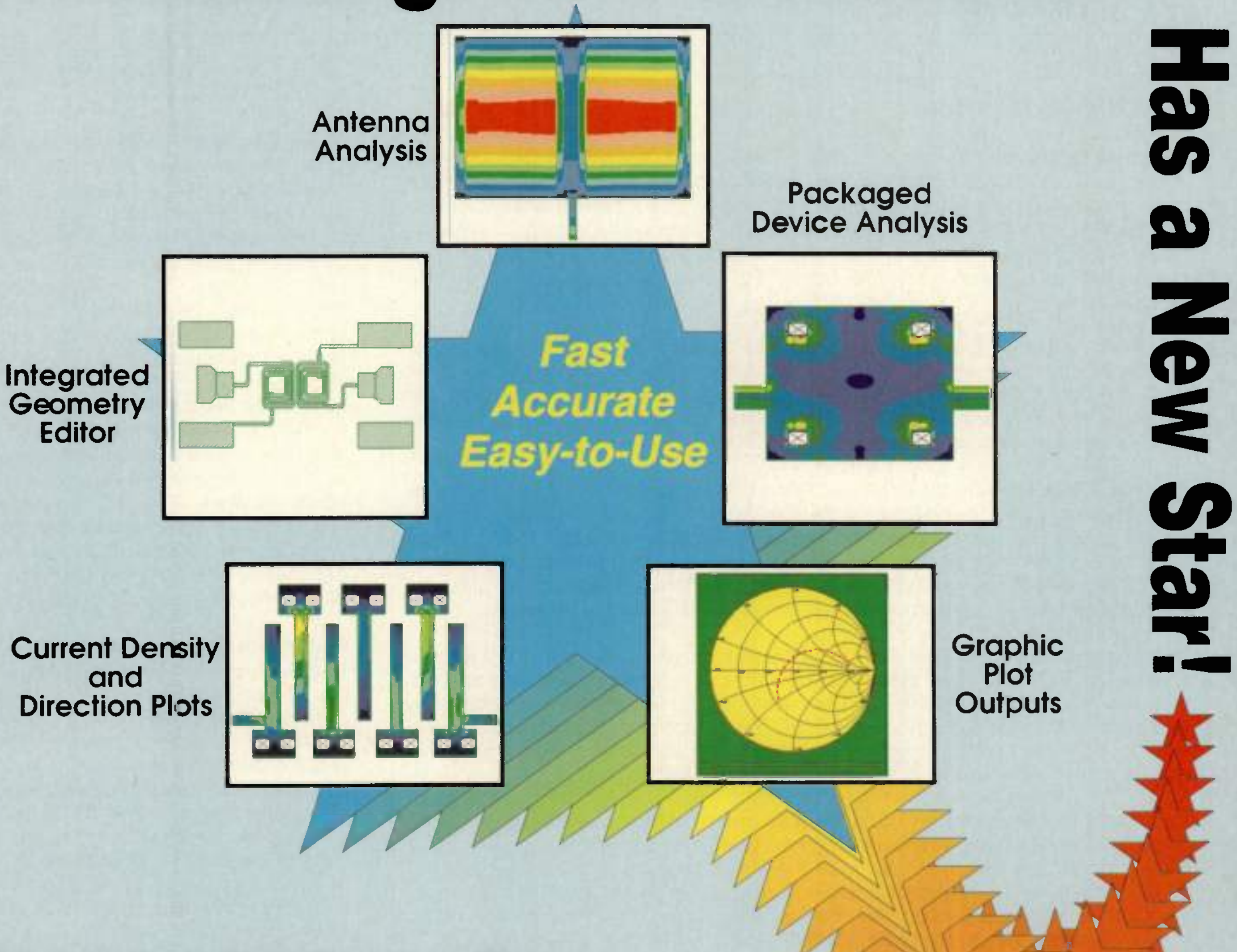
Engineers Observe "Heartbeat" of Superconducting Circuits

Engineers at the University of Rochester have observed the movement of the smallest packet of magnetic charge possible in a superconductor, which makes it possible to measure the "heartbeat" of new ultrafast superconducting electronics. The existence of the single flux quantum (SFQ) was known for some time, but had not been observed until now because the SFQ signal is very fast and faint. SFQ pulses are at the heart of the new ultra-fast electronics that are being created around the country. Detecting and tracing SFQ magnetism is key for engineers trying to build complex superconducting circuits.

Software Helps Engineers Predict Signal

A new software package developed to predict how radio waves transmit and are reflected inside structures could help reduce the cost of installing personal communications systems in offices or other buildings. The patent-pending cell engineering tool (CET) was developed by engineers at the Georgia Tech Research Institute through an applied research program sponsored by Hitatchi Telecom USA. The CET incorporates several distinct analytical methods into a single software package. By describing the geometric configuration of a building's walls, ceilings, windows, and doors, telecommunications engineers can use the tool to make educated judgements about where to locate PCS base stations, thereby requiring fewer stations for the system and reducing system cost.

Electromagnetic Simulation Has a New Star!



Microwave Explorer offers superior Electromagnetic Simulation in both open and packaged environments!

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Business Briefs

Motorola Introduces INReach™ Radio Telephone – Motorola's Cellular Infrastructure Group has introduced its new radio telephone system. INReach™ is a radio telephone system that enables an individual to use a cellular phone to place and receive calls anywhere within a building or campus-like setting. Customers include mid-to-large industrial and commercial businesses for their mobile employees, as well as convention centers, hotels, and resorts for temporary use by visitors and guests.

Wavetek Acquires Communications Test Division from Schlumberger – Wavetek Corporation announced that it has acquired the worldwide assets of the Schlumberger Communications Test Division. The division includes both the Radio Communications Test Equipment business and the Telecommunications Test Equipment business located in Saint Etienne, France.

American Superconductor Achieves Record Performance in a High Temperature Superconducting System – American Superconductor Corporation demonstrated a high temperature superconducting (HTS) magnet system that achieves world record performance. The HTS magnet coil exceeds the threshold of performance required of magnetic coils in commercial motors and generators, and sets the stage for the development of smaller, more efficient electrical equipment.

Micronetics Acquires Sole Rights to Manufacture Qualcomm VCO Line – Micronetics, Inc. announced that it has acquired sole rights to manufacture and distribute wideband Voltage Controlled Oscillators (VCOs) designed and developed by Qualcomm, Inc. Micronetics plans to migrate the Qualcomm VCOs from pin- type to surface mount technology in order to cut production costs, offer more aggressive pricing, and provide customers with a wider choice of packaging options.

Intelligent Instrumentation Wins Data Acquisition Software Competition – Intelligent Instrumentation's Visual Designer Application Generator Software was a winner in the "live test" Competition at the Messcomp show in Wiesbaden, Germany, September 13-16. Manufacturers of nine leading data acquisition and control software packages participated in a live competition to demonstrate their ability to quickly solve a typical data acquisition and control problem.

Intellitag Joins Industry in Statement Supporting 900 MHz AVI Frequency – Intellitag Products has joined nine other electronic toll and traffic management (ETTM) manufacturers in support of continued use of the 902-928 MHz frequency band for Automatic Vehicle Identification (AVI). The statement of support was made to the Federal Communications Commission. The letter recommends the FCC finalize the process for reserving this frequency.

Cadence Outlines Silicon-Based Logic Design™ Technology Roadmap – Cadence Design Systems, Inc. has outlined a strategy for delivering silicon-based Logic Design (SBLD™) solutions that will improve first-run ASIC and IC success for systems designers. The SBLD tools will provide access to physical design information within the logic design process.

Merix Receives Top Award in Oregon Quality Competition – Merix Corporation was named winner of the Governor's award for quality in the first Annual Oregon Quality Awards Competition. Merix was judged best of all applicants against the state's quality performance standards.

Boonton Electronics Corp Moves to New Location – Boonton Electronics Corporation has announced the relocation of its corporate headquarters to a larger facility. The new address is 25 Eastmans Road, Parsippany, NJ, 07054-0465, tel: (201) 386-9696, fax: (201) 386-9191.

Chomerics Acquired by Parker Hannifin Corp. – Chomerics, Inc. has been acquired by the Parker Hannifin Corporation from W.R. Grace & Co. Chomerics will operate as a division of the Parker Seal Group, headquartered in Irvine, CA.

Contracts

Motorola and E.F. Johnson Sign Joint License Agreement – Motorola's Land Mobile Products Sector and E.F. Johnson Company have signed a joint licensing agreement for digital radio technology used in public safety and other markets worldwide. The agreement gives E.F. Johnson technology rights to Motorola's ASTRO™ and APCO Project 25 digital radio products.

RF Power Products Acquires Brounley RF Technology – RF Power Products has acquired critical technology for its next generation of radio frequency power supplies by signing an exclusive five year technology transfer and product development agreement with Brounley Associates. The purchase price includes cash, consulting services, and royalties.

Scientific-Atlanta Gets NASA Contract – Scientific-Atlanta, Inc. will provide two 11 meter antennas with X and S band data reception for the National Aeronautics and Space Administration (NASA) to receive data transmitted by satellites, sounding rockets, and the Space Shuttle. The contact is valued at $11.6 million, with options bringing the total potential value of the award to $23 million.

Aydin Vector Receives U.S. Army Contract – Aydin Corp. announced that it received a U.S Army contract to supply Wideband Telemetry Systems. The contract, which calls for conditioning modules, digital encoding units, and wideband video transmitters to be used in the Weapons Systems Evaluation Program for air-to-ground missiles, is valued at about $3.9 million.

Teknektron and McCaw to Develop PCS Specs – Teknektron Communications Systems, Inc. and McCaw Cellular Communications, Inc. have agreed to develop specifications for personal communications products based on the new IS-136 standard for TDMA digital. The new standard will provide new consumer benefits, and will allow for the development of PCS products and systems.

Trans-tech Gets Duplexer Order – Trans-tech received an order in excess of $20 million from Motorola's Cellular Subscriber Group to build ceramic duplexer filters. The contract covers a two-year span, and will enable Motorola to keep pace with the dramatic growth in demand for its line of cellular phones.

RF Distributors and Reps – Expertise is Part of the Bargain

By Andy Kellett
Technical Editor

RF distributors and representatives hold a special place in the RF marketplace. Whereas some electronic components are sold as commodities (DRAMs, for example) RF components still tend to be specialized devices. RF distributors and reps provide services without which buyers and sellers might never meet.

RF Distributors

What do buyers have to gain by making their purchases through a distributor? Being able to buy a part off the shelf from a distributor is preferable to waiting weeks to get a part directly from a manufacturer. Steve Ulett, Marcom Manager for Penstock, Inc. points out that many companies are reducing paperwork and accounting costs by reducing the number of vendors from which they buy. John Williammee, President of Component Distributors Inc. gives another reason, "Let's face it, distributors offer more flexible credit terms."

Distributors also provide access to large manufacturers for smaller orders. Says Williammee, "The smaller customer gets partnering with a distributor who has significant clout." In addition to acting as liaison between a customer and a supplier, distributors can also be a direct partner in making purchase orders, carrying inventory, scheduling, and delivery says Greg Peloquin Business Unit Manager for the RF Components Division at Richardson Electronics, Ltd., "We've moved to the next step where we actually manage their purchasing and inventory," says Peloquin.

But apart from the advantages of buying from a distributor qua distributor, there are other reasons why many *RF* parts are sold through *RF* distributors. "Front-end design requires a lot of knowledge," says Penstock's Ulett, "so ninety percent of our sales force has at least a BSEE." "[Distributors] have to understand what the customer is saying, but they also have to be able to interpret the answers that the supplier gives them on a technical level," says Richardson's Peloquin.

Selling through a distributor has advantages from the factory's standpoint as well. Distributors can dedicate effort to smaller, second-tier accounts says CDI's Williammee. Williammee points out that a product offered through a distributor lets potential customers know the product is real and available, "It's something that does make a difference on new product introductions."

Clearly, the market for RF and microwave products is growing, and more broadline distributors are interested in getting a part of the RF market. However, a distributor cannot become an RF distributor overnight. Richardson's Peloquin notes that it takes a large dollar investment because of the type of sales people that must be hired, and it takes years of experience with customers to gain their trust in your knowledge.

Of course one way to get that expertise and trust is to buy an established RF distributor, as Avnet did when it acquired Penstock this last July. A source close to the deal that brought Penstock under the wing of Avnet says that people from the Avnet side of the deal acknowledged that it would have taken them five to ten years to gain the knowledge that Penstock has in the RF field.

The changing RF marketplace has also changed the types of products sent from the factories to the distributors. As the larger manufacturers have narrowed their lines in recent years, smaller companies have stepped in to supply the niche markets. "More and more niche suppliers are going after specific markets or programs or applications, as opposed to making broadlines," says Peloquin. CDI's Williammee notes that the broadline distributors often don't want to handle the relatively small volumes most RF component manufacturers deal in.

RF Reps

By acting as a "sales force for hire", manufacturers' representatives (or reps) can offer companies an effective sales effort with less overhead. Setting up a direct sales office can cost $100,000 a year says, Charles Dickinson, President of C/G Associates, Inc, by hiring a rep, a company nominally only pays commission. Another advantage cited by Dickinson is the continuity offered by reps. If a member of a small direct sales staff leaves a company, much of the information that salesperson has gathered is lost and must be regained. A rep firm is more likely to have its market expertise spread out among several people.

In addition to being a substitute for, or an extension of, a direct sales force, reps can offer special selling expertise. For example, AET Associates represents several U.S. RF manufacturers to Japanese customers. "I think 80 percent of the problems U.S. companies encounter in trading with the Japanese are due to a communication gap," says AET Associates President, Dr. Eiji Tanabe. According to Tanabe, Japanese companies find few problems selling to U.S. customers, while U.S. manufacturers have a harder time selling to Japanese customers. "It's a sort of diode effect between the two countries," says Tanabe. Tanabe brings his knowledge of both Japanese language and business culture to potential customers in Japan, narrowing any communication gap between the Japanese buyer and the U.S. seller.

Reps that handle only RF products are certainly not the rule, but there are plenty of those types of firms around says Ben Findley, President of Quattro Sales Associates, Inc. and Vice-President and Chairman of the RF/microwave Marketing Group of the Electronics Representative Association. Reps in the RF marketplace have had to make some adjustments in recent years, but most have easily made those changes. "Many RF and microwave reps were used to working in small volumes and had to adjust to the cost sensitive aspects that you see in the commercial arena, but it hasn't been a significant problem," says Findley.

The services RF distributors offer may be just as important as the parts they supply in helping their customers get a design from the drawing board to the manufacturing floor. Likewise, an RF rep can help a manufacturer with a useful device find customers they may have never known about. *RF*

A Low Cost Doppler Detector

By Milton Luiz Gomes and Adirson Mauro da Silva Jr.
M2SAT Eng. & Cons. ltda

This project is part of an automotive alarm system using the Doppler effect in microwaves. When the Doppler sensor detects a large movement in the area under protection, it transmits trigger pulses to a microcontroller which actuates the vehicle's horn, turns on its blinkers, and turns off the electronic ignition.

According to reference 9, the action of ultrasonic, infrared and laser sensors can be subject to failure or impairment because of weather conditions such as frost, snow or even mud; ultrasonic sensors can become dulled due to heavy rain; and infrared sensors are affected by bright sunlight. All this would thereby favor the choice of the microwave Doppler sensor. The Doppler effect occurs when microwave energy is reflected by a moving target, giving a shift in frequency. All Doppler radars use this principle.

On the international market there are manufacturers that produce Doppler sensor modules in waveguides, which thereby become impractical for use in automotive alarm systems due to high cost and the size of the sensors.

Upon research we concluded that the best answer would be to use a MMIC (Monolithic Microwave Integrated Circuits) based oscillator in order to reduce the sensor cost.

Project Details

Although the costs of active components for microstrip applications at S band are lower than those for X band, the following problems arise from the use of a lower frequency:

1. The target gain is inversely proportional to the wavelength, which diminishes the range of the protected area for the same target size (Figure 1).

2. The Doppler frequency obtained is directly proportional to the target velocity and frequency transmitted, impying a very low Doppler frequency for processing (Figure 2).

3. Free space path loss (Figure 3).

To obtain the Doppler effect with the MMIC, it is necessary that the signal from the local oscillator be transmitted by the input port, at the same time that the signal goes to the mixer to convert the signal which comes from the directional coupler or circulator (see Figure 4). These configurations would necessitate oscillators, mixers, circulators or directional couplers, which in turn, would increase the final cost of the alarm.

A preferable choice would be an integrated mixer and amplifier. To obtain the effect of transmission and reception by the input port, it would be necessary for S_{12} to be equal to S_{21} for non-isolation of the system (Figure 5). Avantek/HP's MMIC MSF8685 was used to avoid high isolation in accordance with functioning on the self-oscillator configuration (Figure 6). We solved the problem of isolation with the RLC circuit seen on Figure 6, which gave rise to a 60% cost reduction, as well as reduced size.

$$P_{out} - P_{in} = \alpha s - 2G_{ant} - G_T \quad (1)$$

where:

P_{out} = Transmitted power (dBm)
G_{ant} = Antenna gain (dBi)
αs = Two-way patch loss from Fig. 3 (dB)
P_{in} = Received power (dBm)
G_T = Target gain from Fig. 2 (dB)

$$P_{out} - P_{in} = \alpha s - 2G_T$$
$$-6 - P_{in} = 80 - 10 - 20$$
$$P_{in} = -56 \text{ dBm}$$

Table 1. Radar equation calculations.

Theoretical and Practical Results

The results seen in Figure 7, were obtained from the spectrum analysis of the oscillator. The transmission line in series with the tank circuit, ensures that the total electrical length of the device, be equal to 360 electrical degrees. The resistor will determine the loss of the tank circuit and at the same time give the maximum gain and change the compression point.

In the final circuit, the resistor was eliminated to maximize the power level delivered to the antenna. This circuit can be seen in Figure 8.

Performance of the System

The antenna used was a rectangular microstrip patch, providing a gain of 5 dBi with a covering range of approximately 120 degrees in the E plane and 90 degrees in the H plane (Figure 9).

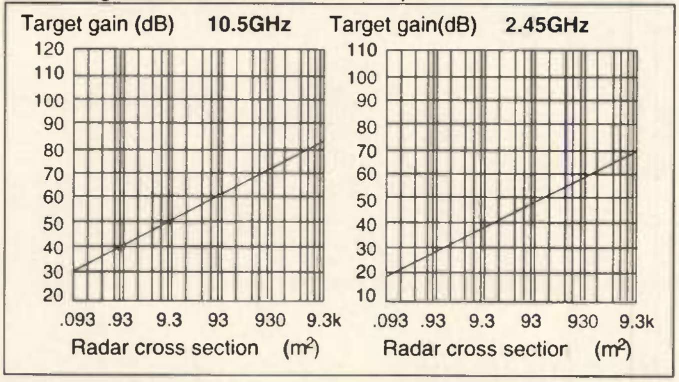


Figure 1. Target gain versus target size for 2.45 and 10.5 GHz.

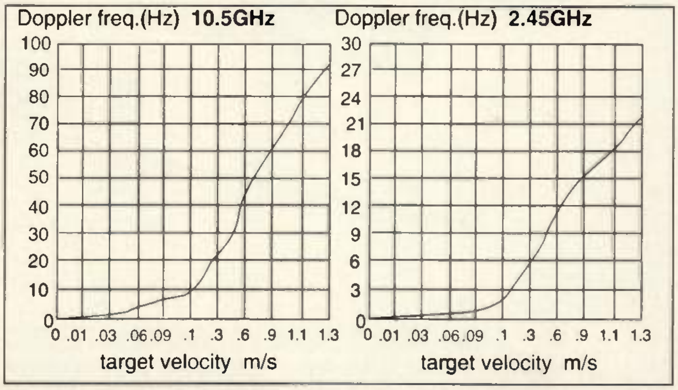


Figure 2. Doppler frequency versus target velocity for 2.45 and 10.5 GHz.

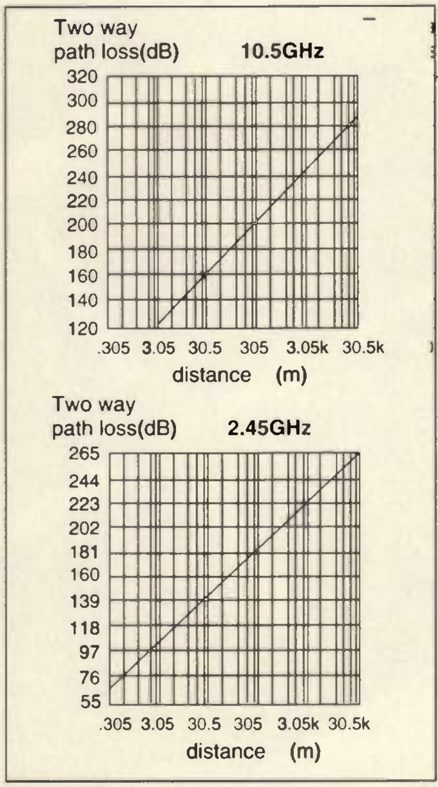


Figure 3. two-way free space path loss for 2.45 and 10.5 GHz.

The system was tested in the laboratory, using a metallic sphere of approximately 35 cm diameter, equivalent to a radar cross section of 0.1 m^2. With a minimum sensitivity adjustment we obtained a range of 1 meter.

Minimum Sensitivity

One way to determine the received power level in the sensor uses equation 1 in Table 1, and Figures 1 and 3 shown before.

Table 1 shows the calculations used to calculate the expected received signal strength. For a –56 dBm received signa level, the audio level for processing is approximately 200 μV_{rms}, which provides a signal to noise ration (s/n) of approximately 16 dB.

The audio level produced by this system is less than that produced by the waveguide modules because of the low video impedance. For this reason, low-noise operational amplifiers were used for processing detected Doppler signal.

Frequency vs. Voltage and Frequency vs. Temperature

The behavior of the oscillator remains stable for a tolerable voltage variation of ±2 V with only frequency deviation.

The frequency drift can be reduced by replacing the tank circuit of Figure 8 with a coaxial resonator. Temperature behavior was found to be very good, the frequency drift remaining around ±300

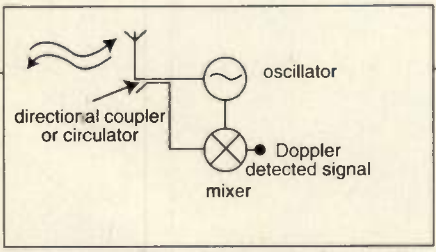


Figure 4. Circuit to produce illuminating signal and to detect Doppler signal.

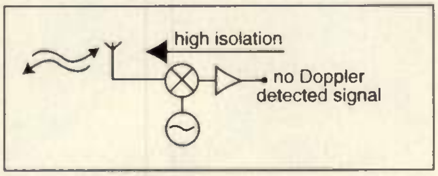


Figure 5. High isolation prevents Doppler detection

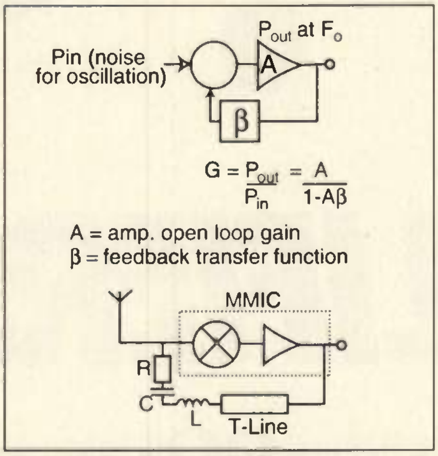


Figure 6. Self oscillating circuit using a MMIC and feedback network.

kHz for a temperature variation between 0 and 80 °C.

Final Circuit

Figure 10 is a photograph of the detector circuit and processor. The block diagram shown in Figure 11 shows the processing sequence. (The detector provides a trigger pulse to the alarm activating processing sequence.)

The circuit was built on a fiberglass circuit board material, using surface mount components. The results obtained were a total success. The number of false alarms was nearly reduced to zero by the use of the microcontroller.

Defects did not occur related to detector caused by stress due to vibration, thermal variations or noise produced by the vehicle itself. The circuit was duly patented in Brazil.

Electromagnetic Field Exposure

During the running of the vehicle, the

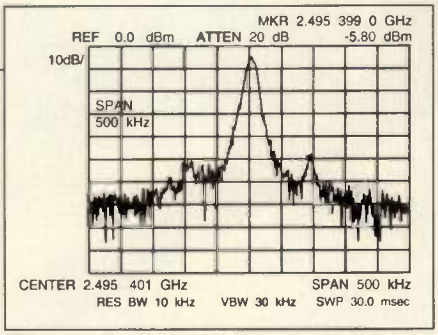


Figure 7. Spectral output of the oscillator.

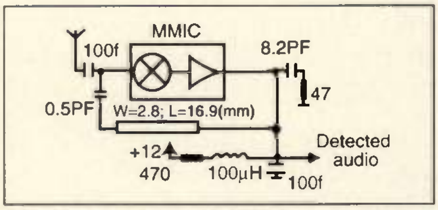


Figure 8. Actual implementation of Doppler detector.

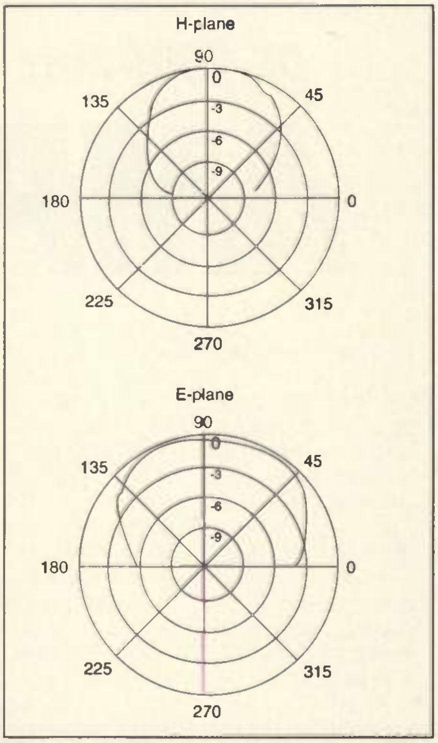


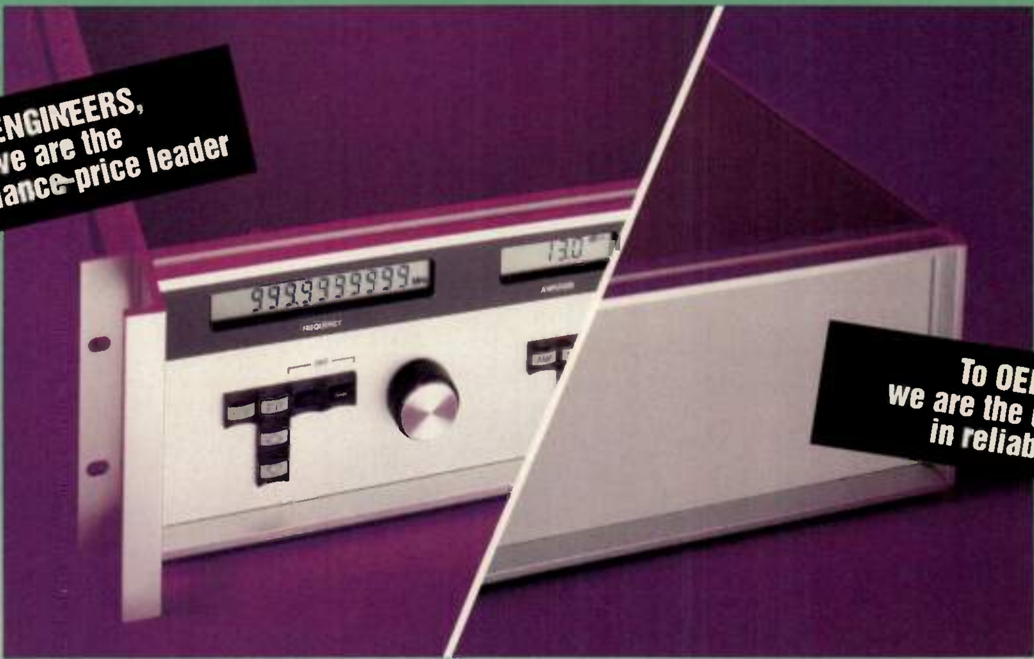
Figure 9. Typical antenna radiation patterns for patch antenna.

oscillator remains turned off, thereby safeguarding the user from any electromagnetic radiation. Also, when the car is stationary, the potential density remains at safe levels. According to ANSI C95.1-1991 rules, the level permitted for human body exposure at 2.45 GHz is 1.0 mW/cm^2. Table 2 shows the calculations used to find the power density.

Conclusions

The Doppler effect could be usefully

Split Personality



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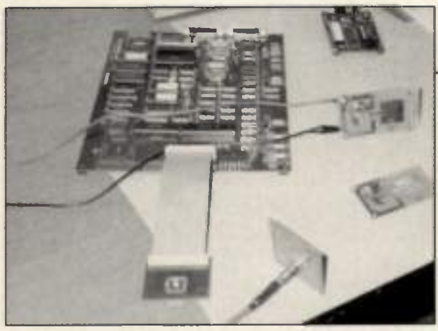

Figure 10. Photo of detector circuit and processor.

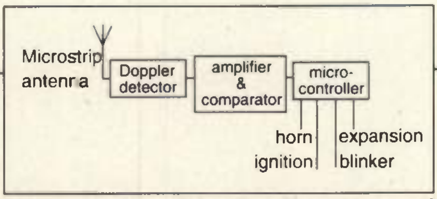

Figure 11. Block diagram of entire security system.

applied in many problems. With the advance of technology, costs are falling, thereby making the use of Doppler an increasingly useful and important tool. *RF*

$$DP = \frac{P \cdot G}{4\pi R^2} \qquad (2)$$

where:

P= transmitted power (mW)
G = antenna gain (dBi)
R = Distance for determined power density (cm)
DP = power density (mW/cm^2)

R>0.28 cm for a safe level r = 0.28 x 10 = 2.8 cm

where the factor of ten is a safety factor

Table 2. Power density calculations for exposure levels.

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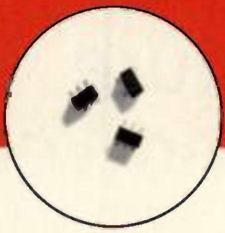

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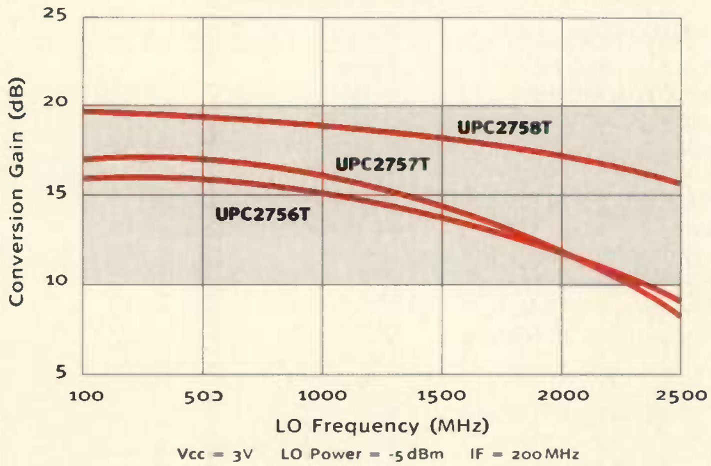
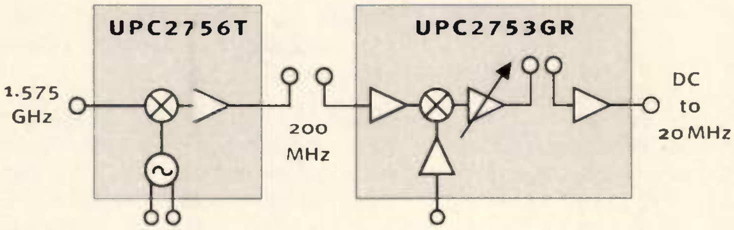


RECEIVER LINEUP



TYPICAL SPECIFICATIONS

PART	OPERATING VOLTAGE	I_{CC}	CONVERSION GAIN	OUTPUT IP3
UPC2758T[1]	3V	11mA	17dB	+10dBm
UPC2757T[1]	3V	5.6mA	13dB	+5dBm
UPC2756T[2]	3V	5.9mA	14dB	+5dBm

1. Measured at 2.0GHz 2. Measured at 1.6GHz

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New UHF Receiver Architecture Achieves High Sensitivity and Very Low Power Consumption

by Darrell L. Ash, Sr. VP of Engineering
RF Monolithics, Inc.

For the first time in more than 50 years, a basically new receiver architecture has been conceived and realized. This receiver's characteristics are ideal for short range RF link applications. Without adjustments or critical PC board layouts to contend with, this new SAW-based receiver demonstrates superior range performance compared to conventional receivers. The new receiver operates from a 3 volt lithium button cell with a current drain of approximately 1 mA. The receiver is entirely self-contained, with an RF antenna input port and a CMOS compatible data output port in a small surface mount package. Unlike other receivers, the new receiver reliably operates in today's crowded frequency spectrum due to outstanding frequency selectivity.

Short range, unlicensed RF links are becoming extremely popular all over the world [1]. The applications include, but are not limited to, garage door and gate openers, remote entry/anti-theft systems for automobiles, wireless security systems for homes and businesses, remote utility meter readers, wireless bar code readers and wireless computer/peripheral links. These links are primarily in the 200 to 960 MHz UHF band. For example, the most popular frequency in Europe is 433.9 MHz, the Far East primarily uses 303.8 MHz, and the popular US frequencies include 303.8 MHz, 315 MHz, 345 MHz, 390 MHz, 418 MHz and the 902 to 928 MHz band [2]. The transmitter power output is typically regulated to less than 1 milliwatt for these applications. Most of the transmitters used in such applications are now SAW stabilized to prevent frequency drift with temperature and time, and to simplify meeting regulatory requirements for harmonic levels [1]. Receivers used in the past have primarily been inductor/capacitor-stabilized superregenerative receivers with their inherent problems of poor stability, little or no frequency selectivity, and poor sensitivity. More recently, SAW-stabilized superregenerative receivers [3] and SAW-stabilized superheterodyne receivers [4] have been used to improve the performance of such systems.

The receiver is the limiting factor in most low power RF links. There are primarily four areas of concern: performance, cost, manufacturability, and ease of design and interface in the engineering phase. Included in these four areas of concern are the following industry needs:

- Most applications need improved range. The typical open-air, line-of-sight range for such systems varies from 100 to 300 feet. This range is further degraded when the receiver is placed inside an automobile or building. The primary factors that affect range are receiver sensitivity and selectivity.
- Many of the receivers are powered by battery. As a result, the power consumption must be lowered.
- "Tweaks" or adjustments need to be eliminated to make the receiver more engineering- and manufacturing-friendly as well as to improve its reliability.
- Minimizing the number of receiver components and the PC board space.
- Engineers with little or no RF experience should be able to design the receiver into their system with predictable results.

Receiver Architecture Background

Around the turn of the century, the first RF receivers were simple diode detectors, as shown in Figure 1a. The receiver drove a set of headphones. This receiver was not very sensitive so an RF amplifier was added, (see Figure 1b). The sensitivity was then limited by the amount of stable gain that could be achieved in the RF amplifier.

Prior to World War II, the super-regenerative receiver was conceived, as shown in Figure 2. The extremely high gain exhibited by an oscillator during its turn-on cycle was used to advantage in this type of receiver. The RF oscillator was turned on and off by a quench oscillator running at many times the frequency of the modulated data to be recovered. The oscillator turn-on time was changed by the level of the incoming RF signal applied to it. This change in turn-on time manifested itself as a change in the average power output of the oscilla-

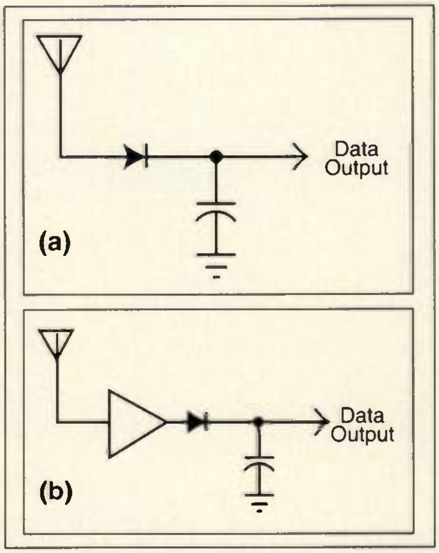


Figure 1. Diode detector receiver (a), and Diode detector receiver with amplifier (b).

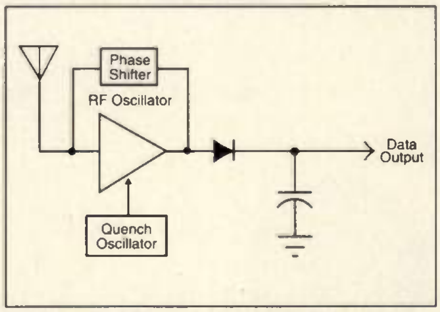
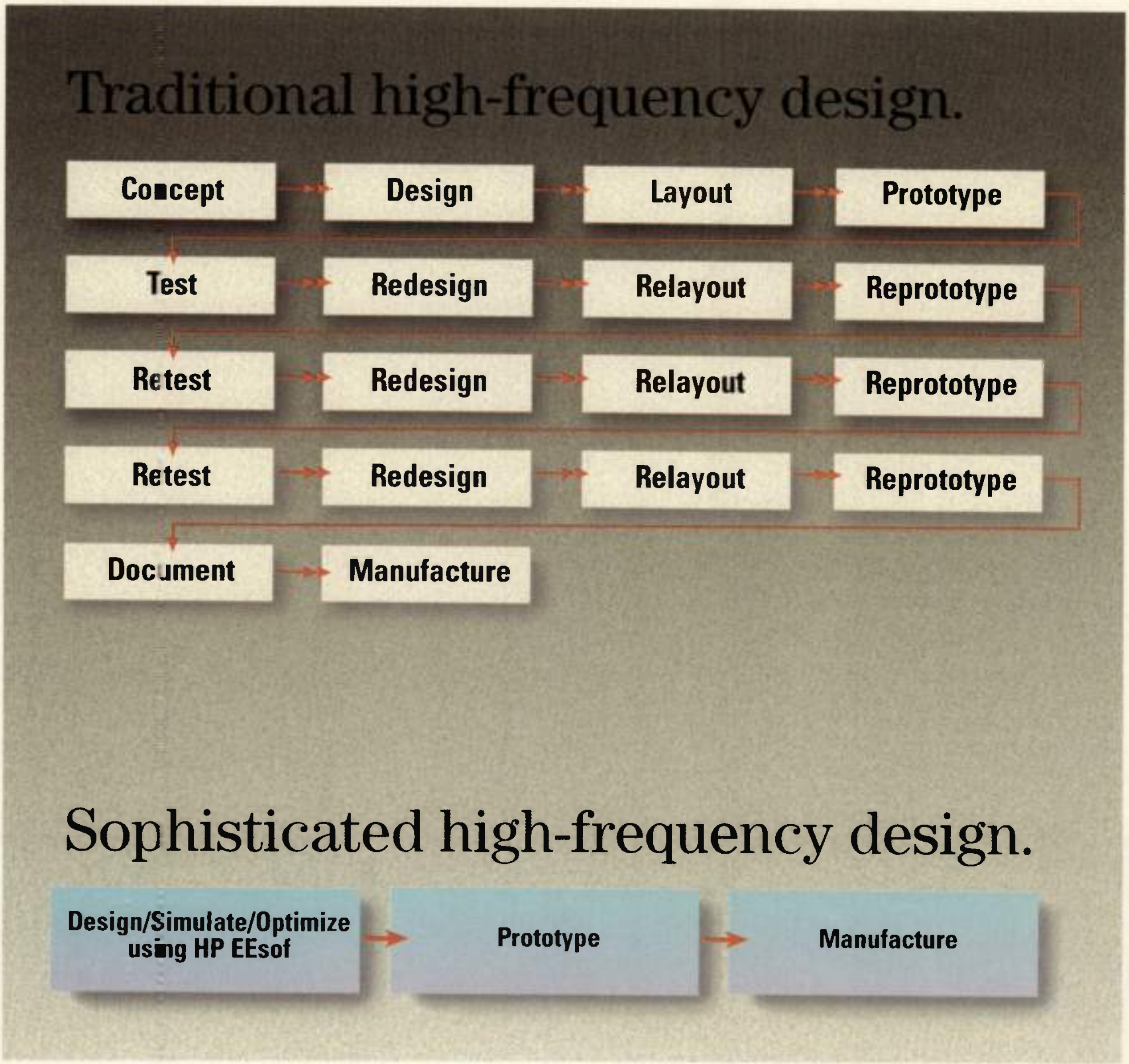


Figure 2. Superregenerative receiver.



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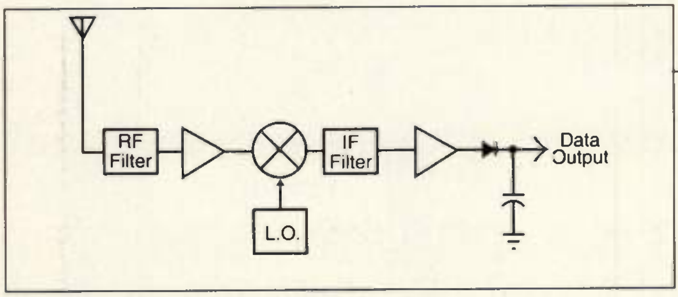

Figure 3. Superheterodyne receiver

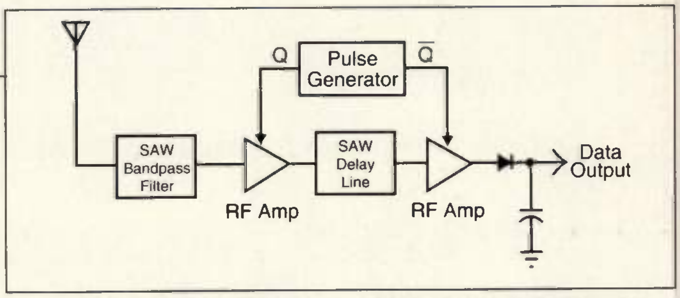

Figure 4. Amplifier Sequenced Hybrid (ASH) Receiver.

tor, which could be detected with a simple detector circuit, as shown in Figure 2. A primary disadvantage of this type of receiver was the need for at least two critical adjustments. The oscillator center frequency had to be adjusted to the desired signal frequency, and the oscillator turn-on time had to be set by adjusting the bias or gain of the amplifier. If the oscillator reached saturation too soon, the gain or sensitivity of the resultant receiver would be greatly decreased. Adjustment was, and still is, a balancing act. An advantage of this type of receiver is the low current requirement from the power supply.

The superheterodyne was the next receiver architecture to be conceived (Figure 3). This receiver is really a return to the amplified diode detector receiver. The superheterodyne receiver solved the stability problem of the simple amplified detector receiver and thus allowed a great increase in sensitivity. By splitting the gain between an RF amplifier and an IF amplifier, the stability issue was resolved. The principle at work here is simple frequency diversity. The RF amplifier and the IF amplifier are not at the same frequency, so the feedback from the IF amplifier output to the RF amplifier input does not cause a stability problem. Even more stable gain can be achieved with such a receiver by increasing the number of conversions or IF's. In addition, the RF filter and the IF filter allow more rejection of unwanted signals than could be achieved by cascading RF filters, once again due to frequency diversity. The primary disadvantages of this receiver architecture are the need for a stable RF oscillator, mixer spurious responses, critical circuit board layout, relative complexity, the need for adjustments, higher cost, and high current consumption.

The ASH Receiver

A basically new type of receiver has been conceived at RFM to address the shortcomings of previous receiver architectures in short range RF link applications. This new receiver architecture achieves the same result as the superheterodyne receiver, but it uses the principle of time diversity rather than frequency diversity. Figure 4 is a simplified block diagram of the new amplifier-sequenced hybrid (ASH) receiver [5]. Referring to Figure 4, the incoming sig-

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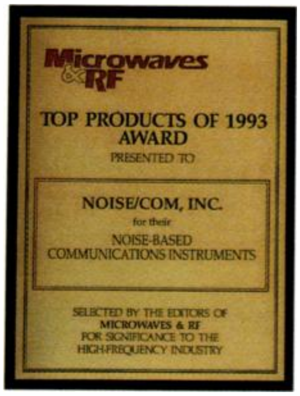

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Wireless Telecom Group ensures the quality of its products by maintaining a modern inspection system (ISO-9001 certification will be completed in the near future). In addition, certified instructors, inspectors, and assemblers for the MIL-STD-2000 workmanship standard are in-house. Wireless Telecom Group's EMI-shielded calibration department has standards traceable to NIST.

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Wireless Telecom Group has a broad customer base. It includes 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.

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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, a series of innovative two-page, four-color ads was inserted in five international magazines. Additionally, the Company's new products were featured on five exclusive magazine front covers. Wireless Telecom Group also presented a major paper at the Wireless '94 conference in California.

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

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NOISE/COM WIC Wireless International Corp.

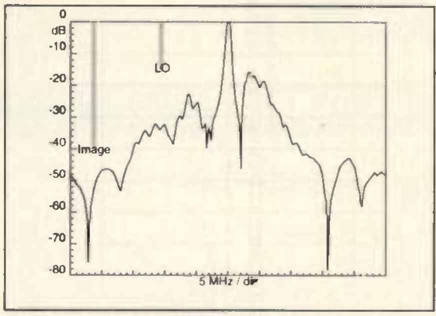

Figure 5. 433.92 MHz coupled resonator filter.

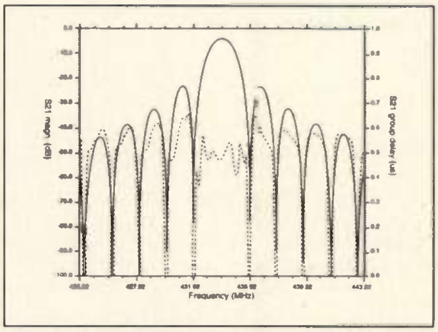

Figure 6. Frequency response of 0.5 μs SAW delay line.

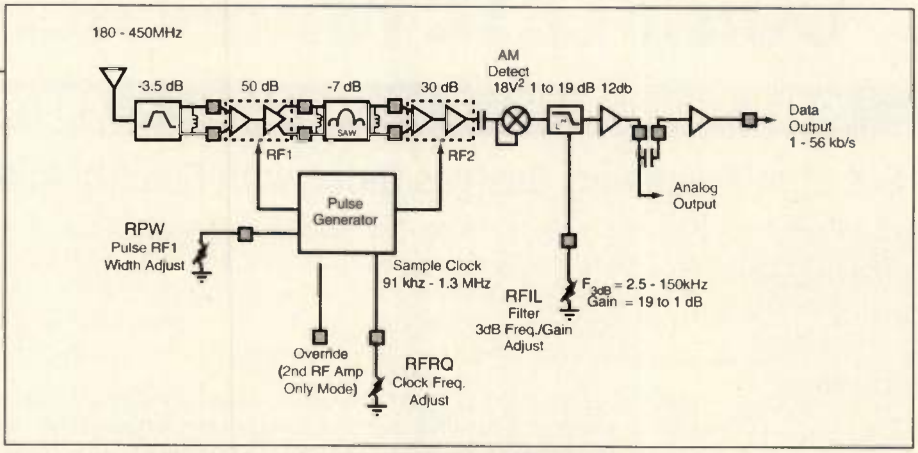

Figure 7. ASH receiver functional block diagram.

nal is first selected by the SAW bandpass filter and then applied to the first RF amplifier. This RF amplifier is turned on by the pulse generator. The output of the RF amplifier is then applied to the input of a SAW delay line. As is illustrated in the diagram, the second RF amplifier is turned off when the first amplifier is on and vice versa. When the signal is emerging from the delay line, the first amplifier is turned off and the second amplifier is turned on. The output of the second amplifier is then applied to a detector circuit. Gains similar to that of a single-conversion superheterodyne receiver can be achieved with this new receiver with excellent stability. Since the two amplifiers are not on at the same time, feedback from one amplifier to the other does not cause the circuit to become unstable. The delay of the delay line is chosen to obtain hundreds of samples per incoming data bit. A typical delay used is 0.5 microseconds. The gating signal is then simply removed from the data signal with a low-pass filter following the detector.

The amplitude response of the SAW delay line is tailored to provide further filtering of the incoming signal prior to detection. The out-of-band rejection of both the SAW bandpass filter and the delay line filter is approximately 50 dB each. Normally, two filters at the same frequency would be limited in out-of-band rejection to much less than the resultant cascaded 100 dB by the crosstalk level that could be achieved with a particular circuit layout. However, the same mechanism that provides isolation between the two amplifiers completely eliminates crosstalk as a factor in the delay line filter. Crosstalk around the delay line filter is effectively gated out by the switched amplifiers. When the signal is present at the input of the delay line, the second amplifier is turned off. Since crosstalk is instantaneous, any signal leaking around the delay line filter is simply ignored. Only the desired delayed signal is amplified in the second amplifier. The result is a receiver with sensitivity similar to a superheterodyne receiver and approximately 100 dB of rejection to undesired out-of-band signals.

The analogy between the superheterodyne and ASH receivers is also true for further increases in receiver gain. Additional switched amplifiers and delay lines can be added to the ASH receiver to further increase the available stable gain just as additional frequency conversions can be added to the superheterodyne receiver.

The ASH receiver architecture has many advantages over previous architectures including the superheterodyne receiver. All of the functions, except the two SAW devices, can be included in a single custom integrated circuit, making it possible to put the entire receiver in a small hybrid package. No adjustments are needed since the frequency of the receiver is entirely determined by the two SAW devices. No RF oscillators are included in the ASH receiver, completely eliminating concerns about meeting strict LO radiation levels specified by the various regulatory agencies. The absence of an LO also eliminates concerns about spurious mixer responses like the image frequency.

ASH Receiver Implementation

The primary goal was to develop a new receiver that could be included in a surface mount package of approximate dimensions 0.5 × 0.4 × 0.1 inches. The surface mount module was to accept an RF input from an antenna and have a data output capable of driving CMOS logic. This requirement was driven by the recent introduction by RFM of a hybrid transmitter module in a similar style surface mount package of dimensions 0.4 × 0.34 × 0.1 inches. The hybrid transmitter has a CMOS-compatible modulation input and a pulse modulated RF output with greatly suppressed harmonics to meet regulatory requirements. Thus, the desire was to have a companion receiver module. As mentioned in the previous section, this receiver architecture lends itself well to total integration of all of the active functions with the SAW devices performing the filter and delay functions. The frequency range had to be limited to ease the design requirements for the RF amplifiers in the proposed custom IC. The target specifications for the new receiver are listed below:

- Center Frequency: 180 to 450 MHz.
- Pulse Modulation (On/Off Keyed)
- –100 dBm sensitivity at a1.0 kb/s data rate
- 50 Ω input impedance
- 80 dB ultimate out-of-band rejection
- –20 dBm maximum desired signal level
- 500 kHz minimum RF bandwidth
- Operate with 2.7 to 3.5 volts battery voltage
- 1.0 mA current at 3.0 volts and 25° C
- Work with varying duty cycle data

A secondary target specification was to make the receiver capable of handling data rates up to 56 kb/s with a sensitivity of –85 dBm. This meant the receiver baseband bandwidth and sampling rate would necessarily be variable to allow the receiver to be optimized for various data rates. The current consumption was expected to increase with higher data rates.

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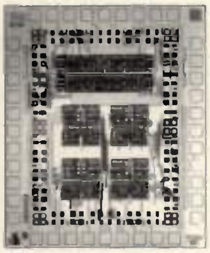

Maxim's QuickChip design automation approach consists of several "core" array families of high-speed bipolar transistors, capacitors, and resistors, optimally configured for interconnection. QuickChip arrays are easy to use, and since there are only a few masks to design, QuickChip is less expensive and less time consuming than the full custom approach. Once final designs are completed and approved, finished wafers can typically be delivered within 4 weeks.

This QuickChip 7 array on the GST-1 process has one digital (ECL) macro-tile and four analog macro-tiles for a total of: 592 NPNs, 56 PNPs, 64 Schottky diodes, 64 ESD diodes, 1,408 resistors, 48 MOS capacitors, and 40 pads.

QuickChip Project Flow

Definition (4 weeks)

Determine feasibility, establish objective specifications, choose process, order software.

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Maxim engineers will train you to use QuickChip Design Tools included in the QuickTools package: ADS (Analog Design System), QuERC, and QuicKic.

Design & Layout (project dependent)

Using ADS, you design and simulate the circuit, check electrical rules with QuERC, and layout IC with QuicKic. Maxim will review both design and layout.

Tapeout & Wafer Fabrication (4 weeks)

Using your QuickChip design, Maxim will manufacture die. Up to four custom masks required.

Packaging (3 weeks)

Maxim packages ICs. Over 95% of 1st pass ICs meet the original objective spec. Production testing available.

Delivery of Prototypes

Final prototypes can be evaluated in your system.

World-Class Design Tools and Process Capabilities

Maxim's design tools shorten design time and help meet target specifications on the first pass.

QuickTools is a powerful software package that provides design engineers with complete IC, schematic, simulation, and layout capabilities. It includes:

- **ADS,** an integrated schematic capture, circuit simulation, results processing, and display environment.
- **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**.
- **GST-1** is a high-speed self-aligned double-polysilicon bipolar process ideally suited for highly integrated, mixed analog, and digital ICs. **GST-2** offers the highest speed and device density, with 27GHz f_Ts and up to 60K gates/IC.

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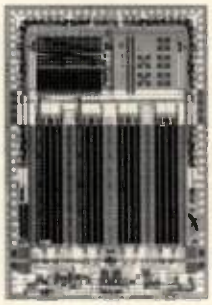

In addition to the QuickChip approach, Maxim also offers a high-frequency full custom capability. This method is ideal for high-volume products where optimized unit cost reduction and ultimate high frequency performance are key factors. Full custom offers complete flexibility in choosing individual devices and location. Your custom IC can be fully designed by either Maxim's experienced design staff or by your own skilled analog designers using Maxim's design tools.

This 8-bit 500 Msamples/sec A/D converter is a full custom design. It has full flash topology and greater than 500MHz small signal bandwidth.

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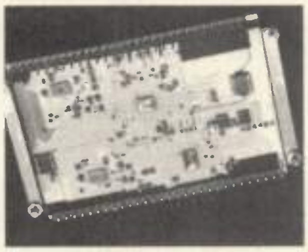
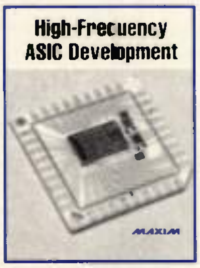


Our high-frequency hybrid design and manufacturing group can develop your complete system. Using HCAD-III, an internally developed hybrid software design and layout system, multi-chip modules (MCMs) can be developed that will work right the first time. Process capabilities include: thick film, thin film, multilayer ceramic, MCM, chip and wire, mixed technologies, electro-optic, and electrical test and trim up to 60GHz. Examples of previously designed hybrids include 350MHz video display drivers and ATE pin drivers for 100MHz test systems. Our high-frequency packaging and assembly expertise is second to none! Let Maxim help you with high-frequency problems.

This multichip module uses two full custom Maxim ICs and two custom CMOS ICs. It represents a complete 200MHz analog oscilloscope on a board.



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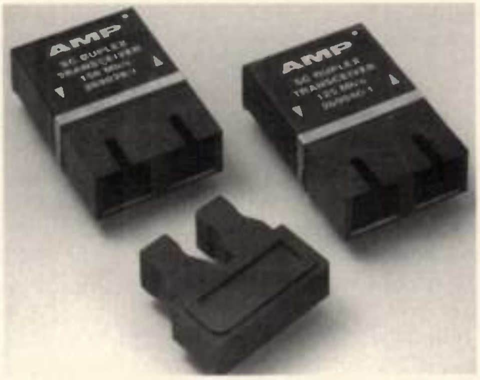
Case History #6: *AMP FDDI and ATM molded optronic transceivers contain three Maxim QuickChip semicustom ICs for fiberoptic communication physical media solutions. These QuickChips use Maxim's high-speed bipolar process. In addition, Maxim's module capability, including precision chip-on-board processing, enables AMP to simplify the assembly process.*



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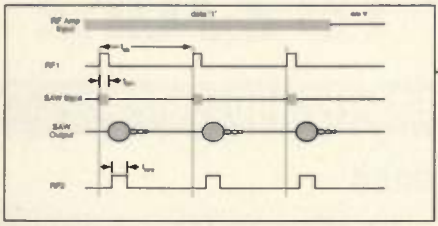

Figure 8. Sequential gain timing.

Front-End SAW Filter

Referring to Figure 4, the front-end filter was most easily realized using SAW coupled-resonator technology [6,7]. The 500 kHz minimum bandwidth could be realized using such a filter and the insertion loss of such a device is lower than that of a SAW transversal filter. An insertion loss of 3.5 dB was achieved at a center frequency of 433.92 MHz. The close-in frequency response of this filter is shown in Figure 5A and the wideband response is shown in Figure 5. The filter has a 2-pole characteristic roll-off rate and exhibits 50 dB out-of-band rejection. This filter is very similar to the RFM RF1172 device used as an RF front-end filter in superheterodyne receivers with a 10.7 MHz IF [8].

SAW Delay Line

Referring to Figure 4, the delay line was realized using a new low loss single phase unidirectional transducer (SPUDT) technology [9]. A delay of 0.5 microseconds was chosen as a compromise to make the input and output SAW transducers long enough to facilitate the customization of the input and output impedance levels, but not long enough to make the chip size cost prohibitive. This made the design of the RF amplifiers in the custom IC much easier. The final design impedance was approximately 400 Ω. In addition, the 0.5 microsecond delay allowed the sample rate in the receiver to be such as to provide hundreds of samples per data bit at the 1 kb/s data rate. The maximum insertion loss of the resulting delay line was 7 dB and the frequency response is included in Figure 6. Another prime consideration in the design of the delay line was to provide additional RF filtering in the receiver. A bandwidth of 1.5 MHz was chosen to provide the needed filtering. This bandwidth was also easy to achieve without compromising the size of the SAW chip. The cascaded responses of the coupled-resonator-filter of Figure 5 and the delay-line of Figure 6 should theoretically yield approximately 100 dB rejection removed 30 MHz from the 433.92 MHz center frequency.

Sampling/Sensitivity Considerations

Figure 7 includes a functional block

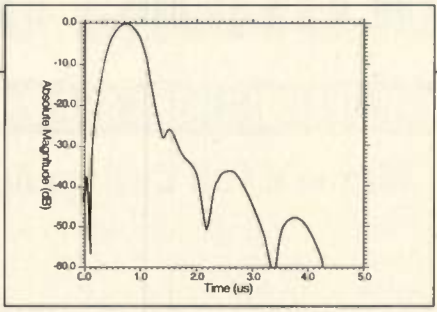

Figure 9. 0.5 μs SAW delay line response to a 0.5 μs RF pulse.

diagram of the custom IC developed for the receiver by RadioCom Corporation. This diagram includes the SAW devices, various control resistors and baseband coupling capacitor. The diagram also shows the gain and loss values for the signal path. Figure 8 is a diagram of the sequential gain timing. Referring to Figure 8, the first line represents the pulse on/off modulated RF signal at the input to the first RF amplifier. A data "1" is carrier on and a data "0" is carrier off. The "RF1" line represents the clocking of the first RF amplifier. When the pulse is high, the amplifier is turned on and vice versa. The "SAW input" line represents the RF pulses applied to the input of the delay line. The "SAW output" line represents the RF output of the SAW delay line and the "RF2" line represents the clocking of the second RF amplifier. Figure 8 also demonstrates that the data is sampled many times per bit by the switching of the two RF amplifiers. As described before, the two RF amplifiers are clocked sequentially to prevent feedback instability in the receiver. The second RF amplifier is turned on immediately after the first amplifier is turned off. The "on" time of the first RF amplifier is equal to or slightly greater than the delay of the delay line. The "on" time of the second amplifier is approximately 1.1 times the "on" time of the first amplifier since the delay line stretches the pulse time to some extent. To illustrate the pulse stretching by the delay line, Figure 9 includes the time response of a 0.5 microsecond SAW delay line to a 0.5 microsecond RF pulse.

The impact on the receiver sensitivity created by sequencing the first RF amplifier (sampling the RF input signal) can be modeled simply by preceding RF1 with a fixed attenuator whose loss is 10(Log(RF1 duty factor)). This is shown in the block diagram of Figure 10. The RF1 duty factor is the ratio of the amplifier "on" time to the time for one complete clock period. Thus, a 10% duty factor would increase the noise figure of the receiver and decrease the sensitivity by 10 dB over that which could be obtained with RF1 on 100% of the time. However,

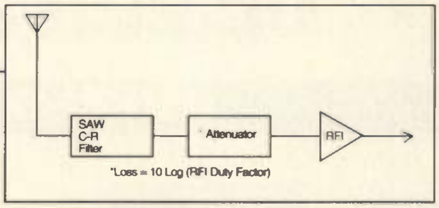

Figure 10. Impact of clocking RF1.

an advantage of duty cycling the RF amplifiers is the resultant decrease in the average current consumption by the receiver. The two RF amplifiers require far more current than the remainder of the circuitry, making it possible to greatly reduce the current in the receiver by lowering the time the amplifiers are on. Since the two amplifiers consume approximately the same current, the receiver architecture already decreases the current by 50%, because the amplifiers are never on simultaneously.

The block diagram of Figure 7 illustrates that the custom IC also includes the clock/pulse generator, a square-law detector following RF2, a 3-pole low-pass filter in the baseband circuit, an operational amplifier and, finally, a data comparator with a built-in threshold. The pulse width of the "on" pulse for RF1 can be changed by changing the value of the resistor, RPW, and is entirely dependent upon the delay of the delay line. The pulse width of the "on" pulse for RF2 is automatically set to 1.1 times that of RF1. The clock rate or period can be changed by changing the RFRQ resistor value. Thus, pulse width and duty factor can be adjusted for any application by setting the values of these two resistors. The bandwidth of the post-detection circuit can be changed by varying the value of RFIL. The value of the coupling capacitor between the operational amplifier and the comparator input depends upon the maximum "on" or "off" time of the data stream.

Noise Power Bandwidth

The noise power bandwidth of the receiver is 2× the 3 dB bandwidth of the low-pass filter following the detector. The required bandwidth of the baseband low pass filter depends upon the desired data rate. The bandwidth should be more than 2× the maximum expected bit rate. The parameters of concern are the rise and fall times of the individual data pulses being presented to the input of the comparator. If the rise and fall times are not small compared to the width of the data pulse, the pulse emerging from the comparator will be wider or narrower than the original pulse. The maximum bit rate divided by 2 is the maximum expected frequency to be encountered in the data stream. Thus, the preferred bandwidth is a minimum of 4× the maximum data frequency The other factor directly related to baseband bandwidth that must not be overlooked is that of receiver sensitivity. For example, the receiver sensitivity is reduced by 3 dB if the baseband bandwidth is doubled. Thus, the sensitivity of this, or any receiver, is dependent upon the maximum data rate.

Final ASH Receiver Characteristics

The final surface mount package dimensions for the complete ASH receiver are 0.540 × 0.370 × 0.1 inches. The case outline drawings for the new hermetic package are shown in Figure 11. A block diagram showing the components and electrical connections required outside the receiver hybrid module is included in Figure 12. There are ten solder pads on the module, three of which are ground connections. Other than the antenna, only three external components are required. All three of these components are capacitors whose values are not critical. A bypass capacitor of 10 µF is used on the 3 volt V_{cc} connection to both reduce externally generated noise on that line and to reduce crosstalk between the various functions included in the custom IC. For example, it is not desirable to have residuals from the internal clock generator present on the power supply line for the baseband operational amplifier and comparator circuits. A coupling capacitor, whose value depends upon the data rate, is required between the baseband output and comparator input pads. One of the design considerations was to capacitively couple these two amplifiers to reduce the impact of a CW or FM interfering signal on the performance of the receiver. Such a signal would generate a DC level on the output of the detector and the first operational amplifier. Such a DC level would cause the comparator to slam to one rail or the other on its output. The capacitor blocks the DC and passes only data pulses. The third capacitor is a 1.0 µF bypass capacitor on the voltage reference pad. This internal voltage reference must be bypassed to prevent instabilities in the various references used in the baseband amplifier chain.

Referring to Figure 12, the RF input from the antenna is applied to pin 10 of the receiver. Best sensitivity is obtained if the antenna impedance is close to 50 Ω. A large VSWR presented to the receiver input will not cause instability problems but the resulting mismatch loss will reduce the sensitivity. The ground pin 9 is the RF ground point associated with the antenna input. Other than presenting a decent impedance to the receiver input, the PC board layout for the receiver is entirely non-critical. There are no points where the RF signal comes back out of the package for processing. The baseband output signal on pin 2 is the raw demodulated, unprocessed data. At signal levels up to the point where the operational amplifier begins to limit or saturate, the level of the data at pin 2 is dependent upon the input RF level. Thus, this output could be used for any function dependent upon signal level such as ranging, direc-

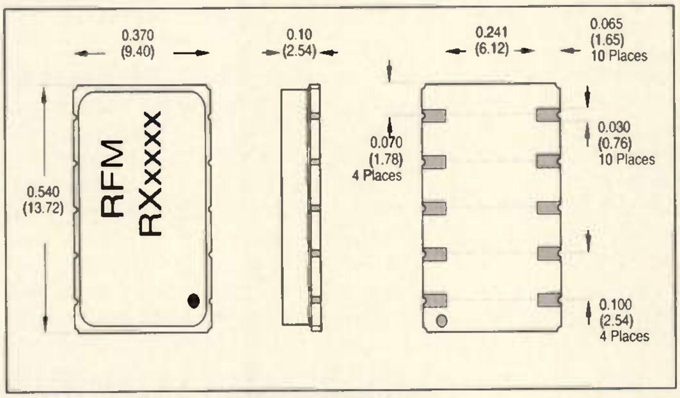

Figure 11. Surface mount package.

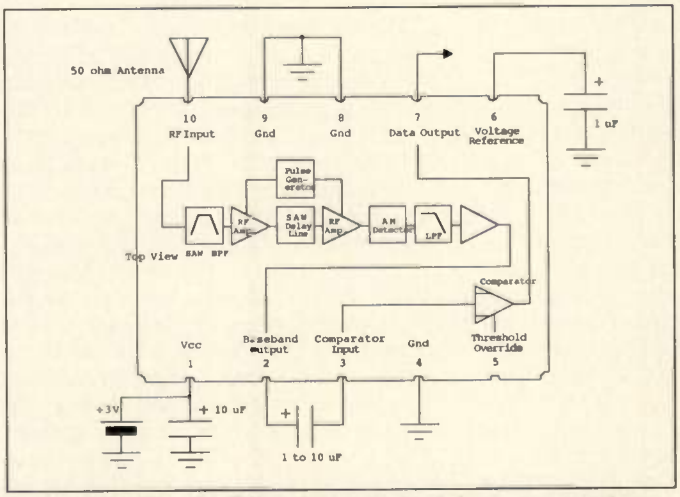

Figure 12. Block diagram and electrical connections.

Characteristic		Sym	Notes	Minimum	Typical	Maximum	Units
Operating Radio Frequency		f_c		433.92 Normal			MHz
Received Carrier Modulation Type			1	Pulse Modulation (OOK)			
RF Band	Sensitivity		2	–100	–102		dBm
	Max Operating Signal			–15			
	Channel Width			$I_c \pm 150$			kHz
	Noise Equivalent BW				4.8		
	Input Impedance				50		Ω
Interference Rejection	Half Frequency Spurious		3		105		dB
	f_c ±1 MHz				20		
Sequencing (Sampling)	Sample Duration		4		700		ns
	Sample Repetition Rate				250		kHz
Baseband	Data Rate		5			2.4	kb/s
	3 dB Bandwidth			2.4			kHz
Comparator Threshold	Default (Pin 5 NC)		6		25		mV
	Override (Pin 5 LO)				0		
Digital Output	CMOS Load Capacitance		7			10	pF
	HIGH Output	V_{HI}		V_{cc}–0.2		V_{cc}	V
	LOW Output	V_{LO}		0.0		0.2	
	Rise TIme	t_R				10	µs
	Fall Time	t_F				10	
Power Supply	Operating Voltage	V_{cc}	8	2.7	3.0	3.5	VDC
	Current at 25°C and 3.0 V	I_{cc}			1.1	1.2	mA
Operating Ambient Temperature		T_A	8	–40		+85	°C
Lid Symbolization (In addition to lot or data code)		RFM RX1000					

Table 1. Characteristics of the ASH receiver.

tion finding or to drive an AGC circuit, if desired. AGC is not required for this receiver to function as a data receiver. As mentioned earlier, the baseband output is then capacitively coupled to the comparator input. The comparator has a built-in internal threshold of 25 mV which was chosen to give a data output from the comparator which would be relatively free of noise in the absence of an RF signal at the receiver input. This can be important in some applications where the logic being driven by the receiver would be confused by extraneous noise. The 25 mV level was chosen as the best overall compromise between receiver sensitivity and noise in the "no signal" condition; however, for those who are more demanding, a threshold override pin has been provided. Grounding pin 5 completely disables the internal threshold, giving an equivalent threshold level of 0 volts. This is the most sensitive condition for the receiver, since the smallest signal present on the baseband output will cause the comparator to toggle. In the "no signal" condition, the zero threshold produces rail to rail noise on the comparator output. If the logic circuit can stand it, this would be the most desirable mode of operation for long data streams. For short data streams, "bursty data", such as that used for control functions, a threshold other than 0 volts is desirable for optimum performance. Finally, the wiper of a potentiometer connected to pin 5 and the other two arms of the potentiometer connected to V_{CC} and ground, or a simple fixed resistive divider, would give the engineer the freedom to set any threshold voltage level desired. The data output from the comparator on pin 7 is capable of driving a CMOS gate or an equivalent impedance.

Performance Characteristics

Table 1 shows the performance characteristics of the ASH receiver internally configured for a nominal 1.0 kb/s or a maximum 2.4 kb/s data rate with a center frequency of 433.92 MHz (RX1000). The baseband bandwidth is set for 2.4 kHz, giving a noise equivalent bandwidth of 4.8 kHz. The channel width is ±150 kHz, which includes the effects of temperature and initial manufacturing tolerance on the SAW coupled resonator filter. The actual minimum filter bandwidth is 500 kHz. The chosen width of the sampling pulse is 0.7 µs and the period is 4.1 µs for a sample repetition rate of approximately 250 kHz. This gives a duty factor for the first RF amplifier of 0.17, which increases the receiver noise figure by 7.7 dB over that achievable with the amplifier on full time (assuming stability could be achieved under such a condition). This duty factor of 0.17 causes the receiver current consumption to be approximately 1.1 mA with a V_{CC} of 3.0 volts. Changing the duty factor to 0.5 yields a current consumption of 2.1 mA and improves the sensitivity or noise figure of the receiver by 4.7 dB. The maximum operating signal level of −15 dBm is very conservative. The receiver has been demonstrated to work very well up to 0 dBm and down to the sensitivity level for over 100 dB of dynamic range.

Frequency Selectivity

The frequency response of the 433.92 MHz ASH receiver is plotted in Figure 13. This plot was generated by applying a pulse-modulated RF signal to the receiver input and raising its level until a 10 dB signal-plus-noise to noise ratio was obtained at the baseband output pin. The RF level was then recorded at each frequency to generate the frequency response plot of Figure 13. This plot shows phenomenal performance for the receiver. When the tiny package size is considered, this performance would be difficult, if not impossible, to achieve with any other receiver architecture. On the low frequency side of the response, approximately 108 dB of rejection was demonstrated and approximately 90 dB was obtained on the high frequency

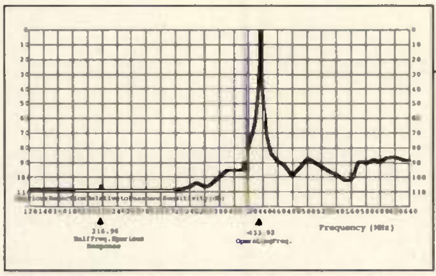

Figure 13. ASH receiver modulated interference rejection.

side. The 3 dB bandwidth of this response, which is primarily set by the response of the SAW coupled resonator filter, was approximately 600 kHz. Theoretically, the only spurious responses for the ASH receiver architecture are produced by applying a subharmonic of the desired signal frequency. If the subharmonic is large enough in amplitude, it could, theoretically, overdrive the first RF amplifier and produce a harmonic which would be "on-frequency". The worst case subharmonic is at half the desired frequency. From Figure 13, the response of the receiver to the half-frequency signal was 105 dB below the in-band response. The third and fourth subharmonic responses were at or below the ultimate rejection of the receiver. Thus, the new receiver is free from any significant spurious responses.

Receiver/Transmitter Range Measurements

An RFM hybrid transmitter, the HX1000, mounted on the head of an automobile ignition key, was used to evaluate the open-air, line-of-sight range for the ASH receiver [1 10]. The RF output of the HX1000 was impedance-matched to the metal key shank using a series chip inductor. This simple antenna circuit, in conjunction with the HX1000, radiated a power level of –10 to –7 dBm. A Motorola MC145026D digital encoder IC was used to modulate the HX1000. This encoder was used

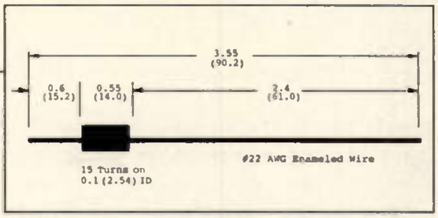

Figure 14. 433.92 MHz antenna.

only because it was readily available. The receiver antenna was a very low cost coil-loaded monopole as shown in Figure 14. This simple antenna has a gain about 2 dB below that of a quarter wave dipole antenna, whose gain is approximately 0 dB. Figure 15 is a schematic diagram of the receiver circuit used in the range test. A piezoelectric buzzer was used to obtain an audible indication that the MC145028 decoder recognized the code coming from the data output pin of the ASH receiver. The key-mounted transmitter was hand carried down the range, being held at a height of about 4 feet. The receiver was sitting on a cardboard box about 3 feet above the ground. The receiver was still recognizing the transmitted code at a distance of more than 1000 feet from the transmitter. On the same range, competitive receiver technologies were showing reception distances, with the same encoder/decoder combination, of 150 to 300 feet. The measured sensitivity of these receivers, which consisted of both super-regenerative and super-heterodyne technologies, was equal to and in one case better than the –100 dBm sensitivity of the ASH receiver. The big difference was the selectivity of the other receivers compared to the ASH receiver. The typical rejection level of the competitive receivers was 60 dB with an occasional 70 dB. Using a dipole antenna and a spectrum analyzer, interfering signals as high as –20 dBm were measured, especially at pager, UHF TV, VHF TV and FM radio frequencies. In addition, there was the occasional radiotelephone transmission at the

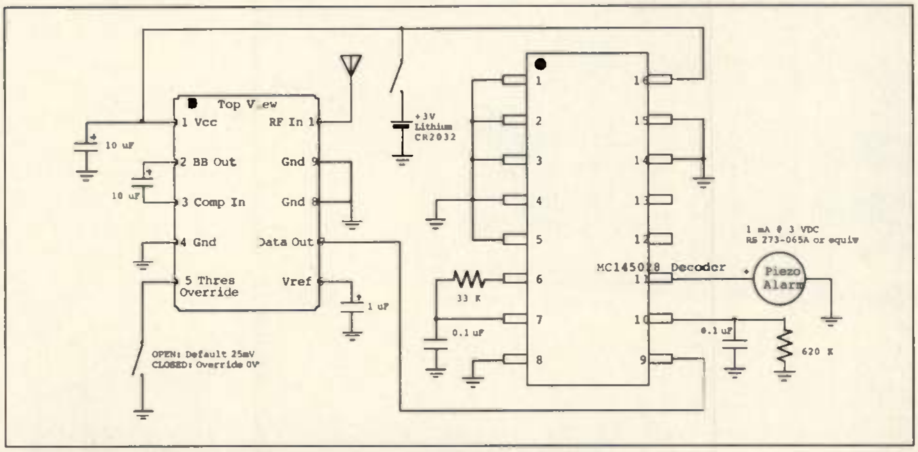

Figure 15. ASH receiver demonstration circuit.

same general level. If the receiver has a rejection of 70 dB and a sensitivity level of –100 dBm, a single –20 dBm interfering signal would desensitize the receiver by more than 10 dB. Each 6 dB loss in sensitivity decreases the free-space range by a factor of two. The theoretical range for a –100 dBm receiver and the power level obtained from the key transmitter is approximately 1000 feet. If we assume that the average desensitization of the receiver with 70 dB of interfering signal rejection is 12 dB due to multiple signals and other factors, the theoretical range would be reduced to 250 feet. This is very close to the 300 feet measurements obtained with the better competing receivers. On the other hand, the ASH receiver with a minimum out-of-band rejection of 90 dB on the high frequency side and more than 100 dB on the low frequency side would see no degradation due to –20 dBm interfering signals and would exhibit the full theoretical range of 1000 feet.

Conclusion

A basically new receiver architecture has been conceived at RFM to address the shortcomings of previous receiver types used in short range RF link applications. This new receiver has been realized using a custom IC for all of the active functions and two SAW devices, a coupled resonator bandpass filter and a delay line. The receiver is completely contained in a 0.54 × 0.37 × 0.1 inch hermetic surface mount package. The receiver can be powered with a 3 volt button lithium battery and consumes only 1.1 mA. The receiver requires only three external components, all of which are capacitors with non-critical values. There is no alignment or adjustment required with this receiver. The circuit board layout is non-critical and there is absolutely no tendency toward instability even with a large VSWR on the antenna port of the receiver.

The receiver does not use an RF oscillator so the many problems associated with meeting radiation requirements as specified by the various government regulatory agencies, become a non-issue. The new receiver does not have spurious frequency responses such as the familiar image frequency associated with superheterodyne receivers. With a sensitivity of –100 dBm and an out-of-band interfering signal rejection of approximately 100 dB, the ASH receiver has been demonstrated to have an open-air range of 1000 feet compared to 150 to 300 feet with competing receiver technologies. Competing technology receivers with the same measured sensitivity of –100 dBm were desensitized by normally-present interfering signals from pagers, UHF and VHF TV, radiotelephones and FM radio due to insufficient frequency selectivity. Iin the current crowded spectrum conditions, it is not good enough to simply have good sensitivity in a receiver. The sensitivity will be lost if sufficient filtering is not incorporated. The new ASH receiver appears to function very well in this environment due to its combination of good sensitivity and excellent out-of-band rejection. *RF*

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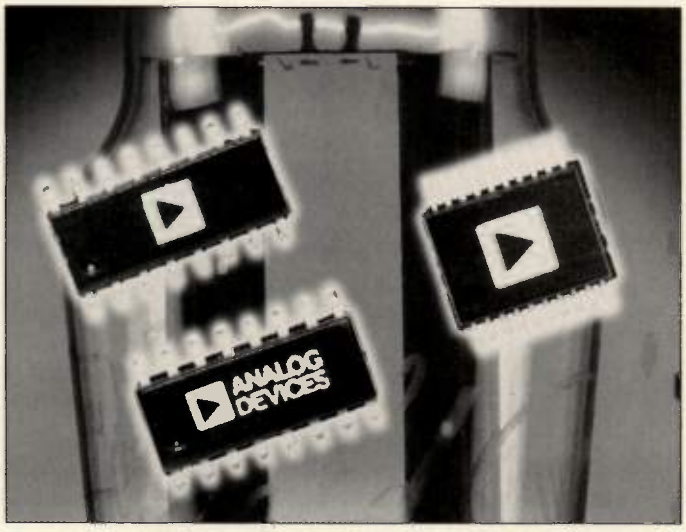
About the Author

Darrell Ash is a founder and Senior Vice President of Engineering at RF Monolithics, Inc. in Dallas, Texas. He has 21 years of experience using SAW devices to solve wireless communications problems. He is the inventor of the SAW stabilized superregenerative receiver and the ASH receiver. He received his BSEE from the University of Evansville and his MSEE from Brigham Young University; and is a Senior Member of the IEEE. Mr. Ash can be reached at 4441 Sigma Road, Dallas, TX, 75244, tel: (214) 233–2903.

3V IF Sub-Systems

The AD607 and AD608 are two versatile parts that integrate all the components of a receiver's RF/IF strip into a compact ultra-low-power, high performance device. Both integrate a high performance RF mixer (500 MHz bandwidth with –5 dBm IP3 compression point), with amplifiers, filter driver, and compensation circuitry. The AD608 is intended for limiting architectures with limiting/RSSI outputs, while the AD607 has a linear IF amplifier (100 dB range), and quadrature demodulator. Both parts operate off 3 V supplies and draw less than 25 mW (operation guaranteed at 2.7 V at –25 °C) The linear I and Q outputs of the AD607 can be interfaced directly to Analog's AD70xx family of baseband converters. The AD608 provides a logarithmic RSSI output with 90 dB range, while its limiter output provides a fast limited output of 400 mV_{pp} with transition times of 7 ns and ±3° phase stability. The mixer in both devices is a double balanced 'Gilbert Cell' type, with a 1 dB compression point of –15 dBm, and conversion gain of 25 dB. The AD608 is available in a 16-pin SOIC for $4.95 in 1,000's. The AD607 is available in a 20-pin SSOP for $5.95 in 1,000's.
Analog Devices
INFO/CARD #250



Waveform Synthesizer

Model 1396 is Wavetek's highest performance VXI arbitrary waveform generator. Standard sine waves are available to 20 MHz, with square waves to 25 MHz. User-defined waveforms, with 12-bit vertical resolution, may be created with as few as 5 waveform points and up to 131,072 points (524,288 points optional). For simulating complex waveform sequences, the linked sequence mode allows linking and looping of up to 4096 waveform segments. In addition to the standard built-in sweep capability, the 1396 offers a frequency

list function which can be used for custom sweeping or frequency hopping applications. Versatile inter-module control allows triggering, summing and phase control among multiple modules. The model 1396 is a single-slot, C-size VXIbus message-based device. It sells for $5,495.
Wavetek Corp.
INFO/CARD #249

RF Die Probe Card

Fresh Quest Corporation has developed a state-of-the-art photolithographic pattern plated probe (P4) technology which provides the unique foundation utilized in the high frequency P4 probe card. The P4 RFM (RF Microwave) probe card allows for fully testing integrated circuits designed for RF/wireless applications (up to 5 GHz) and elimi-

nates the need for temporary bonding to the device. The P4 probe technology provides a mechanical "scrub" action that penetrates surface oxide, if present, on the IC die pad under test. The RFM P4 probe card can be used for devices manufactured with aluminum, gold, and solder-bump bond-pad materials. The probe is manufactured using a photolithographic process that assures probe to pad alignment and addresses a wide range of pad geometries and device input/output/power/ground signal assignments. In addition, the P4 technology provides low contact resistance, low power trace inductance, low crosstalk, elevated and cold temperature performance, and high bandwidth.
Fresh Quest Corp.
INFO/CARD #248

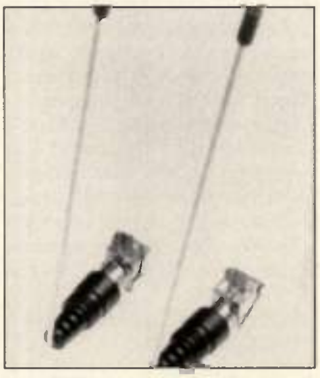
1 kW, 1 GHz Broadband Amp

The model 1000W1000M7 Class A broadband RF amplifier from Amplifier Research provides a minimum of 1000 W RF power over a frequency range of 100 to 1000 MHz without bandswitching. Minimum gain is

60 dB, and flatness with internal leveling is ±0.8 dB. The push-pull circuitry used in all high-power stages of the 1000W1000M7 minimizes distortion and maximizes stability. A front-panel wattmeter permits convenient monitoring of forward and reflected power, and a front-panel gain control with a range of 18 dB minimum permits convenient power adjustment. A rear-panel connector gives remote access to POWER, STANDBY, OPERATE, and RESET control functions. Model 1000W1000M7 weighs 750 lb and is priced at $178,000.
Amplifier Research
INFO/CARD #247

Connector & Antenna

Connect-Tech Products announces their wireless LAN RCA jacks with built-in antenna. This new combination connector and antenna saves cost for both components and production labor, with a volume purchase cost of just $0.59 each. The antenna can be custom configured to any length to meet the specific needs of the application. The connectors are manufactured with metal brackets in one, two, or three positions high, as well as multiple widths, and can be easily and inexpensively modified for custom requirements. Inserts can be any color and the metal brackets lend themselves to improved EMI/RFI radiation protection, grounding



capability, and ease of assembly. Center pin connections are made from phosphor bronze material for superior conductivity and long life.
Connect-Tech Products, Inc.
INFO/CARD #246

Product Spotlight: RF Integrated Circuits

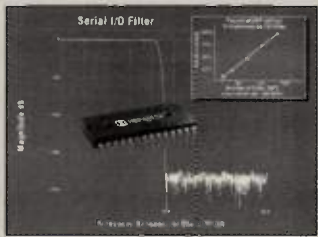
Video Multiplexer

Burr-Brown's MPC104 is a single 2-to-1 multiplexer that distributes and routes wideband analog and digital signals. Key specifications include: 210 MHz bandwidth at 1.4 V_{pp} signal level, 500 V/µs slew rate, 79 dB channel crosstalk and 86 dB off-channel isolation, both at 30 MHz. Differential gain and phase are 0.03%/0.01°. All performance is specified at ±5 V supply voltage. The MPC104 is available in 8-pin plastic DIP and SOIC packages, as well as in die form. Price is from $4.94 in 100-piece quantities.

Burr-Brown Corp.
INFO/CARD #245

24-Bit Hardwired Digital Filter

Harris' HSP43124 off-loads compute-intensive filtering functions from DSP microprocessors in wide dynamic range applications, such as receivers and decimation filters for sigma-delta modulators. The chip implements a 32-bit coefficient filter which can operate on 24-bit words and preserves over 100 dB of input dynamic range. The HSP43124 operates on a



serial data stream, keeping the DSP's parallel ports free for other uses. The 28-pin PDIP or SOIC device sells for $19.94 in quantities of 1000; accompanying filter design software is free.

Harris Semiconductor
INFO/CARD #244

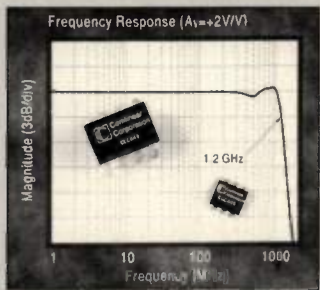
Low Noise Amp

Stanford Microdevices has introduced a family of GaAs MMIC low noise amplifiers (LNAs) designed to cover various communications operating within the 100-4200 MHz spectrum. The SMM-010 typically has 18 dB gain from 100 to 3000 MHz and 16 dB gain from 3000 to 4200 MHz. Noise figure is typically 2.2 dB over the full band. Pricing for model SMM-010 is $55 in 1000-piece quantities.

Stanford Microdevices
INFO/CARD #243

1.2 GHz Op Amp

Comlinear's CLC449 is an ultra-high-speed monolithic op amp, with a typical –3 dB bandwidth of 1.2 GHz at a gain of +2. The op amp supports rise and fall times less than 1 ns, settling time of 6 ns (to 0.2%) and slew rate of 2500 V/µs. The CLC449 achieves 2nd harmon-



ic distortion of –73 dBc at 5 MHz at a low supply current of 12.6 mA. Gain is flat to 0.1 dB beyond 250 MHz, and differential gain and phase are 0.03%/0.02°. Pricing is $4.20 each in 1000-piece quantities.

Comlinear Corp.
INFO/CARD #242

RF Power Modules

The Electronic Device Group of Mitsubishi Electronics America now offers high-power, high-frequency RF power modules for use in vehicle-mounted, two-way 35W mobile FM radios. The modules provide 21.0 dB minimum gain and 40% minimum efficiency. The M67781L is intended for 135 to 160 MHz, while the M67781H is intended for 150 to 175 MHz. Both operate on 12.5 V power supplies. Both are available now and are priced at $58.00 in 1000-piece quantities.

Mitsubishi Electronics America
INFO/CARD #241

BICMOS Op Amp

SGS-Thomson's TSH321 is a wideband op amp offering 400V/µs slew rate, 300 MHz gain bandwidth products, and a typical MOS input-stage current of 2 pA. The TSH321 operates from supplies ranging from ±3 V to ±7 V. Differential gain and phase are 0.01%/0.05°. Available in DIP8 and SO8 packages, the TSH321 is available now at $2.50 in 1000-piece quantities.

SGS-Thomson Microelectronics
INFO/CARD #240

SIGNAL PROCESSING COMPONENTS

Phase Shifters

Electrodyne Systems introduces the first of its family of digital, high-power phase shifters. The RY-35PC operates over the frequency range of 350 to 450 MHz and has an insertion loss less than 2.3 dB. The unit provides better than 6° phase accuracy at any phase shift angle. The RY-35PC can handle maximum power of 50 W CW and 500 W peak.

Electrodyne Systems Corp.
INFO/CARD #239

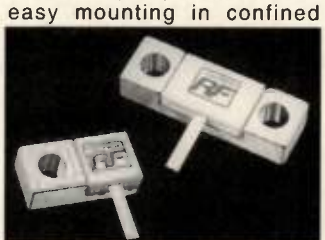
Surface Mount Transformer

Compact size and wide bandwidth are key features of Mini-Circuits' TC4-1W RF transformer. Measuring 0.16 × 0.16 × 0.16 inches, the transformer is surface mountable, suitable for pick-and-place, and available in tape and reel. Bandwidth is 3 to 800 MHz, with DC isolation from primary to secondary. Price is $4.95 each.

Mini-Circuits
INFO/CARD #238

Terminations

Flange-mounted terminations from Florida RF Labs offer a number of power ratings and a unique flange style which allows easy mounting in confined



spaces. Part number 32-1034 handles 30 W; 32-1036 handles 60 W. Both have VSWR < 1.20:1 to 4.0 GHz. Part number 32-1055 handles 100 W and has VSWR < 1.30:1 to 6.0 GHz.

Florida RF Labs
INFO/CARD #237

Couplers and Power Dividers

Lucas Weinschel announces a line of directional couplers and power dividers that operate over the 0.5 to 4 GHz frequency range. The couplers offer high directivity and low SWR in a miniature stripline configuration. Octave, broadband and 90° coupler models are available in coupling factors of 6, 10, 20, and 30.

Lucas Weinschel
INFO/CARD #236

Phase Comparator

TRM's phase comparator, model PC 121-1000 features 1° phase accuracy at 1000 MHz and ±2° at its band edges at 875 and 1125 MHz. Two outputs with sine and cosine relationships proportional to the phase difference are provided. With the RF input levels at +10 and +4 dBm, output levels of ±150 mV h_{min} pp into a 50 Ω impedance are delivered. VSWR is less than 2.0:1. Size is 1 × 0.25 inches in a radial lead flatpack. Other packaging and frequency options are available.

Technical Research and Manufacturing, Inc.
INFO/CARD #235

CABLES & CONNECTORS

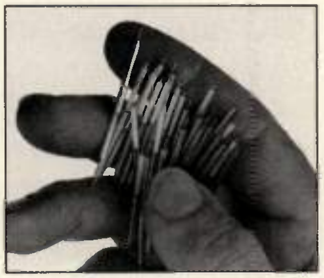
Improved Isolation Cables

RF cables from Storm Products offer improved isolation over traditional RG cables and are well suited for extended frequency use through 5 GHz. Shielding effectiveness is –85 dB at 1 GHz with an insertion loss as low as 0.15 dB/ft. These RG equivalents

use standard, commercially available connectors.
Storm Products Co.
INFO/CARD #234

Miniature Cables

Miniature coaxial cables and cable preps for wireless, GPS and telecomm applications perform from DC to 40 GHz. Choice of outer conductors includes copper, copper-stainless, and aluminum.



Outer diameter sizes are 0.034, 0.047, 0.086, 0.141, and 0.250 inches. End configurations and bends are formed as specified.
SSI Cable Corp.
INFO/CARD #233

SMA Receptacles

United Microwave Products offers SMA female 2-hole and 4-hole panel mount connectors with POGO, spring-loaded pins, on the terminal end. Such pins allow connection without soldering. Connectors meet all requirements of MIL-C-39012 and are available in gold, passivated stainless, or nickel plated brass.
United Microwave Products, Inc.
INFO/CARD #232

AMPLIFIERS

2 GHz FET Amps

CMT has introduced a complete line of 2.5 to 2.7 GHz GaAs FET power amplifiers for use in MMDS (MultiChannel Multipoint Distribution Service). Power levels are from 2 to 100 W. The units are designed for class A and AB operation, and optimized for maximum linearity. Units can be configured for OEM applications or in rack-chassis configurations with integral power supplies. Gains up to 60 dB are available. Nominal noise figures are 4 dB.
Chesapeake Microwave Technologies, Inc.
INFO/CARD #231

300 W Transistor Pallet

A 300 W, 50 Ω transistor pallet is now available from Richardson Electronics. The P300-108 is designed to address the power amplifier requirements of an 88-108 MHz FM broadcast transmitter. All the input and output matching circuitry has been added to provide a 50 ohm interface, so that all the systems engineer needs to do is connect a 48 VDC power source to the pallet and connections to input and output RF lines.
Richardson Electronics, Ltd.
INFO/CARD #230

50W Single Channel

Operating over the frequency band of 869 to 894 MHz, Microwave Power Devices' new single channel amplifier produces 50 W. The amplifier is designed for application in AMPS and CDPD systems. The amplifier's efficiency is better than 35%, and output power can be controlled over a 28 dB range in 4 dB steps via TTL control lines. The unit also features built-in fault detection and graceful thermal overload protection.
Microwave Power Devices, Inc.
INFO/CARD #229

SIGNAL SOURCES

PC Mount OCXOs

Vectron Laboratories has introduced a series of subminiature PC board mount oven controlled oscillators (OCXOs) available in frequencies from 32 kHz to 50 MHz in sinewave or logic outputs. The CO-738S oscillators provide aging rates from 1×10^{-7}/year to 2×10^{-8}/year at 5 MHz with temperature stabilities of $\pm 5 \times 10^{-10}$ over 0 to 50 °C. The standard package measures 1.5 × 1.25 × 0.86 inches.
Vectron Laboratories, Inc.
INFO/CARD #228

Ultra Low Noise Oscillator

Wenzel Associates' model 500-02789D, 100 MHz ultra low noise crystal oscillator boasts a guaranteed noise floor of –174 dBc/Hz at 20 kHz offset; typical units meeting –178 dBc/Hz. An SC-cut crystal provides tempera-

ture stability of better than $\pm 2\times10^{-7}$ from 0 to 50 °C. Mechanical and electrical tuning are provided. A NIST calibration report is available.
Wenzel Associates, Inc.
INFO/CARD #227

Voltage Controlled Oscillators

KVG offers voltage controlled precision oscillators in the standard DIL-14 and in a low-profile SMD-case. The VCXOs have a tuning range greater than ±100 ppm. Clock rates from 2.048 up to 51.84 MHz are available.
KVG GmBH
INFO/CARD #226

OCXOs

Oak Frequency Control Group's 4851 and 4851S OCXOs are designed to provide low cost and superior performance in a 2-inch square by 1.0 inch high package. The 4851 utilizes an AT-cut crystal to attain a temperature stability of $\pm 3\times10^{-8}$ from –20 to +70 °C, and aging of $\pm 1\times10^{-9}$/day. For higher precision, the 4851S utilizes a low-cost SC-cut crystal to attain a temperature stability of $\pm 7\times10^{-9}$ from –20 to +70 °C; its aging is $\pm 5\times10^{-10}$/day. Both devices cover 2 to 10 MHz and offer sine or HCMOS output.
Oak Frequency Control Group
INFO/CARD #225

TEST EQUIPMENT

Network/Spectrum Analyzer

The NSA-1000A is a network/spectrum analyzer that covers 1 to 1000 MHz in one sweep. The network analyzer's tracking generator has output attenuation levels of 0, –10, –20, and –30 dBm, with typical amplitude accuracy of +2 dB and flatness better than 4 dB peak-peak. The receiver portion has fixed resolution bandwidth of 150 kHz and input reference levels of +20, 0, –20, and –40 dBm. When used as a spectrum analyzer, typical sensitivity is –95 dBm. Options include FM demodulator, AM detector, DC power inserter and LPA-1000 log periodic antenna. Price is $3,875.
Avcom
INFO/CARD #224

Peak Power/ Frequency Counters

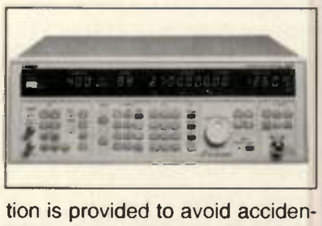
EIP Microwave has introduced a family of broadband microwave pulse/CW frequency counters that incorporate unique peak-power measurement capability over the frequency range of 0.25 to 26.5 GHz. The "Power Counter"™ models 595A/598A provide single-input frequency and power measurement from 0.25 to 20 GHz (595A) and 0.25 to 26.5 GH (598A), with frequency measurement extendible to 170 GHz (598A). Price for the 595A is $13,900; price for the 598A is $16,500.
EIP Microwave, Inc.
INFO/CARD #223

Radio Transmitter Detector

The Scout from Optoelectronics is intended to detect radio transmitters in the near field. The Scout can automatically detect and record 200 unique frequencies and up to 250 repeat hits on any that were previously recorded. Data can be downloaded into a computer using software supplied and an optional TTL or RS-232C interface converter. The price of the Scout is $399.
Optoelectronics Inc.
INFO/CARD #222

2.7 GHz Signal Generator

Model 3222 from Leader Instruments is a synthesized signal generator covering 100 kHz to 2.7 GHz and offering 10 Hz resolution to 1.35 GHz and 20 Hz resolution thereafter. Output level is controllable from +13 to –133 dBm with 0.1 dBm setability. Modulation capabilities include seven modes with 14 simultaneous combinations to choose from. GPIB control is standard. Fifty watt reverse power protec-



tion is provided to avoid accidental damage when working with transceivers. Price is $13,300.
Leader Instruments Corp.
INFO/CARD #221

Simulating Class C RF Amplifiers

By Charles E. Hymowitz, Intusoft
and Bill Sands, Analog & RF Models

Many designers believe that the analysis of the nonlinear characteristics of class C amplifiers is not practical with popular simulators such as SPICE. However, with the proper modeling of the RF transistors and proper accounting of parasitics, virtually every aspect of the class C amplifier can be studied. This paper explores some unique techniques and models for simulating amplifiers running in class C operation using the general purpose SPICE circuit simulation program. Results of the simulation of an 870 MHz amplifier including the transient, power gain, power dissipation, power output and efficiency waveforms are given.

SPICE can be a versatile tool for RF work as long a few simple precautions are taken. Significant parasitics must be included in the circuit description, models of active devices must be represented using subcircuits, and selection of transient analysis options must be considered. The transient options include the total analysis time, the data printout step and delay, and the simulator error tolerances. Of course, SPICE will also do AC analyses of RF circuits, but this is not its strong suit, as many other simulators will also do linear small-signal work. The real strength of a SPICE-based simulator, such as IsSPICE3, is in its time domain capability, where either repetitive or non-repetitive waveforms can be used as stimulus. This ability is handy for burst work, measurement of peak stresses under normal operation or momentary fault conditions, detailed study of bypass networks and many other conditions. Since test points do not load the circuit in any way, measurements that would be impossible on the bench can be easily made with the IsSPICE3 simulation.

Shown in Figure 1 is a typical circuit used to simulate the operation of a class C power device. The device used here, X_1, is the Motorola MRF873 NPN power BJT. It can produce 15 watts of output power in the 806-960 MHz range. R_G provides 50Ω impedance for the generator. C_1, C_2, and L_1 are used for input matching. L_{BB} and R_{QB} are for DC return to ground and Q limiting for the base. L_2, C_5, and C_6 are used for output matching. C_C and L_C form a return to V_{CC} for the collector. R_L is 50Ω. The generators V_B, V_C, and V_{C5} are zero valued sources used to measure the instantaneous circuit currents.

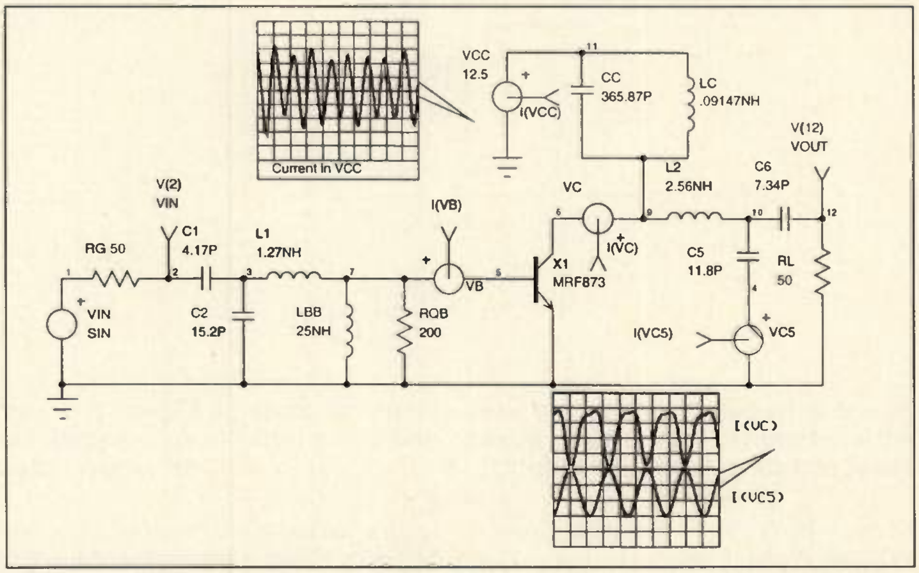


Figure 1. Schematic of an RF amplifier running in class C operation at 870 MHz. The waveforms reveal the transient response of the currents in the power supply, transistor collector, and capacitor, C_5.

A typical simulation of Figure 2 requires 23.6 seconds on a 486/33 (RELTOL=.0003) using IsSPICE3, a new SPICE simulator based on Berkeley SPICE 3E.2. The change in RELTOL was required for increased accuracy, although the default of .001 provided comparable results. At 870 MHz one cycle takes about 1.1 ns. Since class C circuits need some number of cycles to stabilize, this circuit was simulated from T = 0 ns to T = 20 ns with output data accumulated from 1 5 ns to 20 ns. The simulation has about 15 cycles to settle before data is gathered and is pretty well settled by that time.

After initial testing of a nominal case (V_{CC} = 12.5, Power In = 3 W) the parameter sweeping features of IsSPICE3 were used to sweep the input power. The input power is controlled by the voltage of V_{IN}. In order to easily control the simulation parameters, a simple subcircuit was made to convert input power in watts to the peak voltage required by the IsSPICE3 voltage source. The power supply, V_{CC}, was also made a variable. The conversion is shown below.

Replace:	With:
VCC 11 0 12.5 VIN 1 0 SIN 0 Vpeak 870 .5N	VCC 11 0 VTEMP X2 1 0 VSIN {PIN=PTEMP} .SUBCKT VSIN 1 2 VIN 1 2 SIN 0 {(PIN*50)^.5*2*2^.5} 870 .5N .ENDS

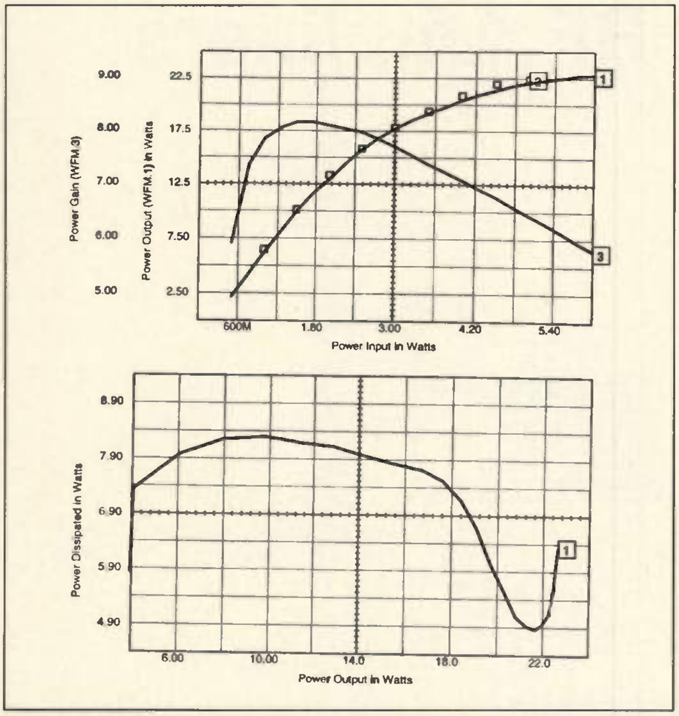


Figure 2. Power output, power gain, and power dissipation results. The square boxes show the data sheet response for power output.

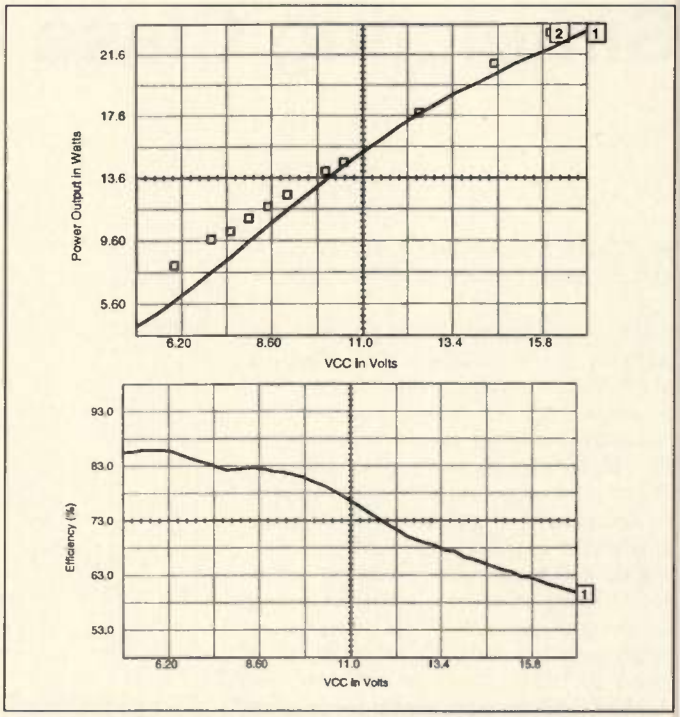


Figure 3. Power output and amplifier efficiency vs. V_{CC}. Square boxes indicate the data sheet response for power output.

After setting up the extended syntax, the control statements,

*OPT VTEMP=5 TO 17 STEP=.25 and
*OPT PTEMP=.5 TO 6 STEP=.25

can then be used to sweep the parameters VTEMP (equal to the power supply voltage) and PTEMP (input power in watts).

During the simulation the waveforms at various points were sampled. INTUSCOPE, a SPICE data post processor, was used to reduce the ISSPICE3 voltage and current data into output power and DC power values. After the sweep, INTUSCOPE then calculated the power gain ($10*lgt(P_{out}/P_{in})$), efficiency (P_{out}/P_{dc}), and dissipation (P_{out}-P_{dc}). Since there is no circuit loading associated with monitoring voltage and current, measurement of the capacitor RMS current and peak voltage is possible. For nominal power input, the peak-peak voltage across C_5 was 93.00 V, while the RMS current was 2.082 A. This type of data is vital for making informed component selection decisions.

Figure 2 (top graph) shows the excellent tracking between the ISSPICE3 simulation and the data sheet values for output power and power gain vs. input power. The lower graph contains the results for the power dissipation in the MRF873. Figure 3 shows the simulation results for efficiency and output power vs. V_{CC} at constant input power.

Once the relationships were studied and a final output power and V_{CC} range were selected for detailed analysis, the physically impractical and somewhat narrow bandwidth lumped element networks in Figure 4 were replaced with transmission lines. The t-line values were calculated to match published input and output impedances. Other values were taken from the Motorola data sheet. The simulation results obtained were more accurate but still within 10% of the lumped element approach. SPICE 2G.6 based simulators have trouble running circuits containing ideal transmission lines with time delays that are short relative to the total analysis time. However, new algorithms in Berkeley SPICE 3E.2 and ISSPICE3 allow ideal transmission lines to be simulated orders of magnitude faster that SPICE 2 based versions. For example,

```
.SUBCKT MRF873 1 2 3
LC 1 4 0.50E-9
LB 2 6 0.60E-9
LE 5 3 0.07E-9
CC 4 3 15.0E-12
CB 4 6 1.00E-12
Q1 4 6 4 QR01
.MODEL QR01 NPN (BF=98 VAF=150 VAR=10.0 RC=.15 RB=1.43 RE=.26
+ IXF=1.0 ISE=7.6E-14 TF=1.2E-11 TR=1.7E-09 ITF=1.7 VTF=5.3
+ CJC=10.7E-12 CJE=12E-12 XTI=3.0 NE=1.5 ISC=2.4E-14 EG=1.11
+ XTB=1.5 BR=2.29 IS=8E-15 MJC=0.33 MJE=0.33 XTF=4.0 IKR=0.5
+ KF=1E-15 NC=1.7 RBM=1.02 IRB=1.60E-02 XCJC=0.5)
.ENDS
```

Table 1. The SPICE subcircuit netlist for the MRF873 RF power transistor. Connections are Collector (1), Base (2), Emitter (3). The subcircuit may be used with any SPICE simulator.

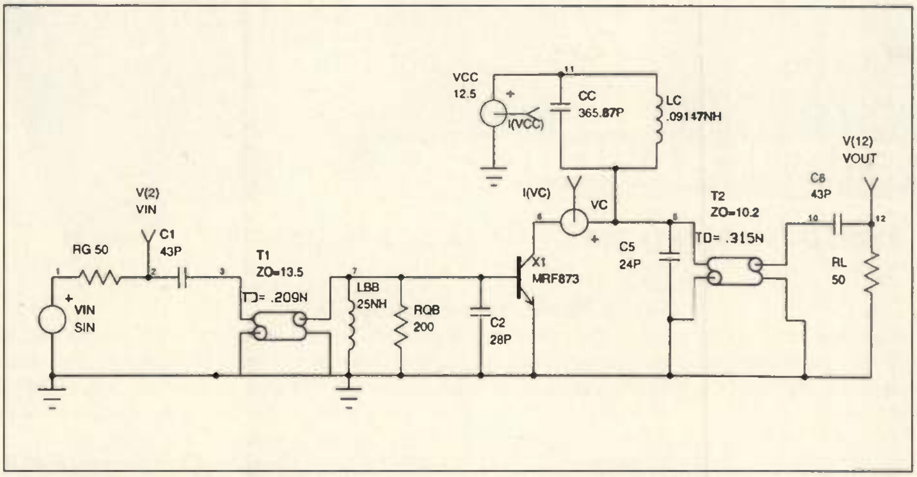


Figure 4. In order to provide a more realistic simulation, the physically impractical lumped elements are replaced with transmission lines. The transmission line values are calculated to match published input and output impedances.

the simulation of Figure 4 took 521.85 seconds on a popular evaluation version of a PC SPICE program based on SPICE 2G.6. IsSpice3 simulated the same circuit in 41.25 seconds (using a 486/25 PC). In addition, IsSpice3 includes two types of lossy transmission lines. Based on the comparable run times and results achieved, either approach, lumped element or transmission line, is acceptable for simulation purposes.

The complete set of simulations contained in this article is available on floppy disk from Intusoft for a nominal charge. (See the address given in the "About the Authors" box below.)

From the accurate results presented here, it is clear that simulation of class C RF circuits using SPICE is practical and productive as long as the circuit and transistors are modeled properly. *RF*

About the Authors

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V_{cc}=3.3V_{dc}

Power Output

pF

F_T

1 dB passband ripple

50Ω

806-900 MHz

dB/$\sqrt{\text{Hz}}$

3 dB Cutoff

X_L

2 - 30 MHz

P_{1dB}

nH

L-Band

Γ_{OPT}

μ_0

S_{11} S_{12}

S_{21} S_{22}

20 dBm IP_3

GROUP DELAY ±20 ns

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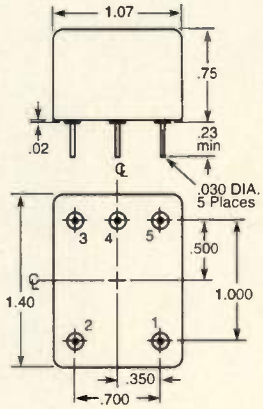
Solder Seal OCXO Small Package



RD Package

Output Options:

TD	= TTL	=	DC to	50 MHz
HC	= HCMOS	=	DC to	50 MHz
RC	= +7 dBm 50Ω	=	DC to	50 MHz

Stability Options

A18	=	$\pm 1 \times 10^{-8}$	0° to +50°C
B28	=	$\pm 2 \times 10^{-8}$	0° to +70°C
D27	=	$\pm 2 \times 10^{-7}$	-40° to +85°C
S38	=	$\pm 5 \times 10^{-8}$	-40° to +85°C

Screening Options:

C = Standard Commercial
S = Class "B" per MIL-O-55310

Typical P/N:

HC RD K1 A 4 D27 C 10.000 MHz

- C — Screening
- D27 — Stability
- 4 — Aging
- A — Supply
- K1 — Predetermined
- RD — Package
- HC — Output

Supply Options:

A	= +5.0 VDC	3 Watts
B	= +12.0 VDC	3 Watts
C	= +15.0 VDC	3 Watts
D	= +24.0 VDC	3 Watts

Aging Options:

2	= 1×10^{-8}/day	2×10^{-6}/year
3	= 5×10^{-9}/day	1×10^{-6}/year
4	= 3×10^{-9}/day	5×10^{-7}/year
5	= 1×10^{-9}/day	2×10^{-7}/year

Phase Noise (10 MHz Sinewave)

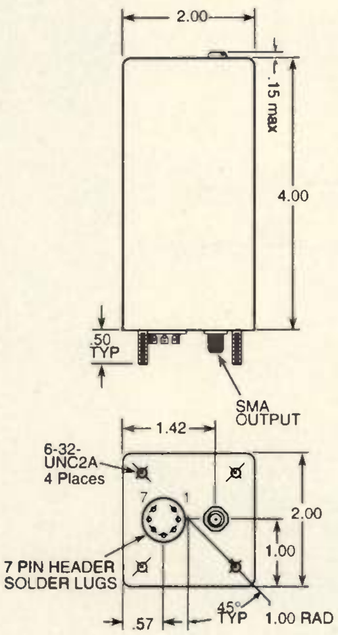
At	10 Hz	= -100 dBc
	100 Hz	= -127 dBc
	1.0 KHz	= -148 dBc
	>10.0 KHz	= -155 dBc

Pinouts:

Pin 1 = Output
Pin 2 = Gnd, Case
Pin 3 = VCO Input*
Pin 4 = VCO Reference*
Pin 5 = Supply

*When specified

High Stability HF OCXO



V1 Package

Output Options:

RC	= +7 dBm 50Ω
RE	= +13 dBm 50Ω

Stability Options

A50	=	$\pm 5 \times 10^{-10}$	0° to +50°C
A30	=	$\pm 3 \times 10^{-10}$	0° to +50°C
B70	=	$\pm 7 \times 10^{-10}$	0° to +70°C
C29	=	$\pm 2 \times 10^{-9}$	-20° to +70°C
C19	=	$\pm 1 \times 10^{-9}$	-20° to +70°C
S29	=	$\pm 2 \times 10^{-9}$	-40° to +70°C

Screening Options:

C = Standard Commercial
S = Class "B" per MIL-O-55310

Supply Options:

B	= +12.0 VDC	12 Watts
C	= +15.0 VDC	12 Watts
D	= +24.0 VDC	12 Watts

Aging Options:

6	= 5×10^{-10}/day	1×10^{-7}/year
7	= 3×10^{-10}/day	5×10^{-8}/year
8	= 1×10^{-10}/day	2×10^{-8}/year
9	= 7×10^{-11}/day	1×10^{-8}/year

Phase Noise (5 MHz)

At	10 Hz	= -120 dBc
	100 Hz	= -140 dBc
	1.0 KHz	= -155 dBc
	>10.0 KHz	= -157 dBc

Typical P/N:

RC V1 M1 C 7 C29 C

- C — Screening
- C29 — Stability
- 7 — Aging
- C — Supply
- M1 — Predetermined
- V1 — Package
- RC — Output

Frequency Options:

1 MHz	5 MHz	10 MHz
20 MHz	50 MHz	100 MHz

Pinouts:

Pin 1 = Supply
Pin 2 = Gnd, Case
Pin 3 = No connect
Pin 4 = Supply
Pin 5 = VCO Reference*
Pin 6 = VCO Input*
Pin 7 = VCO Return*

*When specified

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85.38 MHz

CDMA Subscriber SAW Filter

Part Number 854596

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The excellent skirt selectivity of this device, coupled with the superior temperature stability of the quartz substrate material, ensures that adjacent channel suppression requirements are met or exceeded over an operating temperature range of -30° C to +80° C.

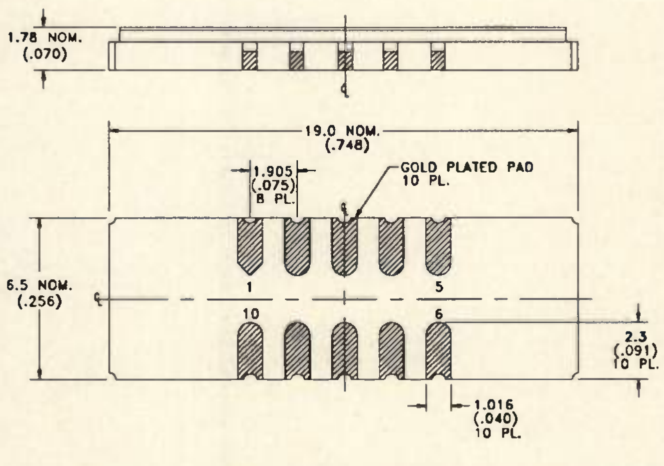
The device is externally impedance matched with standard, fixed-value matching components and hermetically sealed in a ceramic surface mount package to preserve device integrity in the demanding environmental conditions typical of subscriber applications.

Device Characteristics at +25°C

Parameters	Units	Min/Max	Typical
Center Frequency	MHz	85.38 nominal	85.38
5 dB Bandwidth	MHz	1.26 min	1.31
33 dB Bandwidth	MHz	1.80 max	1.78
Ultimate Rejection fo ± 9 MHz	MHz	45 min	>54
Insertion Loss	dB	14 min 16 max	14.71
Passband Variation	db	0.5 max	0.33
Triple-Transit Suppression	dB	30 min	34
Phase Linearity	degree (rms)	2.5 max	1.9

Features

- ▼ Low-profile, surface mount package
- ▼ Quartz stability
- ▼ Low cost
- ▼ Excellent out-of-band rejection
- ▼ Low phase and amplitude variation
- ▼ Excellent triple-transit suppression



PADS 2, 3, 4, 7, 8 & 9 ARE CASE GROUND
DIMENSIONS ARE NOMINAL IN MILLIMETERS (INCHES)
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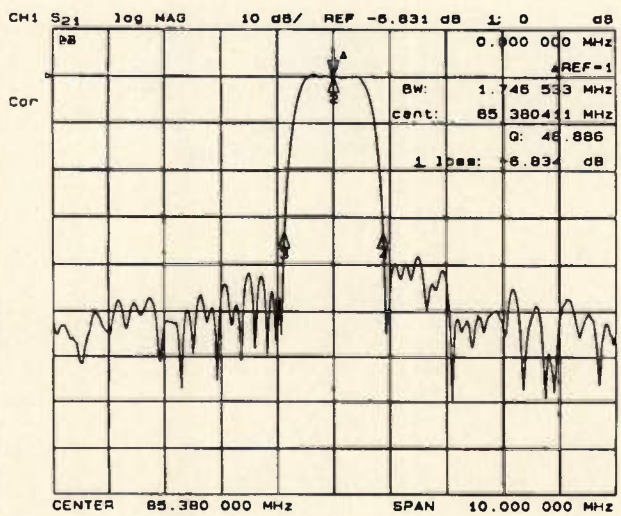
Outline Drawing of SMP-75 Ceramic Surface Mount Package



Frequency Response of the CDMA Subscriber SAW Filter

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Trimmer Capacitors

The 2400 series trimmer capacitors are extremely durable single turn surface mount devices that are available in a wide range of capacitance values. A high Q over a broad frequency range combined with a high maximum operating voltage (400 VDC) and temperature stability are the characteristics found with this unique ceramic package.

Characteristics

- Rated voltage: 400 VDC (test voltage 800 VDC)
- Insulation resistance: >10^4 megΩ
- Operating temperature range: −55°C to +125°C
- Torque: 0.05 to 1.0 oz. in.
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- Setting drift: <1%
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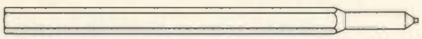
JMC Tuning Tool 4192



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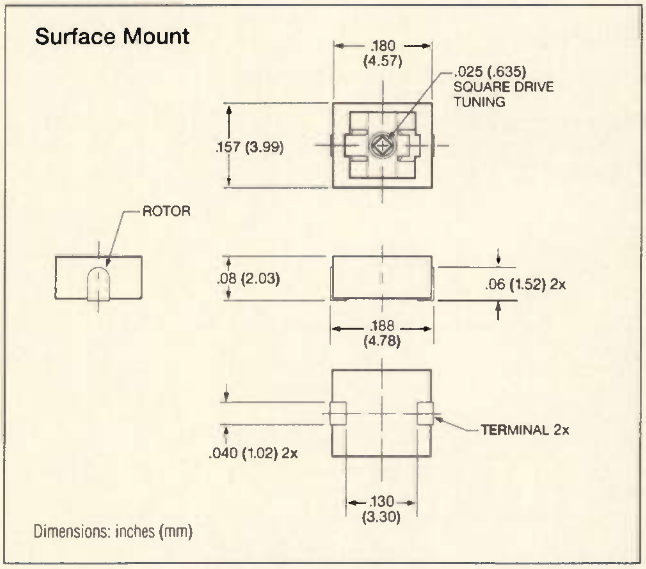
Johanson standard tape and reel packaging is available in .472 inch (12 mm) carrier tape in quantities of 500 on 7 inch (178 mm) reels and 2,500 on 13 inch (330 mm) reels. When ordering, add suffix to Johanson Part Number of either R1 for 7 inch reel or R2 for 13 inch reel.



Specifications

JMC P/N	RANGE pF	TC PPM/°C	MIN. Q @ 200 MHz
2400-0	0.7 to 2.0	NPO ± 200	2000
2400-1	1.5 to 4.0	NPO ± 200	1000
2400-2	3.0 to 9.0	200 ± 200	500
2400-3	5.0 to 15.0	−750 ± 500	400

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1 MHz - 2 GHz • 1 W - 1 kW

Part No.	Output Power	Gain	MODULES DC Supply	MODULES PKG
2 MHz - 30 MHz				
30-2-5-35	5W	35dB	24/28V	E3
30-2-50-35	50W	35dB	24/28V	E3
30-2-100-35	100W	35dB	28V	E3
30-2-200-35	200W	35dB	28V	E3
30 MHz - 100 MHz				
100-30-5-35	5W	35dB	24/28V	E3
100-30-100-35	100W	35dB	28V	E3
50 MHz - 150 MHz				
150-50-2-40	2W	40dB	12/15V	C3
150-50-100-35	100W	35dB	28V	A3
150 MHz - 200 MHz				
200-150-100-10	100W	10dB	28V	A1
200-150-100-18	100W	18dB	28V	A2
200-150-100-35	100W	35dB	28V	A3
200-150-200-35	200W	35dB	28V	A3
50 MHz - 250 MHz				
250-50-200-10	160W	10dB	28V	A1
250-50-200-18	160W	18dB	28V	A2
250-50-200-35	160W	35dB	28V	A3
50 MHz - 400 MHz				
400-50-1-30	1W	30dB	12/15V	C3
225 MHz - 400 MHz				
400-225-1-35	1W	35dB	12/15V	C3
400-225-10-35	10W	35dB	24/28V	A3
400-225-30-10	30W	10dB	24/28V	A1
400-225-30-18	30W	18dB	24/28V	A2
400-225-30-35	30W	35dB	24/28V	A3, B3

Part No.	Output Power	Gain	MODULES DC Supply	MODULES PKG
400-225-50-10	50W	10dB	24/28V	A1
400-225-50-18	50W	18dB	24/28V	A2
400-225-50-35	50W	35dB	24/28V	A3
400-225-100-10	100W	10dB	28V	A1
400-225-100-18	100W	18dB	28V	A2
400-225-100-35	100W	35dB	28V	A3
225 MHz - 600 MHz				
600-225-30-10	30W	10dB	24/28V	A1
600-225-30-18	30W	18dB	24/28V	A2
600-225-30-30	30W	30dB	24/28V	A3, B3
400 MHz - 600 MHz				
600-400-30-10	30W	10dB	24/28V	A1
600-400-30-18	30W	18dB	24/28V	A2
600-400-30-30	30W	30dB	24/28V	A3, B3
925 MHz				
925-1-8	1W	8dB	12/15V	D1
100 MHz - 500 MHz				
500-100-5-30	5W	30dB	24/28V	A3
500-100-10-30	10W	30dB	24/28V	A3
500-100-100-30	100W	30dB	28V	A3
500 MHz - 1000 MHz				
1000-500-10-8	10W	8dB	24/28V	A1
1000-500-10-16	10W	16dB	24/28V	A2
1000-500-10-30	10W	30dB	24/28V	A3
10 MHz - 1200 MHz				
1200-10-10-30	10W	30dB	24/28V	A3

* Test Fixture (Option "B") includes heat sink, fan, thermal shutdown, and electrical fuse protection
** Rack-mount amplifiers: 120 Vac - 60 Hz / 240 Vac - 50 Hz

MODULES - SMALL SIZE • HIGH EFFICIENCY

- 200 watts
- 150 - 200 MHz
- 55% overall efficiency
- 35 dB gain
- 4.84" x 2.0" x 1.0"

- 100 watts
- 225 - 400 MHz
- 45% overall efficiency
- 10 dB gain
- 3.0" x 2.0" x 1.0"

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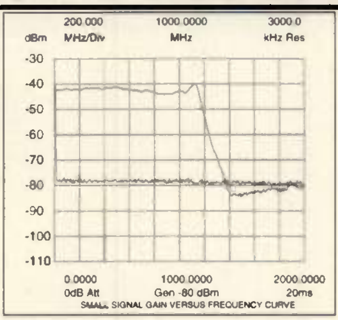

- 10 MHz - 1200 MHz
- 10 watts CW
- 40 dB
- 19" x 7" x 18"
- 35 lbs maximum

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Features:

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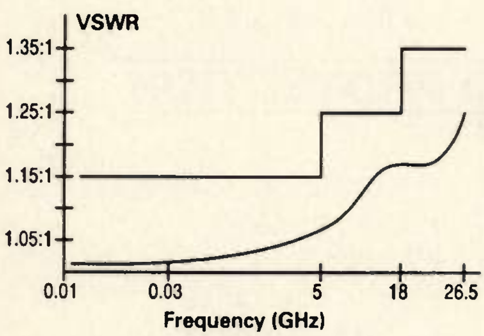
- VSWR less than 1.15:1 from 10 MHz to 5 GHz for units with 5 to 7 dB or 14 to 16 dB ENR
- Temperature coefficient less than 0.009 dB/°C
- Noise output variation with voltage less than 0.002 db/%ΔV
- Operating temperature 0°C to +55°C
- Input power +28 VDC ±2 VDC at 15 mA typical for NC 346 A, B, & D
- Built-in regulator

Noise Com's NC 346 Series is designed for precision noise figure measurement applications. The VSWR has been improved, reducing multiple reflections of the test signals and significantly increasing the measurement accuracy of most noise figure set-ups.

The NC 346 Series noise sources have broadband coverage and extremely good temperature and voltage stability, which makes them the finest noise figure meter compatible laboratory standards. Outputs of 6, 15.5 and 22 dB ENR are available, allowing the units to accurately measure noise figures up to 20, 30 and 36 dB respectively.

The return loss of the noise sources is measured in both the on and off states and is included in the calibration report provided with each noise source. Each noise source is also supplied with calibration data traceable to NIST.

See page 16 for package styles and dimensions.



Typical VSWR for NC 346C

Express

NC 346 COAXIAL SERIES

NOISE COM MODEL	RF CONNECTOR	FREQUENCY (GHz)	OUTPUT ENR (dB)	VSWR (MAXIMUM @ ON/OFF) 0.01-5 GHz	5-18 GHz	18-26.5 GHz	26.5-40 GHz
NC 346 Y	SMA Male	10 kHz - 1 GHz	14 to 16	1.20:1			
NC 346 A	SMA Male	0.01-18.0	5 to 7	1.15:1	1.25:1		
NC 346 A Precision	APC3.5 Male	0.01-18.0	5 to 7	1.15:1	1.25:1		
NC 346 A Option 1	N Male	0.01-18.0	5 to 7	1.15:1	1.25:1		
NC 346 A Option 2	APC7	0.01-18.0	5 to 7	1.15:1	1.25:1		
NC 346 A Option 4	N Female	0.01-18.0	5 to 7	1.15:1	1.25:1		
NC 346B	SMA Male	0.01-18.0	14 to 16	1.15:1	1.25:1		
NC 346B Precision	APC3.5 Male	0.01-18.0	14 to 16	1.15:1	1.25:1		
NC 346B Option 1	N Male	0.01-18.0	14 to 16	1.15:1	1.25:1		
NC 346B Option 2	APC7	0.01-18.0	14 to 16	1.15:1	1.25:1		
NC 346B Option 4	N Female	0.01-18.0	14 to 16	1.15:1	1.25:1		
NC 346 C	APC3.5 Male	0.01-26.5	13 to 17	1.15:1	1.25:1	1.35:1	
NC 346 D	SMA Male	0.01-18.0	19 to 25*	1.50:1	1.50:1		
NC 346 D Precision	APC3.5 Male	0.01-18.0	19 to 25*	1.50:1	1.50:1		
NC 346 D Option 1	N Male	0.01-18.0	19 to 25*	1.50:1	1.50:1		
NC 346 D Option 2	APC7	0.01-18.0	19 to 25*	1.50:1	1.50:1		
NC 346 D Option 3	N Female	0.01-18.0	19 to 25*	1.50:1	1.50:1		
NC 346 E	APC3.5 Male	0.01-26.5	19 to 25*	1.50:1	1.50:1	1.50:1	
NC 346 Ka	K Male**	0.10-40.0	10 to 17	1.25:1	1.30:1	1.40:1	1.50:1
NC 346 V	V Male***	TBD-60.0	TBD to 17	Consult Factory			

*Flatness better than ±2 dB
** Compatible with SMA and APC3.5
*** Compatible with APC2.4

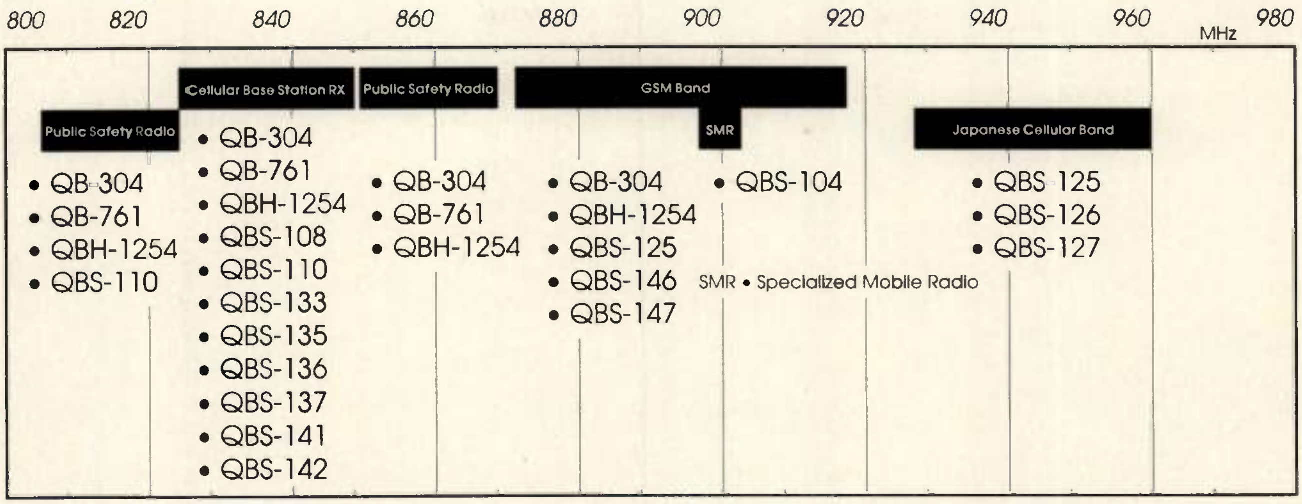
NC 346 WAVEGUIDE SERIES WITH BUILT-IN ISOLATOR*

Noise Com Model	Flange	Frequency (GHz)	ENR (dB)	VSWR (on/off)
NC 346B WR 229	CPR229F	3.7 - 4.2	14 to 16**	1.15:1
NC 346B WR 90	UG39/U	8.5 - 9.6	14 to 16**	1.15:1
NC 346B WR 75	UBR 120	10.5 - 13.0	14 to 16**	1.15:1

*Inquire for other flanges or waveguide sizes
** Flatness better than +/-0.15 dB

NOISE/COM
E. 49 Midland Avenue, Paramus, New Jersey 07652
(201) 261-8797 • FAX (201) 261-8339

Q-bit® Commercial Radio & Cellular Band Amplifiers



Specification Summary

Guaranteed Specifications @ 25 °C

Model	Frequency Range MHz	Gain dB	Output P1dB dBm	VSWR	Noise Figure dB	Reverse Isolation dB	3rd OIP[1] dBm	DC Power Vdc/mA	Housing
QB-304	800-900	20.0	24.0	1.5:1	3.0	37	40/	15/300	19202
QB-761	806-870	23.0	18.0	1.5:1	3.5	42	32/	15/140	187-2
QBH-1254	804-901	12.5	23.5	1.5:1	3.0	26	37/	15/142	TO-8
QBS-104	896-925	27.0	26.0	1.7:1	2.0	37	41/	15/450	19069
QBS-108	824-849	8.0	25.0	2.0:1	5.0	12	40/	15/200	19134
QBS-110	806-849	27.0	26.0	1.7:1	2.0	37	41/	15/450	19069
QBS-125	896-960	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-126-1	925-960	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-126-2[2]	925-960	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-127-1	925-960	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-127-2[2]	925-960	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
QBS-133	824-849	33.0	19.0	2.0:1	1.3	41	35/	15/250	19121
QBS-135	824-849	40.0	24.0	2.0:1	1.3	51	39/	15/425	19121
QBS-136	824-849	14.0	25.0	2.0:1	5.5	21	40/	15/325	19134
QBS-137	824-849	26.0	15.0	2.0:1	1.3	36	28/	15/150	19134
QBS-141-1	824-849	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-141-2[2]	824-849	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-142-1	824-849	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-142-2[2]	824-849	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
QBS-146-1	870-915	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-146-2[2]	870-915	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-147-1	870-915	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-147-2[2]	870-915	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
Power Amplifiers									
QBS-227	800-960	40.0	40.0	2.0:1	-	60	50	24/2600	
QBS-230	800-960	40.0	43.0	2.0:1	-	60	53	24/4400	
QBS-233	1800-2200	40.0	40.0	2.0:1	-	60	52	12/4600	

Specifications are 25°C Typical
[1] OIP = Output Intercept Point

[2] Soft fail design with built in regulation and fault indication circuitry

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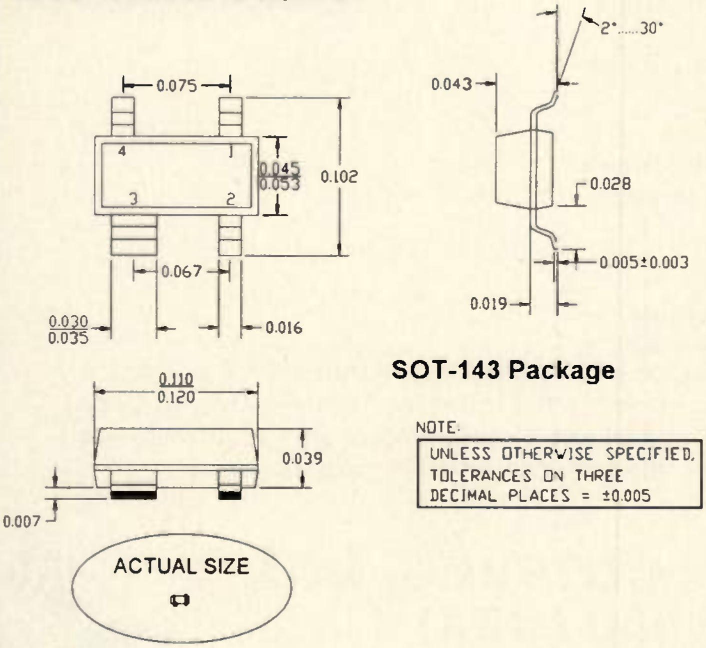
NEW PRODUCTS !

SILICON BIPOLAR MONOLITHIC AMPLIFIER

MODEL NUMBER	SBA-1		SBA-2		SBA-3	
Operating Frequency:	DC - 2000 MHz		DC - 2000 MHz		DC - 2000 MHz	
Gain (dB):	Typ	Min	Typ	Min	Typ	Min
100 MHz:	9.0	7.0	11.0	10.5	18.0	12.0
500 MHz:	9.0	7.0	10.5	10.0	16.5	11.0
1000 MHz:	8.5	6.5	9.5	9.0	15.0	10.0
2000 MHz:	6.8	5.5	7.8	6.0	10.0	7.5
Typical Output 1 dB Comp Pt.:						
100 MHz:	+12 dBm		+9 dBm		+14.8 dBm	
500 MHz:	+12 dBm		+9 dBm		+13.7 dBm	
1000 MHz:	+9.5 dBm		+8.5 dBm		+11.8 dBm	
2000 MHz:	+6.5 dBm		+8.0 dBm		+10.5 dBm	
Typical VSWR:	Input	Output	Input	Output	Input	Output
100 MHz:	1.3:1	1.5:1	1.3:1	1.5:1	1.1:1	1.5:1
500 MHz:	1.3:1	1.5:1	1.3:1	1.5:1	1.2:1	1.5:1
1000 MHz:	1.3:1	1.5:1	1.3:1	1.5:1	1.2:1	1.5:1
2000 MHz:	1.3:1	1.5:1	1.3:1	1.5:1	1.3:1	1.5:1
Typical Noise Figure:						
100 MHz:	6.0 dB		5.5 dB		3.5 dB	
500 MHz:	6.2 dB		6.0 dB		3.5 dB	
1000 MHz:	6.5 dB		6.2 dB		4.0 dB	
2000 MHz:	7.0 dB		7.0 dB		5.0 dB	

Mechanical Outline:



SOT-143 Package

NOTE:
UNLESS OTHERWISE SPECIFIED, TOLERANCES ON THREE DECIMAL PLACES = ±0.005

Maximum Ratings:

Parameter	Symbol	Unit
Device Current	I_D	60 mA
Total Power Dissipation, T_s < 99 °C	P_{tot}	250 mW
RF Input Power	P_{RFin}	10 dBm
Junction Temperature	T_j	150°C
Ambient Temperature	T_A	-65 to +150°C
Storage Temperature	T_{stg}	-65 to +150°C

Notes:
Test Conditions:
1. T_A = 25°C
2. V_D = 4.7Volts, I_D =42 mA, Z_O = 50Ω

SYNERGY®
MICROWAVE CORPORATION
201 McLean Boulevard •Paterson, New Jersey 07504• Tel:(201) 881-8800•Fax:(201)881-8361

Specifications subject to change without notice.

TEMEX STANDARD 10.7MHZ MONOLITHIC CRYSTAL FILTERS CHANNEL SPACING FOR 12.5 • 20 • 25 AND 50KHZ

ELECTRONICS, INC.

CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

NO. POLES	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ dB-MIN	TERM. (Rp//Cp) OHM/PF
2	TE5000	3	3.75	20	18.0	–	—	2	1.0	50	1800//+4
4	TE5010	3	3.75	30	14.0	–	—	3	2.0	60	1500//+3
6	TE5020	6	3.75	60	12.5	–	—	4	2.0	70	1500//+3
8	TE5030	6	3.75	60	10.0	90	12.5	5	2.0	80	1500//+3
2	TE5040	3	6.5	20	30.0	–	—	1	1.0	50	2700//0
4	TE5050	3	6.5	30	15.0	–	—	2	2.0	75	3100//0
6	TE5060	6	6.5	60	19.5	–	—	3	2.0	90	3100//0
8	TE5070	6	6.5	60	13.0	80	17.5	4	2.0	100	3100//0
2	TE5080	3	7.5	20	35.0	–	—	1	1.0	50	3000//0
4	TE5090	3	7.5	30	17.5	–	—	2	2.0	75	3300//0
6	TE5100	6	7.5	60	22.5	–	—	3	2.0	90	3300//0
8	TE5110	6	7.5	60	15.0	80	20.0	3	2.0	100	3300//0
2	TE5120	3	15.0	20	70.0	–	—	1	1.0	35	5000//-1
4	TE5130	3	15.0	30	35.0	–	—	2	2.0	60	5000//-1
6	TE5140	6	15.0	60	45.0	–	—	2	2.0	90	5000//-1
8	TE5150	6	15.0	60	30.0	80	40.0	3	2.0	100	5000//-1

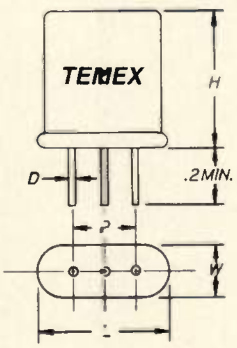
NOTES:

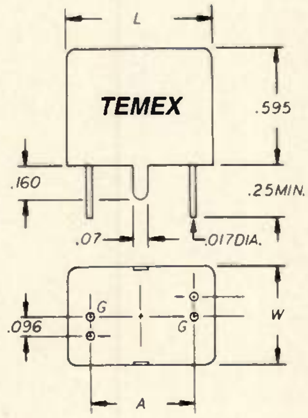
1. Maximum inband ripple over temp. range -20°C to 70°C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matches.]
4. These models available in other packages not shown below.

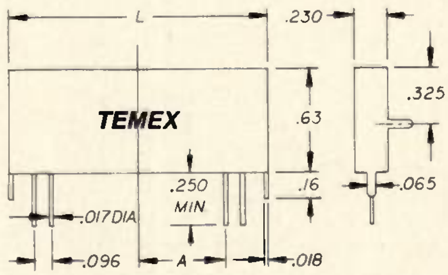
TO ORDER: TEMEX P/N and PACKAGE TYPE: Example: TE5100M5.

# POLES	PACKAGE SELECTION
2	M3 or 4
4	M3 or 4(x2)M5, 6, 7, 8 or 9
6	M3 or 4(x3)M5, 6, 8 or 9
8	M3 or 4(x4)M6 or 9

(x2)=2 cases (x3)=3 cases (x4)=4 cases







PKG	L	W	H	P	D
M3	.435	.185	.45/.53	.192	.017
M4	.750	.350	.750	.486	.030

HC-18/3:M3 HC-6/3:M4
HC-49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

All specifications subject to change without notice.

*Consult **TEMEX** for your custom crystal and filter requirements.*

3030 W. Deer Valley Rd. • Phoenix, AZ 85027 • 602-780-1995 • (FAX) 602-780-2431

TEMEX STANDARD 21.4 MHZ MONOLITHIC CRYSTAL FILTERS CHANNEL SPACING FOR 12.5 • 20 • 25 AND 50KHZ

E L E C T R O N I C S , I N C .

CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

NO.	TEMEX	PASSBAND		STOPBAND				LOSS	RIPPLE	ULT. REJ	TERM. (Rp//Cp)
POLES	P/N	dB	±KHz	dB	±KHz	dB	±KHz	dB	dB-MAX	dB-MIN	OHM/PF
2	TE5180	3	3.75	15	12.5	–	—	2	1.0	50	850//+6
4	TE5190	3	3.75	30	12.5	–	—	3	2.0	70	850//+5
6	TE5200	6	3.75	60	12.5	–	—	4	2.0	90	850//+5
8	TE5210	6	3.75	60	10.0	80	12.5	5	2.0	100	850//+5
2	TE5220	3	6.5	15	20.0	–	—	2	1.0	50	1300//+2
4	TE5230	3	6.5	30	22.5	–	—	3	2.0	70	1400//0
6	TE5240	6	6.5	60	22.5	–	—	4	2.0	90	1400//0
8	TE5250	6	6.5	60	17.5	80	22.5	4	2.0	100	1400//0
2	TE5260	3	7.5	15	25.0	–	—	2	1.0	50	1500//0
4	TE5270	3	7.5	30	25.0	–	—	3	2.0	70	1600//0
6	TE5280	6	7.5	60	25.0	–	—	4	2.0	90	1600//0
8	TE5290	6	7.5	60	20.0	80	25.0	4	2.0	100	1600//0
2	TE5300	3	15.0	15	50.0	–	—	2	1.0	45	3000//0
4	TE5310	3	15.0	30	45.0	–	—	3	2.0	60	3000//-1
6	TE5320	6	15.0	60	45.0	-	—	3	2.0	90	3000//-1
8	TE5330	6	15.0	60	33.0	80	45.0	4	2.0	100	3000//-1

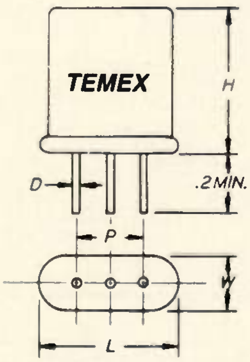
NOTES:

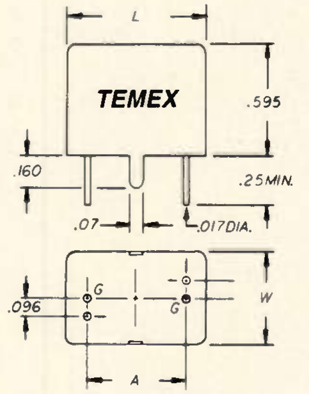
1. Maximum inband ripple over temp. range -20°C to 70°C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matched.]
4. These models available in other packages not shown below.

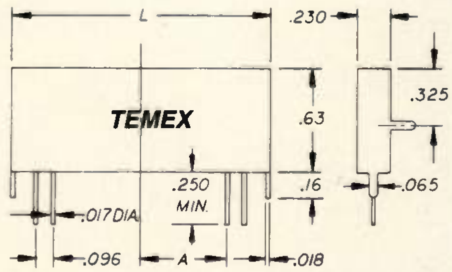
TO ORDER: TEMEX P/N and PACKAGE TYPE: Example TE5280M3

# POLES	PACKAGE SELECTION
2	M1, 2 or 3
4	M1, 2 or 3(x2)M5, 6, 7, 8 or 9
6	M1, 2 or 3(x3)M5, 6, 8 or 9
8	M1, 2 or 3(x4)M6 or 9

(x2) = 2 cases (x3) = 3 cases (x4) = 4 cases







PKG	L	W	H	P	D
M1	.300	.100	.310	.114	.017
M2	.310	.125	.320/.345	.148	.017
M3	.435	.185	.45/.53	.192	.017

HC-44/3:M1 HC-45/3:M2 HC-18/3:M3 HC49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

Consult ***TEMEX*** *for your custom crystal and filter requirements.*

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TEMEX STANDARD 45.0 MHZ MONOLITHIC CRYSTAL FILTERS

ELECTRONICS, INC.

CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

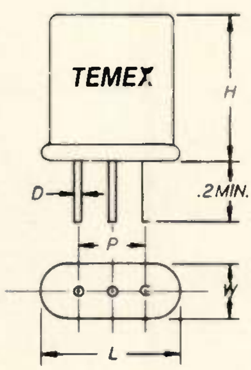
NUMBER OF POLES	MODE	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN	TERMINATION Ohms/pF
45 MHz MONOLITHIC CRYSTAL FILTERS										
2	30T	TE7420	3	7.5	18	28	2	1	40	3000//-1.0
4	30T	TE7430	3	7.5	40	30	3	1	70	3000//-1.0
2	30T	TE7440	3	15	15	47	2	1	40	8000//-1.5
4	30T	TE7450	3	15	30	50	3	1	70	8000//-1.5
2	FUND	TE7730	3	15	15	50	2	1	40	1100//+1.5
4	FUND	TE7740	3	15	40	60	3	1	70	800//+1.0

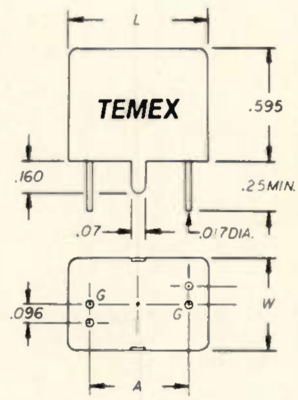
NOTES:

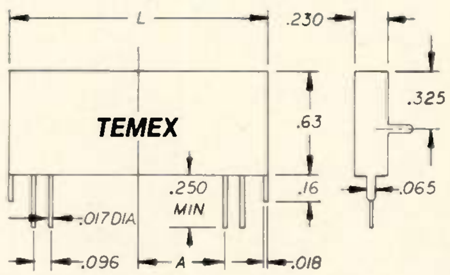
1. Maximum inband ripple over temp. range -20° C to 70° C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matched.]
4. These models available in other packages not shown below.
5. Standard package = M2.
6. 50 Ohms Z I/0 available in our M5 or larger packages.
7. 30T = Third overtone crystals.
   Fund = Fundamental crystals.
8. Other models available, consult factory.

# POLES	PACKAGE SELECTION
2	M1, 2 or 3
4	M1, 2 or 3(x2)M5, 6, 7, 8 or 9

(x2) = 2 cases







PKG	L	W	H	P	D
M1	.300	.100	.310	.114	.017
M2	.310	.125	.32/.345	.148	.017
M3	.435	.185	.45/.53	.192	.017

HC-44/3:M1 HC-45/3:M2 HC-18/3:M3 HC-49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

*Consult **TEMEX** for your custom crystal and filter requirements.*

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VARIL Low Cost Surface Mount VCO's

The new VCO 190 Series Voltage Controlled Oscillators represent the latest high performance surface mount source designs for cost sensitive wireless applications.

Electrical

The VARI-L patented oscillator circuit is applied as required, to provide the portable wireless designer with the very best combination of excellent power efficiency coupled with low output phase noise. In addition, each device contains a high isolation pad/buffer stage to provide flat spurious free power into almost any output load. All VARI-L VCO designs are fundamental single ended oscillators and therefore totally free of non-harmonic spurious outputs. Further, the harmonic outputs of these new oscillators are filtered and controlled as specified to provide for simplified end use designs.

A separate frequency modulation (FM) control port is supplied on some models for locked loop modulation, coarse/fine high speed dual loops, or DC fine tune requirements. This option is also special order available on other models shown.

Many of these oscillators are incorporated into the new award-winning* PLL 200 Programmable Phase Locked synthesizer modules for wireless and commercial applications. For this reason, the VCO-190 models shown were developed with full knowledge of the unique requirements for phase locked wireless applications.

Finally, all oscillators are 100% electrical tested using fully automatic computer controlled test stations. Simply, every part shipped is guaranteed specification compliant with S.P.C. data retained for monitoring quality and yield and associated continuous process tuning.

Assembly

The 190 Series of VCO's are available in tape and reel and are designed to withstand a minimum of two automatic reflow insertion exposures.

Mechanical

The unique surface mount package shown provides excellent mechanical solutions to shielding, low profile, ease of mounting, and repeatable in-circuit performance. These new VCO's are automatic re-flow assembled using the latest very high volume robotic manufacturing techniques. This results in superior electrical and mechanical product uniformity while allowing for low cost and virtually unlimited production capacity. Volume manufacturing is accomplished in an ISO 9000 compliant facility.

Temperature

Tuning linearity, output power, and phase noise are stable and flat over 0 to 70°C commercial temperature range. Operation from -35°C to +85°C is also specified with derated performance.

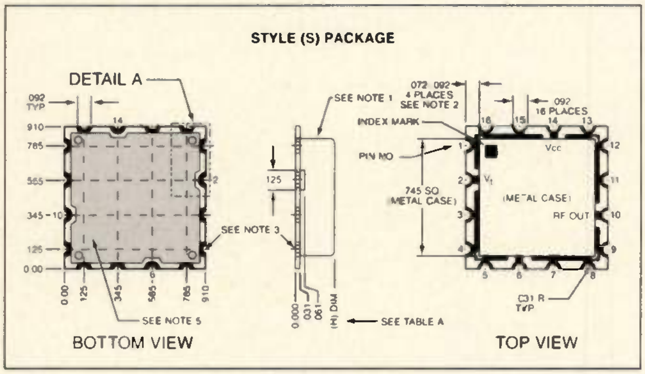
Supply

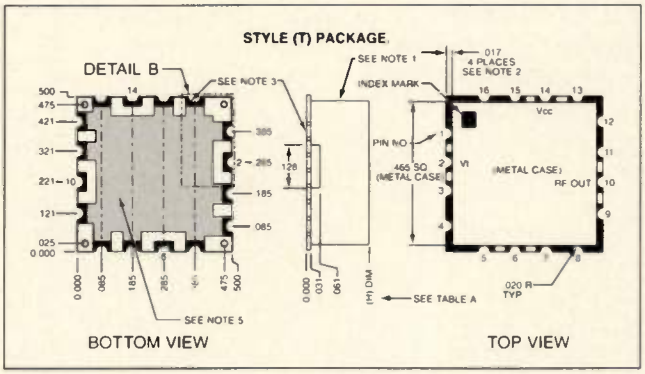
All specifications are published utilizing a 5 Volt supply. However, operation with a supply of 3 Volts or less is routinely possible with reduced parameter performance. Conversely, a series dropping resistor will allow proper operation at any greater supply voltage. The dropping resistor may be used in conjunction with an appropriate bypass capacitor (RC Filter) to yield: improved power supply, de-coupling/noise suppression, improved oscillator supply voltage regulation with temperature, as well as improved oscillator pushing performance.

General

Detailed product data sheets for the models shown are available upon request. In addition to the standard catalog line, VARI-L offers a complete line of custom designed devices to meet specific customer requirements. These include tailored frequency ranges, custom output buffering, improved performance of selected parameters such as linearity, noise, modulation rate, etc., custom packaging, additional temperature range or temperature compensation and special power supply requirements. (For example contact VARI-L Sales Engineering for information on optimized 3V designs.)

*Winner of the *Microwaves & RF* Top 12 Product Award for 1993.

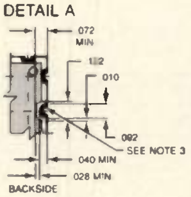




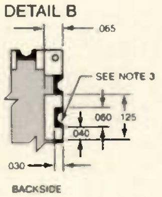
Note, Unless otherwise specified:

1. The metal case is ground and is composed of tin electroplated brass.
2. This dimension is between the metal case and the edge of the board.
3. All half via contacts are plated thru from the pad on the top side to the pad on the bottom side of the board.
4. All dimensions shown in Detail-A and B are typical of all isolated contact pads.
5. Cross hatched areas are ground and are covered with LPI solder mask. All contact areas are plated with SN-63 solder.
6. Substrate material: FR-4.
7. For surface mount pad patterns, request Bulletin 101 "Surface Mount Package User's Information."

DETAIL A



DETAIL B



PIN OUT			
STYLE (S)		STYLE (T)	
PIN	APPLICATION	PIN	APPLICATION
2	Vt	2	Vt
6	N/C •	6	N/C •
10	RF OUT	10	RF OUT
14	Vcc	14	Vcc

All other pins are ground.
• Optional Audio Modulation Port (types with suffix "M" on Part No.)

TABLE A	
HEIGHT DIM	
-1	250
-2	180
-3	200
-4	100
-5	

Note: For special height requirements contact VARI-L Sales Engineering.

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VCO-190 Series, Voltage Controlled Oscillators Selection Guide

Model VCO-190[1,9]	Frequency MHz	Tuning Voltage[4,8] Min/Max	RF Power[6] dBm	Supply Voltage[3] Volts	Supply Current mA	Phase Noise 10 KHz Offset[7] dBc/Hz	Average Modulation Sensitivity MHz/Volt	Modulation Bandwidth MHz	Harmonic Suppression dBc	Pushing MHz/V	Pulling[2] MHz-PP	Drift MHz/°C	Separate Modulation Port: Deviation 1 VPP at 1 KHz[8] KHz	Separate Modulation Port: Deviation Variation Over the Band %	Separate Modulation Port: Distortion 1 KHz at 1 VPP Bandpass .3 - 3 KHz %	Package Style/Height See Table 1: S	Package Style/Height See Table 1: T[9]
45	44-46	1-4	0	5	9.5	116	.7	>.5	20	.05	.05	-.008				1	—
70	68-72	1-4	0	5	9.5	116	1.0	>.5	20	.07	.07	-.01				1	—
72	70.5-73.5	1-4	0	5	9.5	116	1.0	>.6	20	.07	.07	-.01				1	—
72M	70.5-73.5	1-4	0	5	9.5	116	1.0	>.6	20	.07	.07	-.01	10±2	±10	<.5	1	—
112	75-150	1-16	0	5	9.5	111	1.0	>.5	10	.4	.25	-.02				1	—
125	120-130	1-9	0	5	9.5	118	1.2	>.8	20	.10	.10	-.015				1	1
135	130-140	1-9	0	5	9.5	117	1.3	>.8	20	.15	.15	-.015				1	—
150	100-200	1-16	0	5	9.5	113	7.5	>.5	10	.5	.3	-.025				1	1
200	150-250	1-16	0	5	9.5	113	10.0	>.75	10	.75	.4	-.028				1	—
250	245-255	1-4	0	5	9.5	116	2.6	>1.0	20	.25	.25	-.025				1	—
250A	200-300	1-12	0	5	9.5	113	12.0	>.75	12	1.0	.5	-.03				1	—
300	250-350	1-10	0	5	9.5	113	13.0	>.75	12	1.1	.7	-.035				1	—
350	300-400	1-9	0	5	9.5	112	15	>1.0	12	1.3	.8	-.037				1	—
400	350-450	1-9	0	5	9.5	112	16	>1.0	12	1.4	.85	-.04				1	—
422	415-430	1-4	0	5	10.0	118	7.0	>2.0	20	.5	.5	-.04				1	3
422M	415-430	1-4	0	5	10.0	118	7.0	>2.0	20	.5	.5	-.04	10±2	±10	<.5	1	3
450	442-458	1-4	0	5	9.5	118	7.25	>2.0	20	.5	.5	-.04				1	3
450M	442-458	1-4	0	5	9.5	118	7.25	>2.0	20	.5	.5	-.04	10±2	±10	<.5	1	3
450A	400-500	1-9	0	5	9.5	112	16	>1.0	12	1.5	1.0	-.045				1	3
450AM	400-500	1-9	0	5	9.5	112	16	>1.0	12	1.5	1.0	-.045	11±3	±35	<.5	1	3
490	482-498	1-4	0	5	10.0	118	7.5	>2.0	20	.5	.5	-.04				1	3
550	500-600	1-9	0	5	9.5	110	17	>1.0	12	1.8	1.3	-.06				1	3
675	600-750	1-9	0	5	10.0	108	23	>2.0	12	2.5	1.8	-.08				2	3
680	667-693	1-4	0	5	9.5	112	11	>1.0	20	.55	1.5	-.05				2	3
752	739-765	1-4	0	5	10.5	110	11	>1.0	20	.6	1.8	-.06				2	3
773	760-786	1-4	0	5	10.5	110	11	>1.0	20	.6	2.0	-.06				2	3
775	700-850	1-9	0	5	10.0	107	26	>2.0	12	3.0	2.2	-.09				2	3
810	797-823	1-4	0	5	10.5	110	11	>1.0	20	.65	2.0	-.065				2	3
836	823-849	1-4	0	5	10.5	110	10	>1.5	20	.7	2.0	-.070				2	3
836M	823-849	1-4	0	5	10.5	110	10	>1.5	20	.7	2.0	-.070	10±2	±10	<.25	2	3
864	851-877	1-4	0	5	10.5	110	10	>2.0	20	.8	2.0	-.075				2	3
900	800-1000	1-9*	0	5	10.0	106	30	>2.0	12	3.5	2.5	-.10				2	3
902	889-915	1-4	0	5	10.5	110	10	>3.0	20	.8	2.0	-.08				2	3
915	902-928	1-4	0	5	10.5	110	10	>3.0	20	.8	2.0	-.08				2	3
926	913-939	1-4	0	5	10.5	110	11	>3.0	20	.8	2.0	-.08				2	3
947	934-960	1-4	0	5	10.5	109	11	>3.0	20	.85	2.0	-.085				2	3
964	951-977	1-4	0	5	10.5	108	11	>3.0	20	.85	2.0	-.085				2	3
992	979-1005	1-4	0	5	10.5	108	11	>3.0	18	.85	2.2	-.085				2	3
1100	1085-1115	1-4	0	5	10.75	106	11.5	>4.0	18	.85	2.2	-.085				2	3
1100A	1000-1200	1-9*	0	5	11.0	104	30	>2.0	12	4.5	3.5	-.13				2	3
1200	1185-1215	1-4	0	5	10.75	106	12.0	>5.0	18	1.0	2.3	-.09				2	3
1500	1450-1550	1-6	0	5	11.0	103	28	>10.0	15	1.2	2.5	-.13				2	3
1550	1500-1600	1-6	0	5	11.5	102	28	>10.0	15	1.3	2.7	-.15				2	3
1650	1600-1700	1-6	0	5	11.5	100	28.5	>10.0	15	1.4	2.7	-.16				2	3
1750	1700-1800	1-6	0	5	11.5	99	28.5	>10.0	15	1.5	3.0	-.18				2	3
1850	1800-1900	1-6	0	5	11.5	98	28.5	>10.0	15	1.5	3.1	-.19				2	3
1900	1500-2300	1-15	0	12	14.5	80	70	>10.0	10	2.5	5.0	-.3				2	3
1950	1900-2000	1-6	0	5	11.5	97	29	>10.0	15	1.6	3.2	-.2				2	3
2050	2000-2100	1-6	0	5	11.5	96	30	>10.0	15	1.7	3.4	-.26				2	3
2150	2100-2200	1-6	0	5	11.5	95	30	>10.0	15	2.0	3.5	-.28				2	3
2250	2200-2300	1-6	0	5	11.5	95	30	>10.0	15	2.5	3.7	-.30				2	3
2200	1800-2600	1-15	0	12	15.5	80	70	>10.0	10	3.8	7.5	-.4				2	3
2350	2300-2400	1-6	0	5	11.5	95	30	>10.0	15	2.9	3.9	-.3				2	3
2450	2400-2500	1-6	0	5	11.5	95	30	>10.0	15	3.0	4.0	-.22				2	3
2450A	2400-2500	1-4	0	4.5	11.5	90	50	>10.0	20	3.7	6.0	-.37				—	4

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Notes on High-Speed Digital Signals

By Gary A. Breed
Editor

Although space is limited for this month's tutorial, we will try to identify the problem areas presented by high-speed digital signals. These signals have a combination of digital and RF properties that offer challenges to engineers designing both purely digital systems and combined systems with analog and digital circuitry.

From a design engineer's perspective, there are three primary issues that arise from high-speed digital signals:

- Transmission line effects on their digital behavior.
- Increased radiation over lower frequency digital signals.
- Self-interference in combined analog and digital systems.

These issues are all interrelated, and they all deal with the high frequency nature of the signals. In many cases, these problem areas affect both RF/analog and digital designers.

Transmission Line Effects

Behavior of signals in lines (reflection, radiation, dispersion, coupling) is a function of wavelength. Of course, higher frequency signals have shorter wavelengths. When physical dimensions remain the same, a higher frequency system will have more pronounced effects.

For example, the original IBM PC had a clock of 4.77 MHz. A 12-inch trace on a circuit board is only about 0.005 λ at that frequency. Microprocessors and DSP devices now routinely operate with 50 MHz clock frequencies, where that same circuit trace is more than 0.05 λ. This is 18° electrical length at 50 MHz, a "long" conductor to any RF engineer.

If this transmission line is not terminated in its characteristic impedance, power will reflected and standing waves will occur, altering the shape of the wave and potentially causing a failure to reach the logic threshold voltage at the destination device.

Making the situation worse, digital signals have plenty of energy in harmonics of the clock frequency. The actual amount of energy is dependent on the repetition rate (clock frequency), the rise and fall times, and the duty cycle [1]. A line carrying a 50 MHz clock signal should perform well to at least the third harmonic of 150 MHz.

While termination is the first step in dealing with high-speed digital signals, it doesn't fix everything. Coupling to adjacent lines is a significant problem. While smaller size helps with signal transmission, it unfortunately places lines close together, creating the opportunity for coupling.

Proper routing of signal lines is the typical solution to coupling problems. High-speed data lines need to be kept as far apart as possible, while low-speed or status lines can be grouped closer to one another.

Radiation Problems

Radiation is one more problem that arises in high-speed digital systems. Not only does it make compliance with FCC Part 15 standards difficult, it can create problems internal to the unit. Self-interference will be discussed later, but for compliance purposes, there are a few key techniques to be evaluated by the designer.

One method is to place signal lines between ground plane layers in multi-layer circuit boards. This creates stripline transmission lines, which have far better field containment than microstrip, which has a ground plane only below the conductor. Multi-layer boards are widely used for both higher density signal routing and control of electromagnetic radiation.

Another, more extreme, method is to use localized shielding in areas of the circuit where high frequency energy is concentrated. Product compliance can be very expensive if failure to meet the required standards delays shipment. As a repair or retrofit technique, shielding is the most expedient, although it is usually much more costly than a integral solution designed into the product earlier in the process.

Nearly all high-speed digital products are packaged in metal or conductive plastic enclosures. This measure of shielding is necessary for compliance, but even shielding has areas of concern to designers.

Cables and apertures are the primary trouble spots, since this is where the continuity of the shield is broken. Apertures include slots for disk drives and CD-ROMs, keyboards and displays. Waveguide theory suggests how much they will radiate, but it's not a complete analysis. The apertures are usually penetrated by panels, and various wires and circuit board conductors approach the outside of the enclosure.

Perhaps the most difficult radiation problems are caused by cables. Filtered connectors can be some help, as can shielded cables. However, the high-speed signals must still be carried through the cables' conductors, and even a small amount of energy can create a significant electromagnetic field strength when the "antenna" comprising the cable and equipment is a sizeable fraction of a wavelength (especially if it becomes resonant!).

The integrity of the cable shield is essential, as is the reduction of current on the outside of the cable. The latter may require ferrite chokes or 100 percent shield coverage instead of just braided shielding. The proper selection of connectors for high-reliability mating is very important, too.

Self-Interference in Combined Analog and Digital Systems

In the November 1994 issue of *RF Design*, a self-interference situation wa described by Egan and Lucas [2]. In this case, a high-speed prescaler had a low-frequency oscillation that modulated a VCO in a synthesizer. This points out an unusual problem with high-speed digital devices — they can have very high analog gain, which s related to the inverse

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

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of frequency. If nothing else, this example illustrates that these devices can present new problems not encountered with previous generations of digital devices.

Although unusual problems occur, an engineer is more likely to find more typical problem areas. These well-known problems include ground bounce, power supply line coupling, and crosstalk. In a high-speed environment, the frequency-related behavior already noted makes them more difficult to address.

Ground bounce is the small variation in ground potential caused by the pulsed current consumption of digital circuits. With lower-frequency logic, ground bounce is usually far removed from the RF frequencies of analog circuitry. Separate ground planes for analog and digital circuitry are usually sufficient in this case. But high-frequency digital signals are within the RF operating range of many applications. Isolation between digital and analog circuitry must be improved beyond grounding, to avoid coupling from digital ground to RF circuits.

Power supply lines are subject to effects similar to ground bounce. In this case, the typical solution is better decoupling at the device. Usually, the normal bypass capacitor is augmented by a ferrite bead, to create a lowpass L-C filter. New types of planar capacitors may help, as well. They have high capacitance and very low inductance, making them more effective at high frequencies.

Finally, crosstalk is the most common digital-into-analog/RF problem. This topic cannot be even introduced effectively in this short note, except to say that wide separation of digital and RF signals is usually required to keep crosstalk under control. In small hand-held equipment, this is certainly a challenge. Refer to the list of references for more information.

Dealing with high-speed digital signals in circuitry common to RF/analog functions is a rapidly growing problem. Through this note, we hope that RF engineers gain an appreciation for the nature and severity of the problems that they may encounter. ***RF***

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Ladder Filter Design Made Simple

By Richard Yeager
Hughes Network Systems, Inc.

LADDER is a PC compatible software program for the design and analysis of lumped-component RF ladder filters up to 2 GHz. Professionals and beginners may use the program to quickly explore many kinds of filters. The program includes features such as: 14 kinds of filters, unequal termination impedances, selectable component Qs, 5%/10% value substitution, editable SPICE file generation, analysis and monte carlo simulation on magnitude, phase and group delay, and hardcopy output.

Have you ever wanted to quickly design an LC filter, but didn't want to go through the tedious denormalization calculations needed to convert Zverev's [1] or Williams' [2] tabularized designs? Did you ever want to see the effect of using standard 5% or 10% inductors and capacitors in your design? What do you do when you need unequal termination impedances in a common ladder filter design? Have you ever wanted to do Monte Carlo runs on phase and group delay, as well as magnitude? I know I have wanted or needed to do these things over the years. LADDER is a PC application that allows you to do all this.

LADDER - The Program

LADDER is an IBM PC-compatible DOS software program written to design lumped-component all-pole ladder filters. The program uses a menu-driven, point-and-click architecture to design 14 kinds of lowpass, highpass, and bandpass filters. Available filter orders range from 2nd to 10th order in general. Design values are taken from Zverev [1] and Fink [3]. Once a filter has been designed, the user may go to an analysis module that can produce the frequency, phase and group delay responses for the design, plus do Monte Carlo runs on the filter. Hardcopy output, to printer or file, can be produced at any time during the analysis session.

The design philosophy for LADDER centered on the objective of being easy to use – that is, requiring as little typing-in of information as possible. To this end, itemized menus, radio-button pick-lists, and push-type command buttons are used wherever possible. This requires that some parameters be quantized to particular values and a discrete choice be given. For instance, the choices of source to load termination impedance (R_S/R_L) generally ranges from 0.1 to 1.0 or 1.0 to 10.0 with ten choices in each range. One should be able to find a suitable choice in this case for most applications. Many filter design parameters such as family, type (lowpass, highpass, bandpass), topology (LO-Z, HI-Z), component tolerances, and order can be set entirely with mouse clicks on menus or lists. Other parameters such as frequency, bandwidth, impedance level, etc., are entered manually in various dialog boxes. Help messages at the bottom of the screen give the user information on the allowable range of values for these inputs. A HELP main menu item displays a help file giving information on the operation of the program in general.

There are three basic modules in LADDER: the MAIN MENU, the ANALYSIS module, and the HARDCOPY module. All available filter design parameters are set via the

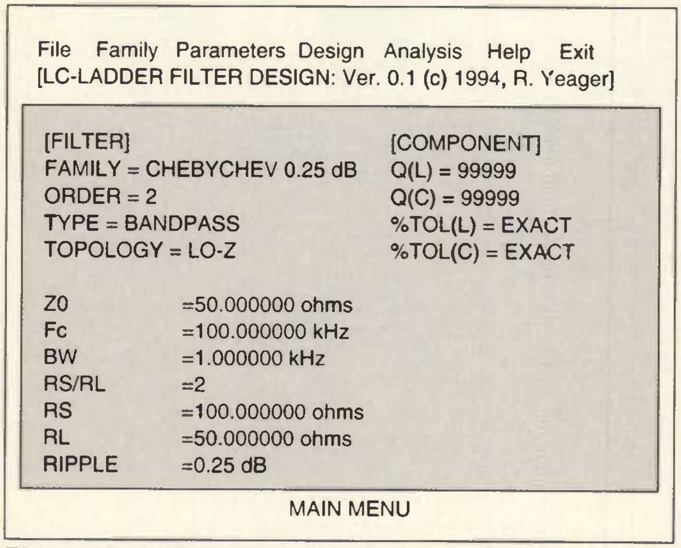

Figure 1. LADDER's main menu showing design parameters for a 100 kHz bandpass filter.

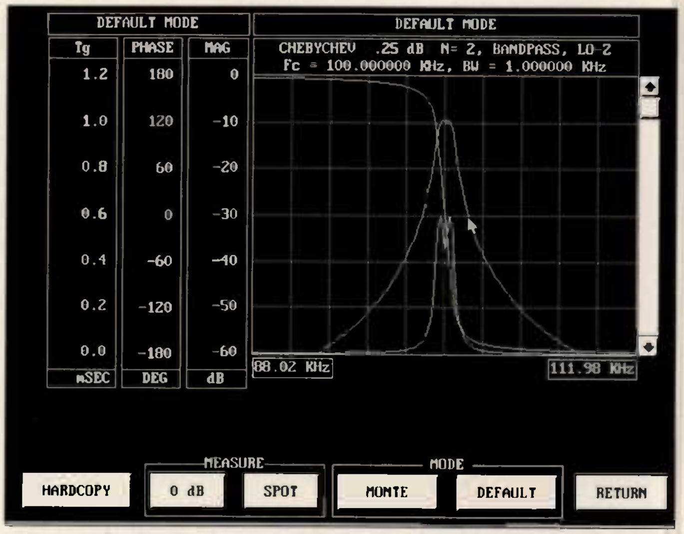

Figure 2. Default graphical analysis mode of LADDER showing delay, phase and magnitude of example 100 kHz bandpass filter.

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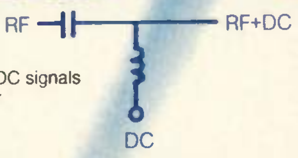

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▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
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▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
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•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
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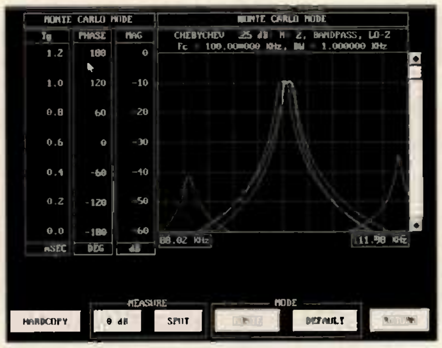


Figure 3. Monte Carlo analysis of filter of Figure 1 with 3 trials and 10% tolerances for components.

MAIN MENU which appears on program start-up. The ANALYSIS module will produce frequency sweeps and Monte Carlo runs on magnitude, phase, and group delay. The HARDCOPY module can output analysis results in a variety of printer formats.

Designing Filters

All-pole filters consist of an alternating sequence of series/shunt branches from input to output; no series-connected parallel traps or non-adjacent node bridges are allowed. The MAIN MENU-FAMILY selection allows you to choose filters from BUTTERWORTH to TRANSITIONAL GAUSSIAN families. I have chosen to call the topology of a filter, (i.e., the way the branches are arranged), by the names LO-Z and HI-Z. LO-Z signifies that the first branch seen by the source is a shunt branch. This implies that the filter input impedance tends toward a short circuit in the stop-band. The HI-Z topology sees a series branch first, and tends toward an open circuit in the stopband. Driving and load impedances may be different, but in a specific way. Even-ordered LO-Z topologies must have source impedances equal to or greater than load impedances. Odd-ordered LO-Z topologies must have source impedances equal to or less than load impedances. If you change the topology to HI-Z, the RS/RL relationships are reversed. All designs are produced such that the load impedance is always equal to Z_0, the system impedance of the filter. Remember that passive filters are bilateral; hence you may drive them from either end, should you prefer the impedance ratio reversed from that shown by LADDER. Lowpass and highpass cut-off frequencies and bandpass bandwidth frequencies are always the 3 dB values in LADDER.

Two features are provided to make your designs more realistic. Inductor and capacitor Qs (each as a group) may be set individually. Finite Q is modeled as a fixed resistance in series with components and is included in LADDER's analysis as well as the generated SPICE files. Inductors and capacitors may also be set to exact values, or, to the nearest 5% or 10% standard values with the click of the mouse. This is particularly valuable for the production-minded engineer.

The actual component values and circuit schematic may displayed at any time by choosing the MAIN MENU-DESIGN-Show Design selection. Filter parameters and values may be saved to an ASCII text file with the MAIN MENU-FILE-Save selection. A SPICE text file for your design will be written to file 'FILTER.CIR' when you select the MAIN MENU-DESIGN-Write Spice File item. The SPICE file will appear in a mini-text editor, allowing you to edit the file before an ESC key saves and closes the file.

Analyzing a Filter

LADDER contains a frequency analysis capability. Choosing the MAIN MENU-ANALYSIS menu item sends you to the analysis module. In the initial dialog parameter entry screen you may enter the minimum and maximum sweep frequencies, plotted point resolution, and Monte Carlo run parameters including the variable quantity to which the Monte Carlo operation is applied (magnitude, phase, or group delay). Monte carlo variations are uniformly distributed in the percentage range entered. Clicking the 'Do Analysis' command button sends you into the analysis display. This display initially plots the nominal magnitude, phase, and group delay of the current design. A vertical scroll bar allows you to view attenuation down to 120 dB. The '0 dB' button will normalize the magnitude display to 0 dB at the highest displayed magnitude value (this mode is toggled on and off by the '0 dB' button). To make measurements from the plot, choose the 'SPOT' button. In this mode the three quantities are continuously displayed on the screen according the position of the mouse along the frequency axis (this mode also toggles on and off with a mouse click). Figure 1 shows a typical example of the analysis display while in the SPOT mode.

To perform a Monte Carlo run, click the 'MONTE CARLO' button. Each sweep will be displayed, concluded by a highlighted MIN-MAX envelope. The Monte Carlo mode also has a 'SPOT' mode which will continuously display the minimum and maximum values on the run for the selected variable quantity. To make a different run you must exit the analysis display to the parameter dialog box and do another analysis.

Choosing the HARDCOPY button in the analysis display sends you to the hardcopy module. The nominal frequency sweep and Monte Carlo run (if one was executed) can be output to a printer of your choosing. Each data set is first displayed for your inspection (hit any key to continue past it). Next a dialog box appears to choose printing parameters. I prefer to send my outputs to a file usually, so that the plot may be copied from DOS to a printer as many times as I like. The HARDCOPY module returns to the analysis module when finished.

Conclusion

LADDER is a versatile PC program intended to aid in designing RF ladder filters. A large selection of filter families allows the working engineer to quickly design and analyze several designs in a short time in order to evaluate and compare various performance factors. Hardcopy output provides permanent records of analysis results. The program is also useful as a tutorial for exploring the shapes and variabilities of various filter structures.

LADDER is available through Argus Direct Marketing. See page 86 for ordering information. *RF*

References

1. Zverev, Anatol I., *Handbook of Filter Synthesis*, Wiley, New York, 1967.
2. Williams, Arthur B., *Electronic Filter Design Handbook*, McGraw-Hill, New York, 1981.
3. Fink, Donald G. and Donald Christiansen, *Electronic Engineers' Handbook*, McGraw-Hill, New York, 1982.

About the Author

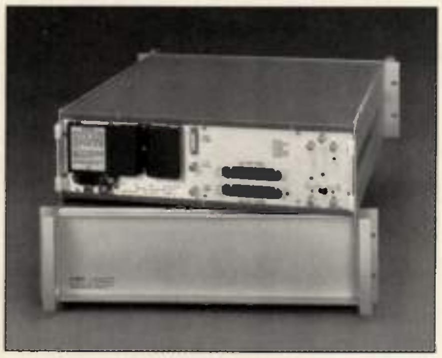
Richard Yeager is Senior Member of the Technical Staff in the Satellite Division at Hughes Network Systems. He has a BSEE from Johns Hopkins University and a MSEE from Drexel University. He can be reached at 11717 Exploration Lane, Germantown, MD 20876, tel. (301) 601-7293, fax. (301) 428-1868.

Frequency Synthesizers Moving Up in the Wireless Marketplace

This month's product forum highlights frequency synthesizers. Several manufacturers offer their opinions on today's marketplace and trends in the industry.

Programmed Test Sources, Inc.

In the test and measurement OEM markets for frequency synthesizers, growth is being driven primarily by two forces: the expansion of high frequency communications technologies (PCS, Mobile phone), and the increasing emphasis on component test at higher and higher clock frequencies (e.g. A/Ds, D/As). Both of these applications demand high quality, low-noise signal sources at "commercial volume" prices. PTS serves this market with a complete line of high-performance, low-noise single and dual channel synthesizers, and will soon be announcing a product covering the 3 GHz spectrum.



The PTS D620, 1-620 MHz.

Technologically, low frequency synthesizers (below 100 MHz) will continue to be driven by improvements in direct digital synthesis. But this technology still only provides a high quality RF signal (better than –60dBc SFDR) over a very limited bandwidth. As a result, higher frequency developments will continue to rely on traditional analog technologies.

Frequency Electronics, Inc.

The market for specialized frequency synthesizers has been concentrated in the military and aerospace sector. Specifically, high stability, low noise multiple frequency satellite generators and vibration tolerant sources for mobile military platforms have been required in small cuantities. This emphasis allowed frequency Electronics, Inc. to develop synthesizers having g-sensitivities of less than $2x10^{-10}$ per g and noise floors of –175 dBc per Hz. Development and manufacturing of such devices is expensive, since a considerable percentage of the cost is involved in alignment and circuit optimization to achieve the required performance.

Although these unique applications still exist, their number had dramatically decreased and a large number of hungry defense contractors are after the available orders. The commercial sector has exploded, and frequency synthesizers for satellite ground stations, PCS, and wireless applications are required in large volume with cost and reliability as the design drivers, rather than state-of-the-art electrical performance. Advanced high volume manufacturing techniques and the availability of low cost integrated circuits and MMICs afford the system designer the opportunity to develop high performance synthesizers that are extremely reliable, consume low power, and are low cost. FEI is applying its extensive experience in thermal control and miniature packaging of aerospace system to a new class of satellite ground station and wireless communications products.

Nova Engineering, Inc.

The proliferation of the "wireless marketplace" is driving traditional RF module-level circuitry to integrated RFIC devices, allowing designers expedient turnaround options to meet market demands. The future of RF synthesizers will encounter transformations equivalent to those of "block" RFIC devices which currently include receive front-ends, downconverters, and power amplifiers. The greatest challenge on the horizon will most likely be the future "Information Superhighway", which in most cases will be supported through RF links. Although the expectations for this market are potentially exaggerated, the demand for increased bandwidths and channel capacity will ultimately expand.

Commercial viability will require a high degree of of integration in synthesizer designs to cover these bandwidths while maintaining low cost. A further constraint is synthesizer spectral purity necessary to support the higher order modulation techniques required for the vast information flow through limited bandwidth. For the synthesizer marketplace, this combination of requirements will form a substantial challenge which will only be met with enhanced RFIC approaches.

Anritsu Wiltron

The growing commercial communications sector is driving demand for signal sources, and is making price competition more keen. Commercial users will pay for only the performance required in their application, and not extra features that are unused and unneeded. Manufacturers are being driven to offer price-competitive products with specific sets of features and performance optimized for specific applications. Therefore, a critical capability is to offer sources that can have features and performance upgraded to meet new application requirements as they emerge.

The biggest technological trend driving microwave signal sources is using software correction algorithms to compensate for inherent analog inaccuracies. Non-linearity in the tuning response of a YIG-tuned oscillator is corrected by a software look-up table having stored correction factors. Software compensations allows accuracy in frequency and power to deliver at least an order of magnitude better compared to relying on the analog performance alone.

The 68237B Signal Generator

RF Prototype Systems

The market is growing for lower cost commercial synthesizers. The market is shrinking for high cost military synthesizers, such as DDS (Direct Digital Synthesis) and machined aluminum housings. This type synthesizer, common a few years back for the miliary markets, now is in less demand. To address this change, we have developed a line of low cost synthesizers in the 10 MHz to 3500 MHz range. Today's market has many smaller companies than in the past, companies with application specific requirements for low cost synthesizers that need to be built in a few weeks. Our synthesizers are designed to be flexible, to accommodate many synthesizer architectures, and our factory is set up to fill these needs in a short period of time. This will be the trend over the next few years – products that offer greater performance, higher reliability, lower cost, and all in a short period of time.

Stanford Telecom

The Stanford Telecom ASIC & Custom Products Division is a world leader in direct digital synthesis, with numerous monolithic NCO families using CMOS, ECL, and GaAs technologies. Each NCO family is supplemented by board level and complete synthesizer subsystems. These board-level synthesizers provide excellent demonstration units for the applicable NCO, and can also be used as standard products where a board-level synthesizer is preferred to building one from ICs. Finally, stand-alone chassis-level products offer the ultimate in DDS subsystem hardware.

Stanford Telecom NCOs provide a wide variety of features, including sine and cosine outputs for quadrature generation, numeric FM and PM on chip, up to 48-bit frequency resolution, both binary and decimal (BCD) devices, and up to 900 MHz clock rates. All feature on-chip sine/cosine look-up tables. The newest member of the family is a very low cost NCO/modulator for the interactive CATV and telephony-over-cable markets. ***RF***

For more information on frequency synthesizers, circle the Info/Card number next to the company of interest:

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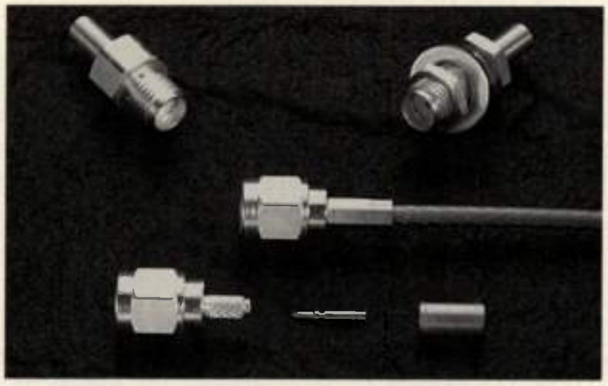

RF software

Time Domain Simulation on Workstations

Compact software announced that it has released a verison of its Super-Spice time-domain simulator for HP 9000 Series workstations. Super-Spice uses Compacts Environment for Analog Simulation (EASi) user interface to provide extensive menu-driven control and graphical output facilities. The EASi interface is based on the OSF-Motif and W-Windows standards. Super-Spice can accept input from either the integrated Serenade schematic editor or standard SPICE 2G.6 netlists. Super-Spice 1.0 for HP Workstations is available for immediate delivery.
Compact Software
INFO/CARD #215

Filter Design and Analysis

TSV Engineering announces the release of version 1.20 of Filter Designer Plus, an RF filter design and analysis program. The low-cost program designs and analyzes 14 of the most commonly used lumped element filters, including Butterworth, Chebychev, and Elliptic responses in high, low, and bandpass configurations. Analysis options include frequency response, Monte Carlo simulation, and yield analysis. Filter Designer Plus requires 300k RAM, EGA color graphics, and 1M hard disk space. Price is $59.95 plus $5.00 shipping/handling. Delivery is from stock.
TSV Engineering
INFO/CARD #214

Analog Optimization

MicroSim has released Paragon, an analog optimizer for Microsoft Windows NT, Windows 3.1, and Sun. Paragon simulates an analog circuit using PSpice or PSpice A/D and adjusts design parameter values until it finds the solution that best meets your target performance specifications. Paragon implements both constrained and unconstrained minimization algorithms. Paragon, along with a year of maintenance, sells for $2,185 on Windows, $4,485 on Sun. When purchased with PSpice or PSpice A/D (and anual maintenance for those programs) before December 23, 1994, that price is reduced by 20%.
MicroSim Corp.
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EMC Compliance

Cadence Design Systems has released DF/EMControl™, which automates the task of verifying printed circuit boards for EMC compliance. A robust set of 30 rules are initially used as an "EMC checklist" to check and warn of EMC problems. Rules and design advice generated by resident EMC experts can be captured and built into the tool for in-process rule checking. DF/ENControl will be available in the fourth quarter of 1994 at a U.S. list price of $35,000.
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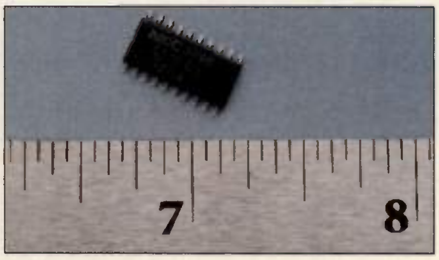
New NEC L-Band Down Converter MMIC with AGC



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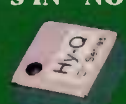

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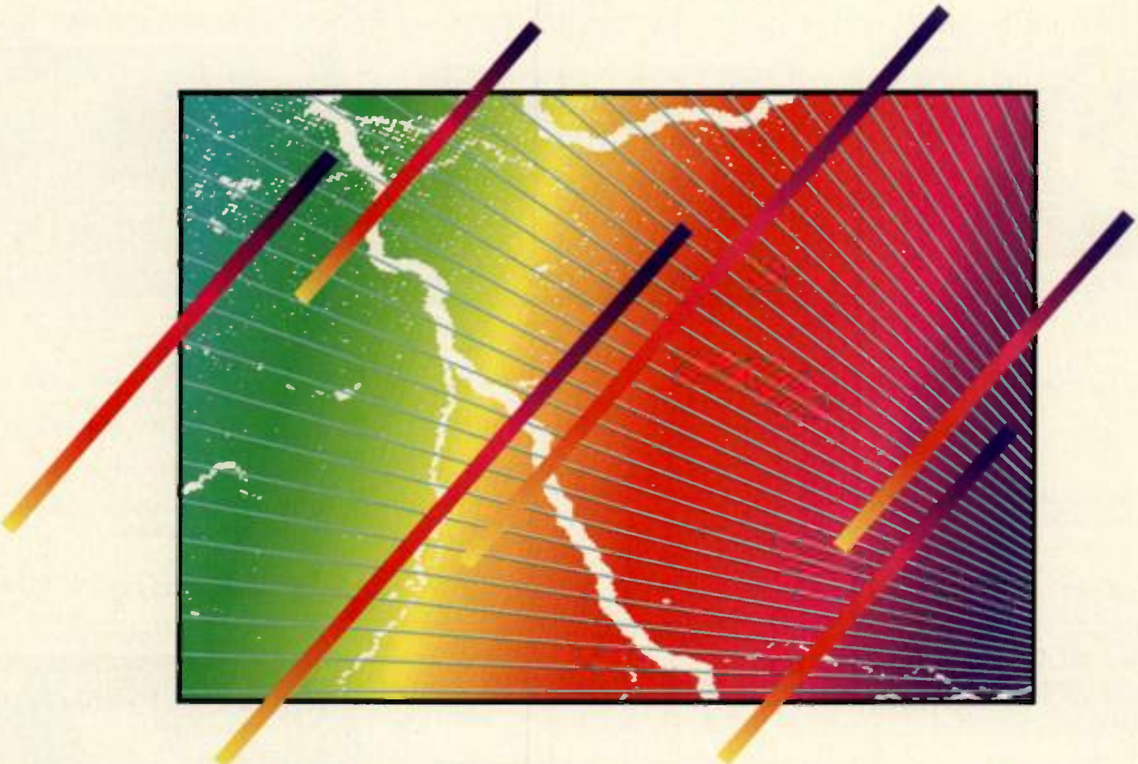

RF literature

Software Catalog

A 12-page catalog from ingSOFT presents the RFDesigner® solution for RF and microwave design engineers. Packed with detailed technical specifications, the catalog describes the family of software from products from ingSOFT and third parties, all working together as an integrated design environment. Featured software operates on all Macintosh configurations, including the new Power Macintosh.
ingSOFT Ltd.
INFO/CARD #210

Broadband Amplifiers

A wider selection of broadband microwave amplifiers from Amplica, Inc. has resulted in a new 36-page catalog from the company. Lower noise figure models and higher output power models have been added for the pre-existing eight frequency ranges of 2 to 18 GHz, and standard EW bands. Amplica is also offering more options for gain combinations – from 10 to 50 dB. The new catalog includes electrical and mechanical specifications for Amplica's narrowband microwave amplifiers and integrated subassemblies.
Amplica, Inc.
INFO/CARD #209

Trimmer Catalog

Voltronics has issued a new eight-page catalog of its line of ceramic trimmer capacitors. There are six different size types with maximum capacitances ranging from 2 to 40 pF. Sizes are from 0.096 to 0.33 inches in diameter, with choices of vertical or surface mount construction.
Voltronics Intl. Corp.
INFO/CARD #208

Military Databook

A 326-page databook describing 150 linear and data acquisition products for military (MIL-STD-833, DESC SMD and JAN) applications is now available from Harris Semiconductor. The new databook, called Analog Military Databook Supplement 1994-95, covers new and redesigned products brought to market since publication of the comprehensive 1989 Analog Military Product Databook.
Harris Semiconductor
INFO/CARD #207

Test Equipment

A 12-page, full color, short-form catalog of Anritsu Wiltron test and measurement products has been released by the company. Products in the short-form catalog are organized by application with a concise listing of specifications and features. A list of all international Anritsu Wiltron offices is included.
Anritsu Wiltron
INFO/CARD #206

EM Simulator Applications

A document from Sonnet Software presents key elements from published papers illustrating circuit and antenna designs where Sonnet's electromagnetic analysis tools have played an essential role. Illustrated design applications include microwave and wireless multi-layer 3D planar circuits, MMICs, antennas, modules, high-temperature superconductor circuits, shielding effects and precision planar filter designs.
Sonnet Software, Inc.
INFO/CARD #205

Wireless Catalog

Narda's comprehensive 44-page Wireless Catalog covers components, networks, and instruments for cellular, SMR, and PCS applications. In addition to traditional components, this catalog features advanced products such as receiver multicouplers, high power hybrid combiners, and the CellGuard™ power and VSWR monitor.
Loral Microwave-Narda
INFO/CARD #204

Antenna Catalog

The Decibel Products Division of Allen Telecom Group Inc. has released an exhaustive reference guide (241 pages) to the company's complete line of base station antennas and antenna systems. All products in the catalog are for applications within the 30 to 2500 MHz frequency spectrum.
Decibel Products Div.
Allen Telecom Group Inc.
INFO/CARD #203

RF and Microwave Products

Murata Electronics North America has released an all-new RF and Microwave Catalog, no. M-10-C, featuring 90 pages of detailed information on the complete product line. The catalog highlights electrical and mechanical specifications on crystal oscillators and VCOs, dielectric resonators, LC filters, isolators, delay lines, microminiature coaxial connectors, HICs, CR chips and the company's new phase lock loop modules.
Murata Electronics North America, Inc.
INFO/CARD #202

Cable Guide

Andrew Corporation is offreing a free, 40-page planning guide for 1/2-inch and smaller Heliax® coaxial cable, connectors and jumper cable assemblies. The guide provides a detailed comparison between Heliax® coaxial cable and braided cable.
Andrew Corp.
INFO/CARD #201

Integrated Circuit Guide

Hearst Business Publishing announces a pre-publication savings offer on the 1995 IC MASTER Catalog. IC MASTER provides electronic design engineers with technical information on all commercially available integrated circuits in one complete and easy-to-use reference source. Subscription orders postmarked by January 31, 1995 will receive a $20 discount of the regular list price of $185.
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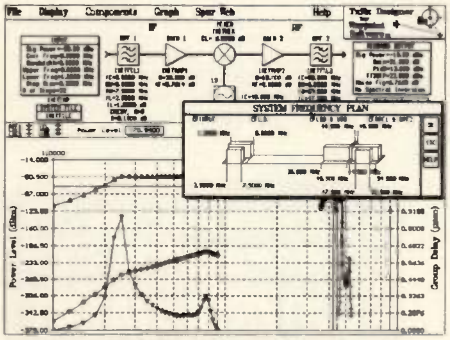

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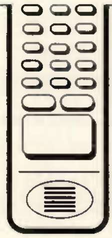

Chief Scientist: Responsible for design of analog and RF systems and circuits for consumer and commercial digital wireless products. Five to ten years experience in RF systems analysis and design. Experience with low-cost design techniques for frequency synthesizers, power amplifiers, up/down converters and baseband circuits for digital communications systems. Must be able to derive RF systems and module requirements to meet overall performance and cost goals. Familiarity with time division duplex or CDMA a plus.

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Systems Engineers: In-depth experience in one or more of the following areas is essential: RF propagation, modem and RF design, wireless protocols and algorithms, low-power, low-cost handheld consumer products. Participation in the development of baseband and RF IC's strongly desired. BSEE

Cellular Basestation: Will design RF circuits for commercial basestation product line. Design responsibilities include specification/evaluation of components & subassemblies, circuit synthesis & analysis, schematic capture, supervising PCB layout, & test, evaluation & integration of design.

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.

BSEE, MSEE desirable plus 5-10 yrs. exp. in design and development of commercial radio products.
RF/Fiberoptics CATV: Design and development. RF experience should be with SCMA circuits in the 5-1000 Mhz region. Fiber optic experience should be with analog circuits using DFB and FP lasers as well as InGaAsP photodetectors, control design of TECs is also desired.

PCS DSP Engineers: You will play a key role in defining and developing architectures and key technologies for next generation wireless mobile communications systems. Experience and background in DSP alogrithm design and simulation in Digital Cellular, CDMA, TDMA, PCS Systems, etc. BS/MS

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Mecahnical Design Engineers: To design mechanical packages and conceptualize mechanical design of cellular communications products mainly consisting of injection-molded plastic parts. Successful candidate should have a BSME with 3 or more years of electromechanical design experience with emphasis on consumer products. Experience in 3-D CAD very desirable with Unigraphics background a plus.

RF Engineer — GSM: We are seeking RF engineers with a BSEE (MSEE preferred), 2+ years RF development experience, including RF circuit design, and background with amplifier, oscillator, VCO, PLL mixer, noise, modulation, filtering matching, linear and non-linear distortion.

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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

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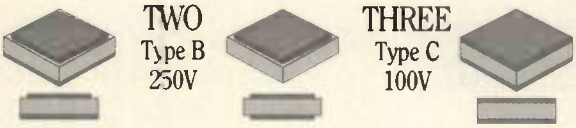

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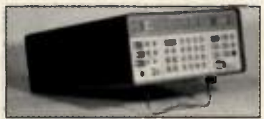

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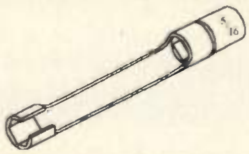

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RF literature showcase

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The MP2500 has a built-in peak power meter with AGC and provides calculated output power from −10 to −110 dBm with better than ±1 dB accuracy. Spurious, local oscillator leakage, and image are suppressed more than 60 dBc through double frequency conversion and filtering techniques.

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SAW Components & Subsystems .... Fax (203) 651-8618

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Wilmanco, 5350 Kazuko Ct., Moorpark, CA 93021 .... (805) 523-2390

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RF design

INTRODUCES THE YELLOW PAGE DIRECTORY SECTION

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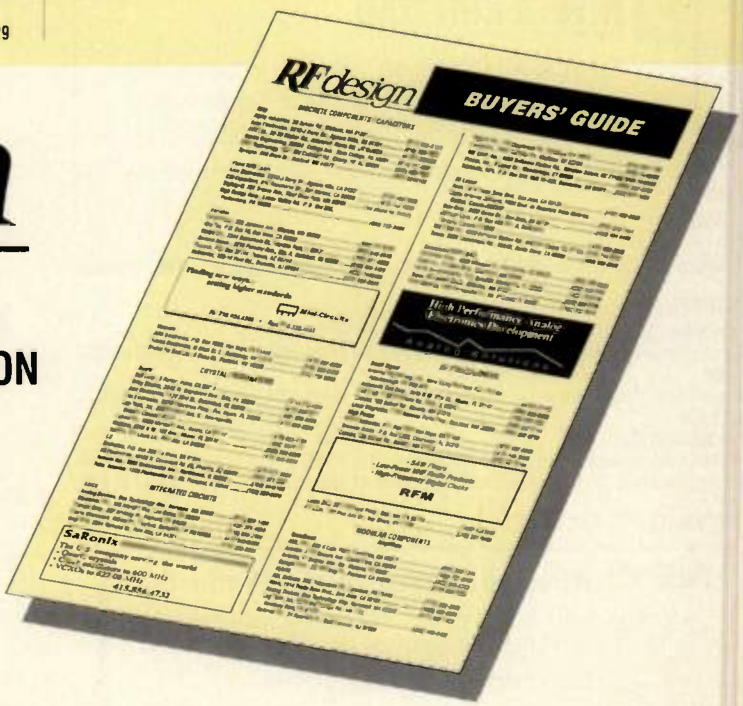


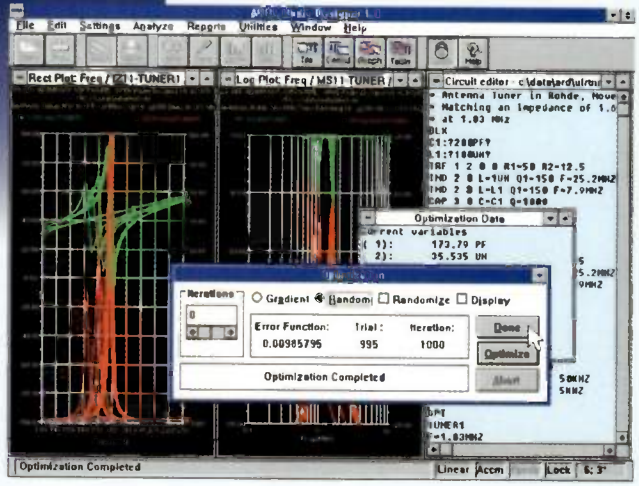
RF advertising index

RF guide to editorial coverage

ARRL Radio Designer

Heavyweight RF CAD features without a heavyweight price

If you've done any hobby computer-aided design, you've probably used CAD mainly for designing and enhancing your antenna system. Now with your PC and *ARRL Radio Designer* you'll be able to build, test and evaluate audio and radio circuits without warming up your soldering iron, running out of parts, or investing in a benchful of expensive test equipment.



Here's what you and *ARRL Radio Designer* will accomplish quickly and easily:

- Model passive and small signal linear circuits from audio to RF.
- Do "what if" circuit modifications without tedious cut-and-try experimentation and measurement.
- Predict and analyze the performance of linear, small-signal active and passive dc, audio and RF circuitry, including amplifiers, filters, matching networks and power splitters and combiners.
- Enter circuits in netlist form using the text-based Circuit Editor.
- Optimize circuit performance to meet goals you specify.
- Display the signal level at any point in a simulated circuit with Voltage Probe.
- Simulate component value variations due to temperature and tolerance with Monte Carlo statistical analysis.
- Simulate circuit performance in response to a steady-state time-domain signal using impulse, step, pulsed carrier or user-defined stimuli.
- Synthesize matching networks with Circles, an interactive Smith® Chart utility.
- Use manufacturer-supplied noise and S-parameter device data for highly realistic circuit simulations.

ARRL Radio Designer simulates and reports

- S, Y, Z, group delay and voltage probe parameters for *n*-port networks;
- Chain (ABCD), hybrid (H), inverse hybrid (G), gain, voltage gain, and stability parameters for two-port networks;
- Magnitude of reflection coefficient, phase of reflection coefficient, VSWR and return loss parameters for one-port networks;
- Gain, gain matching and noise parameters; and
- Complex S, Y, Z, H, G, chain (A), gain matching, noise matching and voltage probe parameters.

ARRL Radio Designer reports can be—

- Rectangular and polar graphs—onscreen and via any *Windows*™ compatible printer, in the colors, fonts and line weights you specify
- Tables—onscreen, in file form and via any *Windows*™ compatible printer

Minimum system requirements for *ARRL Radio Designer 1.0*:

- 386, 486 or Pentium™ IBM PC or 100% compatible (math coprocessor strongly recommended)
- 8 Mbytes of RAM
- Microsoft *Windows*™ 3.1 or higher
- 3.5-inch, high-density floppy drive
- hard disk with at least 5 Mbytes of free space
- Mouse or equivalent pointing device

ARRL Radio Designer 1.0's 28 Circuit elements include

- **Active devices (bipolar and field-effect transistors, operational amplifier)**
- **"Black box" elements (two-terminal impedance specified by resistance and reactance; two-terminal one port specified by admittance, impedance or reflection coefficient; three-terminal two-port specified by admittance, impedance or S parameters)**
- **Controlled sources (current-controlled current, current-controlled voltage, voltage-controlled current, voltage-controlled voltage)**
- **Lossy capacitors, inductors, coaxial cables and transmission lines**
- **Transformers (ideal two- and three-winding types, specifiable in terms of turns ratio or impedance)**

We're pleased to offer *ARRL Radio Designer* as your doorway into a new phase of ham radio's growing computer tradition. The package includes two 3.5" diskettes, circuit examples and a comprehensive reference manual.

ARRL Order No. 4882 Retail $150 (add $5 for UPS delivery).

Technical Specifications for *ARRL Radio Designer 1.0* Analysis:

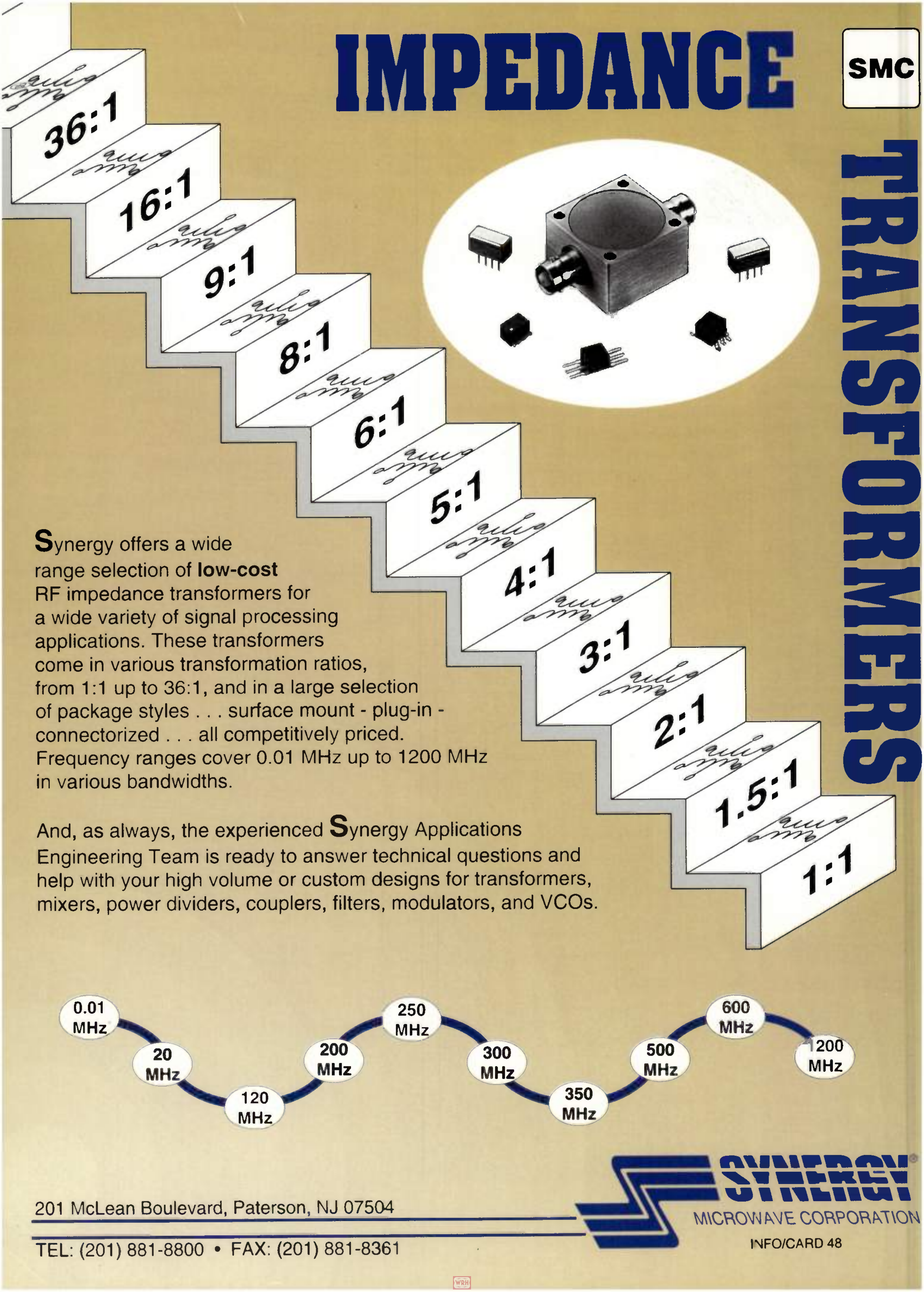
Maximum number of nodes per circuit block*	250
Range of node-number values	0 through 999
Maximum number of ports per circuit block	30
Maximum number of frequency steps	512
Maximum number of statistical histograms	20

* The number of circuit blocks allowed depends on their complexity; generally, 50 or more circuit blocks may be defined in a single *ARRL Radio Designer* netlist.

ARRL Radio Designer is a derivative of Super-Compact®, an industry-standard linear circuit simulator by Compact Software of Paterson, New Jersey.

ARRL 225 Main St. • Newington, CT 06111-1494
Phone (203) 666-1541

INFO/CARD 47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