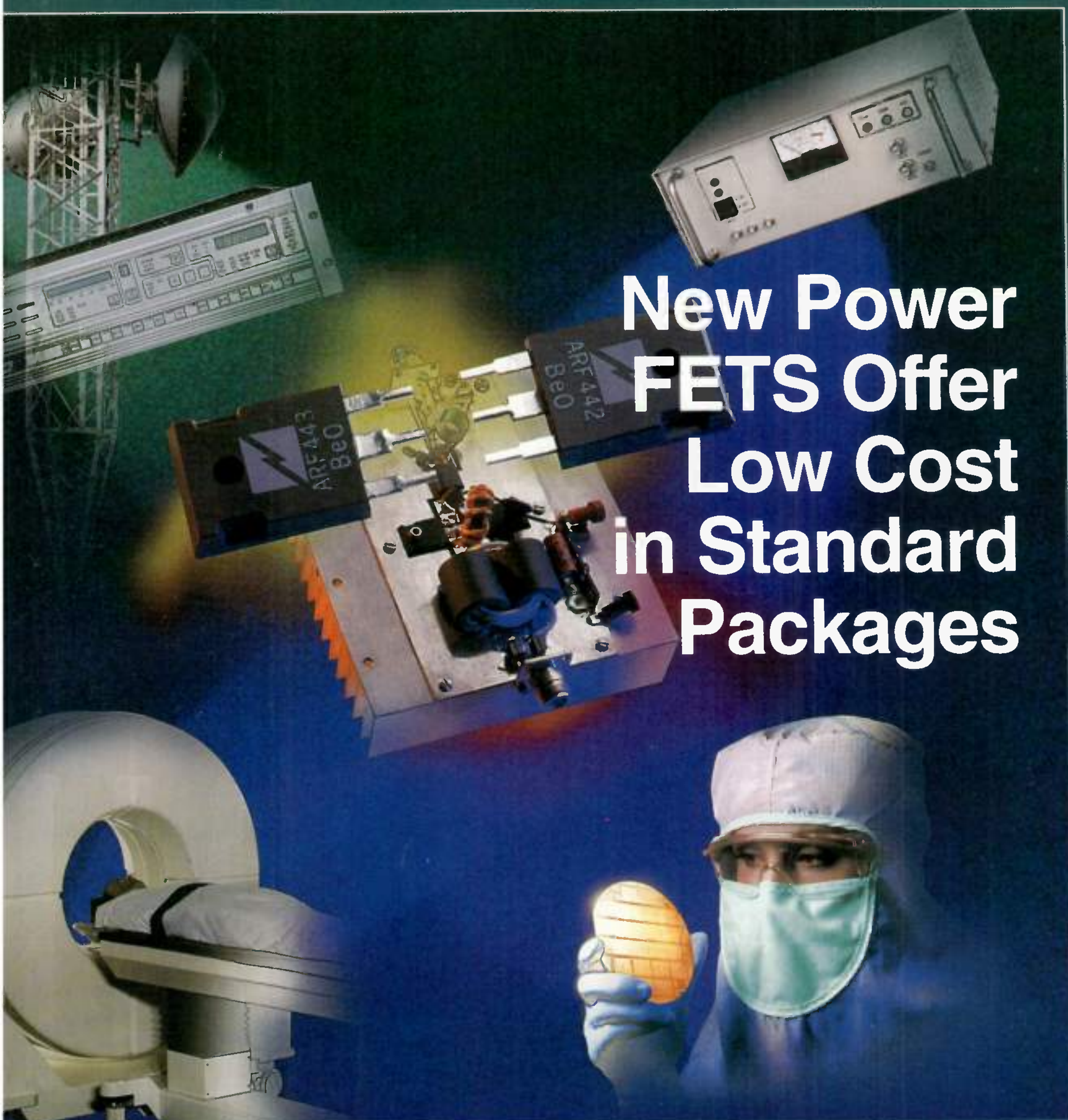
WIRELESS 16 YRS LEADERSHIP

RF design™

engineering principles and practices

August 1995



Featured Technology —
Designing with RFICs

Tutorial
IMD Measurements

Wireless International Corp. solves tough test problems.

As test engineers and designers, you understand the importance of efficient and effective testing for development and production testing. Poor test methods and inaccurate measurements can bring the production of the best designed equipment to a crawl. Wireless International Corp. (WIC) has answered these problems with plug-in-and-run test systems which provide stimulus, control, and measurement capabilities at your fingertips. Here are just a few of the test solutions.

INFO/CARD 1

CDMA Multipath and AWGN test station.

For CDMA testing, WIC's MP-CDMA test system generates multipath and additive noise as specified by IS-98. This system is comprised of the multipath emulator, a precision carrier-to-noise generator, an integrated 486DX/33 computer, and control software with a graphics user interface. The precision carrier-to-noise generator has been designed specifically to operate with extreme accuracy even under the difficult conditions of slow fading for which CDMA systems must be tested. Available frequency ranges are between 800 and 2500 MHz.

INFO/CARD 94

With its new integrated test system, Wireless International Corp. steps to the head of the class.

Multichannel Eb/No versus BER test station.

If you are performing BER versus Eb/No curves for multiple devices simultaneously, then here is your test equipment answer. WIC's Series 800 test stations can generate these curves for up to 8 channels simultaneously, all under the control of a single integrated computer or via the IEEE-488 interface. Each channel contains a precision carrier-to-noise generator and a programmable bit error rate tester. Bit errors and bit error rate data are stored to disk for analysis. Eb/No versus BER curves are generated in both tabular and graphical form for hard-copy output. Data rates up to 8 X 10 MBPS are programmable with error insertion rate, bit slip, and PN code length selections.

INFO/CARD 95

A look into the future.

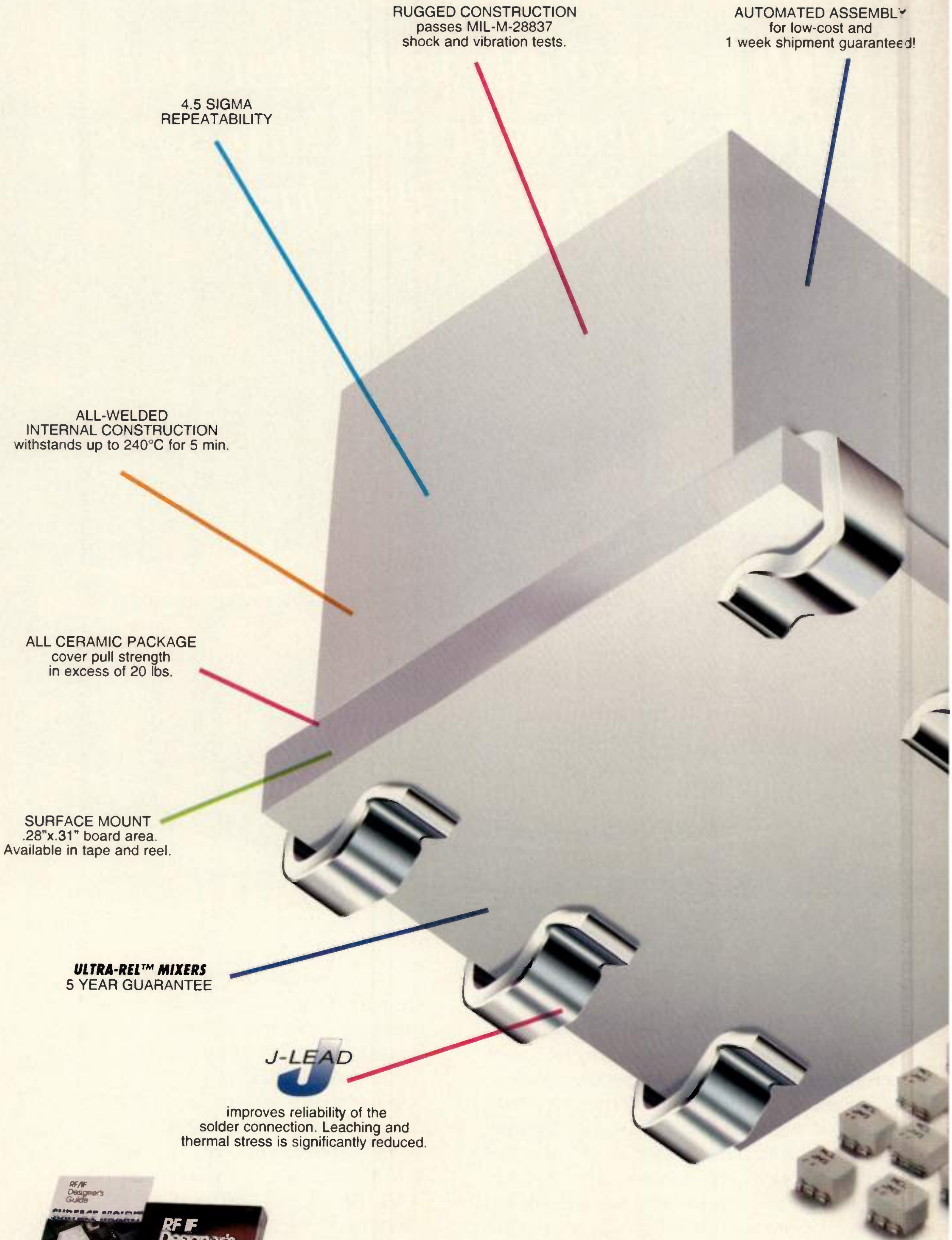
WIC's products are modular to provide easy upgrading. So the instrument that you buy today won't be obsolete tomorrow.

To receive a FREE copy of our application notes and catalog, contact Bent Hessen Schmidt at Wireless International Corp., E. 49 Midland Ave., Paramus, NJ 07652. Tel: (201) 261-8797. Or fax us at (201) 261-8339.

Wireless Telecom Group INC.

NOISE/COM   WIC Wireless International Corp.

INFO/CARD 96



Mini-Circuits RF/IF Surface Mount Designer's Guide features 48 pages of the most up-to-date and complete product and specification information about Mini-Circuits surface mount components. The RF/IF Microwave Handbook is packed with 740 pages of articles, selection guides and detailed specifications for Mini-Circuits components.

Call, write or fax for your free Surface Mount Designer's Guide and Handbook today!

NEW!

J-LEAD J MIXERS UNPRECEDENTED IN VALUE.

All Ceramic 2 to 1900MHz

from $4.25 (qty. 10-49)

Mini-Circuits JMS mixers are at the forefront of the industry for performance, reliability and value! With all-welded construction, these low cost ceramic mixers feature the functional J lead designed for strain relief...and set the pace for ruggedness required to go through surface mount reflow soldering and aqueous wash.

From cellular to satellite applications, this is the tough, reliable surface mount mixer you demand! JMS...from Mini-Circuits!

Mini-Circuits...we're redefining what VALUE is all about!

SPECIFICATIONS

Model	LO (dBm)	Freq. (MHz) LO/RF	Freq. (MHz) IF	Midband (dB, Typ.) Conv. Loss	Isol. L-R	Isol. L-I	$ea. (qty. 1-9)
JMS-1	+7	2-500	DC-500	5.75	45	45	4.95
JMS-1LH	+10	2-500	DC-500	5.75	55	45	8.45
JMS-1MH	+13	2-500	DC-500	5.75	60	45	9.45
JMS-1H	+17	2-500	DC-500	5.90	50	50	11.45
JMS-2L	+3	800-1000	DC-200	7.0	24	20	7.45
JMS-2	+7	20-1000	DC-1000	7.0	50	47	7.45
JMS-2LH	+10	20-1000	DC-1000	6.5	48	35	9.45
JMS-2MH	+13	20-1000	DC-1000	7.0	50	47	10.45
JMS-2H	+17	20-1000	DC-1000	7.0	50	47	12.45
JMS-2W	+7	5-1200	DC-500	6.8	60	48	7.95
JMS-11X	+7	5-1900	5-1000	6.7	35	37	4.25*

Note: *10-49 qty.

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

CUSTOM PRODUCT NEEDS...*Let Our Experience Work For You.*

F 181 Rev A

INFO/CARD 2

RF design

contents

August 1995

featured technology

cover story

tutorial

EMC Pull-Out Section

The August edition of *EMC Test & Design* is included with this issue of *RF Design*. Included is an article about modeling switching power supply emissions, an article about reducing EMI of transistors switching inductive loads, and two other articles.

EMC TEST & DESIGN

departments

RF DESIGN (ISSN:0163-321X USPS: 453-490) is published monthly and semi-monthly in August. August 1995. Vol.18, No. 8. *RF Design* is a registered trademark of Argus Inc. Copyright 1995 by Argus Business, a division of Argus Inc., 6151 Powers Ferry Road, NW, Atlanta, GA 30339, (404) 955-2500. Editorial and advertising offices at 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111, (303) 220-0600. Printed in USA. Second-Class Postage paid at Atlanta, GA and at additional mailing offices. Subscription office: *RF Design*, P.O. Box 1077, Skokie, IL 60076. Subscriptions are $39 per year ($67 for two years) in the United States; $50 (surface mail) or $99 (Air Mail) per year for foreign countries. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $8.00 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700. Authorization to photocopy items for internal, personal or educational classroom use is granted by *RF Design*, provided the appropriate fee is paid directly to Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 and provided the number of copies is fewer than 100. For authorization, contact the Copyright Clearance Center at (508) 750-8400. The Transactional Reporting Service fee code is: 0163-321X/95/$3.00. For those seeking 100 or more more copies, please contact the magazine at (303) 220-0600.

SUBSCRIPTION INQUIRIES: (708) 647-0756.

RF editorial

How Much Do We Need to Know?

By Gary A. Breed
Editor

We live in a world where we are completely dependent on technology, yet we have cleverly arranged things so virtually no one understands how that technology works.

— from an interview with Carl Sagan (paraphrased)

As engineers, it is our job to understand how at least one part of technology works. But, with a clear trend toward integration of technologies in any given product, how much should we know about those other technologies that surround the RF circuitry?

I suppose this is the same question that the medical community faces regarding the value of specialists versus general practitioners. In that field, the trend for several years has been to encourage general practice in order to keep costs under control and promote preventive medicine.

Business has borrowed a term from athletics — cross-training — to describe its efforts to maintain a capable workforce after downsizing has left them with fewer personnel to do the same jobs as before. The secretaries who used to do dictation, typing and filing are now doing sales support or market research. Managers who used to have secretaries now have computers on their desks to do their own letters, memos, and reports.

OK, so what about design engineers? I have always been a proponent of the well-rounded engineer, but that attitude was directed at life *outside* technology; things like the arts, literature, public affairs and sports. I have been forced to re-think my view of the engineer's role in the new inter-disciplinary world. How does an RF engineer fit into this new scheme where digital, analog, video, power, software and mechanical concerns are addressed simultaneously with RF functionality?

Do we simply maintain our specialty, but with better communications among fellow specialists? Should we try to learn about those other branches of engineering, even if we don't become expert? Or, is it our responsibility to become competent in one or more of these additional specialties? The answer could be any of these.

One point that has become clear is that specialists can no longer be purists — a design team has to balance performance and costs against a product specification. To accomplish a successful design, a minimum level of understanding and acceptance of all aspects of product development goals is necessary. If meeting those goals means learning more about digital design, power circuitry, or manufacturing processes, we must do it.

Remember, low-cost products and rapid development are being re-discovered in the U.S. electronics industry. The engineering profession really is changing; it's not an illusion! To get that next widget into production on time, your company might not find an expert for each part of the design, so someone has to step into that void. You may become the most valuable member of the team by being capable of learning something new. On another product, all the talent necessary may be available, and you need only be a good RF circuit designer with a proper attitude toward teamwork.

"How much do we need to know?" The answer seems to be quite simple: "As much as the job requires."

See You at RF EXPO EAST — August 21-23 — Baltimore, MD

"Over the last couple of years, we've seen EMC issues evolve from technical "what" questions to regulatory "when" statements. EMC is now, and at Kalmus we're addressing it head on."

"Our new Model 7100LC 100 watt RF power amplifier is a case in point. It has been designed specifically for EMC test applications. And, true to the Kalmus tradition of manufacturing highly functional, yet extremely cost competitive amplifiers, the 7100LC, we believe, is the smallest, lightest and least expensive 100 watt RF amplifier for EMC testing on the market."

"Another very important way we're addressing EMC is through our new affiliation with Thermo Voltek Corporation, a company focused upon all aspects of EMC. As a member of the Thermo Voltek family, we share their mission and can now offer our customers enhanced sales and service capabilities through Thermo Voltek's worldwide organization."

"As we move closer to global EMC regulations, Kalmus remains steadfast to its engineering heritage and is committed to producing reliable and cost effective RF amplifiers for EMC testing. Call Kalmus or your Thermo Voltek distributor for complete information."

Frank Kalmus
Technical Director

Frank Kalmus is the founder of Kalmus (formerly Kalmus Engineering Inc.), a division of Thermo Voltek Corporation. As Kalmus' principal design engineer, he has designed over 200 RF amplifiers used for EMC test, medical/MRI, general laboratory, and communications applications.

STRAIGHT TALK ABOUT EMC AMPLIFIERS.

Designed specifically for EMC testing, we believe Kalmus Model 7100LC is the smallest, lightest, and least expensive 100 watt RF amplifier on the market. All functions can be remotely controlled via the optional Kalmus Model IF488, pictured (IEEE-488/RS-232 Interface), or hardwired.

MODEL 7100LC
100 Watt Broadband RF Power Amplifier

- Frequency range: 80-1000 MHz Broadband
- MOS-FET circuitry
- Power output: 100 watt CW minimum
- Remote capability and outputs
- Remote functions: all front panel controls - AC, Gain, Output Limit, ALC Speed, Blanking, VSWR Protection
- ±0.8 dB typical ALC gain flatness
- VSWR tolerance: infinite, without damage
- Protection: open, short, temperature, excessive drive power
- Forward and Reflected Power meter
- Automatic Level Control (ALC): output level may be set to a fixed level of ±1/2 dB, with input variation up to 10 dB; selectable response time
- Size: 48 cm x 48 cm x 17.8 cm

All Kalmus products are supported through Thermo Voltek's exclusive worldwide network of service and calibration facilities. Please call Kalmus or an authorized Kalmus distributor for complete information on this model, as well as other EMC test systems for EFT, SURGE, ESD, and PQF. **1-800-344-3341**

KALMUS

Kalmus • 21820 - 87th S.E. • Woodinville, WA 98072 USA
Tel: (206) 485-9000 • Fax: (206) 486-9657

Distributor:
KeyTek • 260 Fordham Road • Wilmington, MA 01887 USA
(800) 753-9835 • Tel: (508) 658-0880 • Fax: (508) 657-4803

Thermo Voltek
COMTEST BENELUX • COMTEST ITALIA • COMTEST UK • KALMUS • KEYTEK • VERIFIER • UVC

INFO/CARD 5

RF design

Established 1978

President — Argus Integrated Media
Stephen Stoneburn

Editorial and Advertising Offices
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111
(303) 220-0600 Fax: (303) 267-0234

Vice President and Group Publisher
David Premo

Editor and Associate Publisher
Gary A. Breed

Technical Editor
Andrew M. Kellett

Consulting Editor
Andy Przedpelski, *The Shedd Group*

Editorial Review Board
Madjid A. Belkerdid, *Univ. of Central Florida*
Alex Burwasser, *RF Products*
Dave Krautheimer, *MITEQ, Inc.*
Ed Oxner, *InterFET Corporation*
Jeff Schoenwald, *Rockwell International*
Raymond Sicotte, *American Microwave Corp.*
Robert J. Zavrel, Jr., *Consultant*

Corporate Editorial Director
Robin Sherman

Account Executives
Janell Count
Mike Henry
Cindy Solomonson
Gordon Henderson
Tisha Hill

Classified Advertising Manager
Shannon Shuman

Vice President — Special Advertising
Drew DeSarle

Vice President — Production and Promotion
Cherryl Greenman

Production Manager
Jenny Black

Reprints Manager
Vivian Peterson

Vice President — Marketing Research Director
Tina D'Aversa-Williams

Vice President — Circulation
Doug Florenzie

Creative Director
Brian Buxton

Art Director
Pamela Bobe

Staff Artist
Susumu Komatsu

List Rental Manager
Etta Davis

Argus Integrated Media Corporate Offices
6151 Powers Ferry Rd., N.W.
Atlanta, GA 30339-2941
Tel: (404) 955-2500

BPA INTERNATIONAL

ARGUS INTEGRATED MEDIA
A Division of Argus Inc.

President — Argus Inc.
Scott Smith

Vice President, Finance — Argus Inc.
Wayne Otterbourg, C.P.A.

Senior Vice President — Argus Inc.
Arthur E. Sweum

General Manager — Argus Trade Shows
Joe Randall

Subscription inquiries: (708) 647-0756


Been there, Done that
USA
For over 30 years Solitron Vector has been a leading supplier of RF and Microwave coaxial connectors, cable assemblies, and thin film products. From low cost commercial applications to the harsh environments of space, Solitron Vector products demonstrate an unwavering commitment to quality and customer satisfaction.
Wherever you're going, shouldn't you first talk to someone who's already been there and done that?
SV MICROWAVE
Solitron Vector Microwave Products, Inc.
3301 Electronics Way
West Palm Beach, Florida 334067
Phone (407) 840-1800 FAX: (407) 844-8551
Photo courtesy of NASA

Capabilities	Giga-tronics 8541	Hewlett-Packard HP 437B	Giga-tronics 8542	Hewlett-Packard HP 438A
Measurement Speed over GPIB (rdgs/sec)	200	20	200	20
Measurement Speed using Fast Modes (rdgs/sec)	4,000	Not Available	4,000	Not Available
Maximum Dynamic Range with a Single Sensor	90 dB	50 dB	90 dB	50 dB
Direct CW and Peak Power Measurements	Yes	No	Yes	No
Built-in Frequency Cal Factors	Yes	No	Yes	No
Measurement Channels/Display Lines	One/Two	One/One	Two/Two	Two/One
Display Pulse Waveform on External Scope	Yes	No	Yes	No

Compare Your Choices

Why Settle For The Standard Power Meter?

Choose The Alternative

The Giga-tronics 8540 Series combines speed, range and capabilities unrivaled by power meters from Hewlett-Packard, or any other company.

Giga-tronics

For more information or a demonstration, call us at 1 800 726 GIGA (4442).
Outside the U.S., call your Giga-tronics representative.

Argentina Coasin S.A.C.I. 155-234-85 • **Australia** Scientific Devices Ltd (Maroubra) 23-445-200; (South Oakleigh) 35-793-622; (Salisbury) 82-813-788 • **Belgium** Air Parts Electronics B.V. 2241-6460 • **Brazil** Wandel & Goltermann 11-505-3266 • **Bulgaria** Amtest Ltd 928-703-88 • **Central America** Wandel & Goltermann 223-225-51 • **Chile** Avantec 26-411-021 • **China (PRC)** Corad Technology 279-303-30 • **Colombia** Wandel & Goltermann Andina Ltda 12-564-001 • **Croatia** Amtest Ltd 54-141-1963 • **Czech Republic** Amtest CA 632-625-34 • **Denmark** Crimp A/S 481-00531 • **England** Sematron UK Ltd 17348-19970 • **Finland** Profelec Oy 805-664-477 • **France** Elexience 1-60-11-94-71 • **Germany** Pro Nova Nachrichtentechnik GMBH 07141-2858-0 • **Greece** American Technical Enterprises 152-406-20 • **Hong Kong** Schmidt Electronics 22507-022-2 • **Hungary** Amtest Ltd 125-155-20 • **India** Technical Trade Links 228-326-719 • **Indonesia** Mecomb Tehnik Division 21-780-8008 • **Israel** Dan-El Technologies Ltd 236-478-770 • **Italy** L.P. Instruments SRL (Milano) 24-84-01-713; (Roma) 68-68-00-119 • **Japan** Midoriya 33-561-5763 • **Korea** Unitek Corporation 255-427-24 • **Lebanon** Mabek 118-644-79 • **Malaysia** CNN Sdn. Bhd 657-958-4 • **The Netherlands** Air Parts Electronics B.V. 01720-43221 • **New Zealand** John Cutler Instruments 644-234-7203 • **Norway** Visitron Feiring A/S 22-64-90-70 • **Peru** BMP Ingenieros SA 149-012-24 • **Oman** Mustafa & Jawad Trading Co. L.L.C. 870-995-5 • **Poland** Amtest Ltd 264-267-74 • **Saudi Arabia** ARASCO 626-610-006 • **Singapore** Mecomb 469-8833 • **South Africa** PNI Electronics 117-863-647 • **Spain** REMA Leo Haag, SA 1-38-39-01-7 • **Sweden** Ferner Elektronik AB 87-608-360 • **Switzerland** Isatel Emitec AG 42-418-041 • **Taiwan** Schmidt Electronics 25-013-468 • **Turkey** Elektro 2-164-18-1270 • **Venezuela** Equilab C.A. 22-393-233

Giga-tronics Incorporated ▪ 4650 Norris Canyon Road ▪ San Ramon, California 94583 ▪ Telephone: 510-328-4650 ▪ Telefax: 510-328-4700

INFO/CARD 9

RF letters

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

Another Broadband Transformer Article

Editor:

It may be of interest to your readers to know that a similar paper [to Don McClure's articles, "Broadband Transmission Line Transformer Family Matches a Wide Range of Impedances - Parts 1 & 2, *RF Design*, Feb. 1994 and May 1995] co-authored by myself and J.D. Harmer was presented and published at the 1974 IEEE International Symposium on Circuits and Systems. The paper is entitled "Transmission Line Transformer with Integer-Ratio Voltage Transformations". If any of your readers are interested, they can contact me for further information or a copy of the paper.

Thomas J. Glusczak
83 Jacobs Rd.
Marlboro, MA 01752

[*The work on transmission line transformers described in Mr. McClure's article was done well before he wrote his articles for* RF Design. *The patent disclosures for the transformers described in his article are dated April 28, 1972., ed.*]

Errata

Tim Dolan, Vice President of Engineering at K&L Microwave was referred to as Tim Nolan in part of July's "Industry Insight" column.

Be published in RF Design!

Upcoming issues will focus on designing for the ISM bands, industrial RF applications, and circuits for DECT & PCS applications. Let other engineers know about your work in these and other areas!

Submit articles to:

RF Design
6300 S. Syracuse Way, Ste. 650
Englewood, CO 80111

Author's guidelines may be obtained by writing to the same address.

Small talk.

Size is everything in today's wireless product market. Ever since the first cellular phone was designed, the big challenges have been how to make them more portable; how to reduce power consumption while extending talk time; and how to add more features.

How do you do it?

Simple. With ITT RFIC power amplifiers. Based on our MSAG®-Lite technology, our line of RFIC power amplifiers can help you reduce total system size while adding more features in the same space. Cell phone talk time can be extended by as much as 30% compared to using discretes or modules. In addition, you can lighten up the entire system by reducing the battery weight required to power the phone.

And all this at an *extremely* competitive price.

Small wonder that designers of all kinds of wireless products are talking to us first.

What about you?

Call us at 540-563-3949.
Or fax us at 540-563-3935.

ACTUAL SIZE

ITT GTC

INFO/CARD 11

MITEQ ... IF SIGNAL

LOGARITHMIC AMPLIFIERS • FREQUENCY DISCRIMINATORS •

3 YEAR WARRANTY

Successive Detection Logarithmic Amplifiers

- Operating frequencies from 10 to 500 MHz
- Standard models up to 80 dB dynamic range
- Custom models up to 100 dB dynamic range
- Linearity from ±0.5 dB

Model Number	Center Frequency (MHz)	Bandwidth (3 dB) (MHz, Min.)	Dynamic Range (dB, Min.)	Rise Time (ns, Max.)	Linearity (±dB, Max.)
LIFD-3010-080	30	10	-70 to +5	110	1
LIFD-3010P-80	30	10	-80 to 0	100	0.5
LIFD-6010-70	60	10	-70 to 0	65	1
LIFD-6020P-80	60	20	-80 to 0	50	0.5
LIFD-12020-80	120	20	-80 to 0	50	1
LIFD-16040P-70	160	40	-65 to +5	25	0.5
LIFD-16040-70	160	40	-70 to 0	30	1
LIFD-300100-60	300	100	-60 to 0	10	1

New Low-Noise Logarithmic Amplifiers

- Ultrafast rise time to 1 ns
- Operating frequencies from 250 to 2000 MHz
- Improved sensitivity from 6 dB typical noise figure

Model Number	Center Frequency (MHz)	Bandwidth (3 dB) (MHz, Min.)	Dynamic Range (dB, Min.)	Rise Time (ns, Max.)	Linearity (±dB, Max.)
MLIF-500/100-70	500	100	-70 to 0	10	1
MLIF-750/500-62	750	500	-65 to 0	2	1
MLIF-1000/250-60	1000	250	-60 to 0	2	1
MLIF-1000/500-65	1000	500	-65 to 3	5	1.5
MLIF-1500/1000-60	1500	1000	-60 to 0	1.25	1
MLIF-1575/20-40*	1575	20	-38 to 3	N/A	1.5

* 1.25" x 1" package available for RSSI module used in GPS applications

Frequency Discriminators

- Operating frequencies from 21 to 1000 MHz
- Peak-to-peak bandwidths up to 75%
- Linearity from ±1.0%

Model Number	Center Frequency (MHz)	Linear Bandwidth (MHz, Min.)	Sensitivity (mV, MHz)	Rise Time (ns, Max.)	Linearity (±%, Max.)
FMDM-21.4/4-5	21	4	1000	150	2
FMDM-30/6-8	30	6	1000	120	2
FMDM--60/10-15	60	10	250	75	2
FMDM-160/35-15	160	35	100	30	3
FMDM-160/50-25	160	50	20	17.5	5
FMDM-300/100-20	300	100	20	20	2.5
FMDM-1000/300-70	1000	300	10	5	5

All models are available with a variety of custom options, including: custom frequencies, special packaging, gain and phase tracking, and integrated assemblies combining multiple functions.

PROCESSING COMPONENTS

AGC AMPLIFIERS • LIMITING AMPLIFIERS • VGC AMPLIFIERS

Call today for your RHG cross-reference guide

Constant Phase Limiting Amplifiers

- Operating frequencies from 10 to 600 MHz
- Standard models up to 70 dB dynamic range
- Maximum phase deviation as low as ±1.5°

Model Number	Center Frequency (MHz)	Bandwidth (3 dB) (MHz, Min.)	Dynamic Range (dB, Min.)	Phase Change (±Deg., Max.)	Output Power (dBm, Min.)
LCPM-30/10-70	30	10	-70 to 0	4	10
LCPM-60/20-70	60	20	-70 to 0	5	10
LCPM-60/14-65	60	14	-70 to -5	2.5	10
LCPM-160/40-65	160	40	-70 to -5	5	10
LCPM-160/40-70	160	40	-65 to 5	3	10
LCPM-300/50-55	300	50	-55 to 0	5	3
LCPM-500/100-45	500	100	-45 to 0	5	3

Variable Gain Control Linear Amplifiers

- Operating frequencies from 21 to 850 MHz
- Standard models up to 75 dB of gain control range

Model Number	Center Frequency (MHz)	Bandwidth (3 dB) (MHz, Min.)	Dynamic Range (dB, Min.)	Noise Figure (dB, Max.)	P. Out @ 1dB Compr. (dBm, Min.)
VGC-7-30/10	30	10	-80 to -10	4	10
VGC-7-60/20	60	20	-85 to -10	6	10
VGC-7-70/10	70	10	-60 to -10	4	10
VGC-6-70/20	70	20	-50 to +10	5	10
VGC-7S-140/40	140	40	-75 to -10	7	10
VGC-6-160/40	160	40	-65 to -5	6	1
VGC-7-250/100	250	100	-70 to -10	6	10
VGC-4-720/100	720	100	-40 to 0	6	0
VGC-4-850/100	850	100	-40 to 0	6	0

Automatic Gain Control Linear Amplifiers

- Operating frequencies from 21 to 850 MHz
- Standard models up to 75 dB of gain control range

Model Number	Center Frequency (MHz)	Bandwidth (3 dB) (MHz, Min.)	Output Power (dBm, Min.)	Power Variation (dB, Max.)	Dynamic Range (dBm, Min.)
AGC-7P-30/15	30	15	10	2	-60 to +5
AGC-8-70/20	70	20	10	2	-75 to 0
AGC-6-70/30	70	30	3	2	-65 to -5
AGC-6-140/30	140	30	4	2	-65 to -5
AGC-4S-140/55	140	55	5	2	-40 to 0
AGC-5S-370/100	370	100	5	2	-60 to -10
AGC-5-387/175	387.5	175	-3	1	-60 to -15

For available options, custom design information, technical questions, or any additional information, please contact Boris Benger at (516) 436-7400, extension 140.

MITEQ

100 Davids Drive, Hauppauge, NY 11788
TEL: (516) 436-7400 • FAX: (516) 436-7430

INFO/CARD 12

RF calendar

August

14-18 **IEEE EMC Symposium**
Atlanta, GA
Information: All About Meetings, Tel: (310) 371-3438, Fax: (310) 371-5268.

21-23 **RF Expo East**
Baltimore, MD
Information: Argus Trade Shows, 6151 Powers Ferry Rd., N.W., Atlanta, GA 30339. Tel: (800) 828-0420, ext. 323.

27-31 **Surface Mount International '95**
San Jose, CA
Information: Yolanda White. Tel: (415) 905–4994.

September

5-7 **International Conference on 100 Years of Radio**
London, UK
Information: HYR95 Secretariat, Conference Services, IEE, Savoy Place, London WC2R 0BL UK. Tel: 071 344 5477. Fax: 071 497 3633.

20-22 **17th Annual Piezoelectric Devices Conference**
Kansas City, MO
Information: Components Group, Electronic Industries Association, 2500 Wilson Boulevard, Arlington, VA 22201–3834. Tel: (703) 907–7500. Fax: (703) 907–7501.

26-28 **Sixth International Conference on Radio Receivers and Associated Systems**
University of Bath, UK
Information: RRAS'95 Secretariat, IEE Conference Services, Savoy Place, London WC2R 0BL UK. Tel: +44 (0) 71 344 5477. Fax: +44 (0) 71 497 3633.

27-29 **6th IEEE International Symposium on Personal, Indoor and Mobile Communications**
Toronto, Canada
Information: University of Toronto, Dept. of Electrical and Computer Engineering, 10 Kings College Rd., Toronto, Ontario M5S 1A4, Canada; Tel: (416) 978-3652.

October

3-11 **TELECOM 95**
Geneva, Switzerland
Information: International Telecommunication Union, Place des Nations, CH-1211 Geneva 20, Switzerland. Tel: 41 22 730 5111. Fax: 41 22 733 7256.

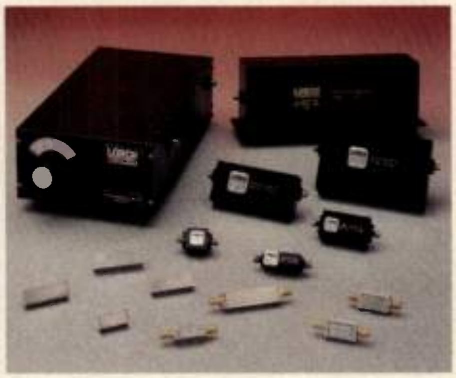
8-11 **1995 Wireless Circuits, Interconnection, and Assembly Workshop**
Tucson, AZ
Information: Wireless Workshop, 100 S. Roosevelt Avenue, Chandler, AZ 85226. Tel: (602) 961–1382. Fax: (602) 961–4533.

THE IMPORTANCE OF A CLEAR SIGNAL.

To some, signal clarity comes naturally. A penguin chick differentiates sound by filtering out all but its mother's call. Your world is filled with noise, interference and crowding, too. At Lorch, we design filters to meet your specific needs precisely, quickly, and at prices nobody can match ... no matter what the quantity.

Whether you require cavity, microminiature, or tunable filters, in frequencies from 1 MHz to over 26.5 GHz, we'll treat your request as if it were a "standard" item. On your first call you'll talk to an engineer who can quote price and delivery. It's all part of our philosophy – high-quality products, delivered on schedule, at the best possible price.

For three decades we've been supplying RF and microwave signal-processing components and integrated modules. We have filters, mixers, switches, phase comparators, attenuators and more. Responding to your particular requests comes naturally to us, too. Call our technical sales staff today at **1-800-780-2169.**



LORCH MICROWAVE

Helping your ideas take wing.™

Lorch Microwave, P.O. Box 2828, Salisbury, MD 21802 USA Phone: 410-860-5100 FAX: 410-860-1949

See us at RF EXPO EAST Booth# 408

INFO/CARD 14


TEMEX
ELECTRONICS, INC.
Temex Electronics manufactures crystals, crystal filters, LC filters and discriminators. We offer a standard line of 10.7 MHz, 21.4 MHz and 45.0 MHz monolithic filters to whatever your company may require. We cover a frequency range of 3.0 MHz to 200.0 MHz. With our computer aided designs we can realize most types of filters with realistic components and manufacture them at a very competitive price. Plus, we've been in business 12 years.
ask about our
Monolithic Crystal
Filter Prototyping
Kits !

RF courses

Introduction to RF & Wireless Engineering
October 10-13, 1995, Atlanta, GA
Principles of Modern Radar
November 6-10, 1995, Atlanta, GA
Information: Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel: (404) 894-2547.

Microwaves and RF Measurements & Applications
October 2-5, 1995, Washington, DC
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel: (818) 995–6335. Fax: (818) 995–2932.

Kalman Filtering
August 28-31, 1995, Los Angeles, CA
Wavelet Transform Applications to Data, Signal, Image and Video Processing
September 11-15, 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.

DSP Without Tears
September 20-22, 1995, Washington, DC
October 9-11, 1995, Dallas, TX
Information: Z Domain Technologies, Inc., 325 Pine Isle Court, Alpharetta, GA 30202. Tel: (800) 967–5034, (404) 587–4812. Fax: (404) 518–8368.

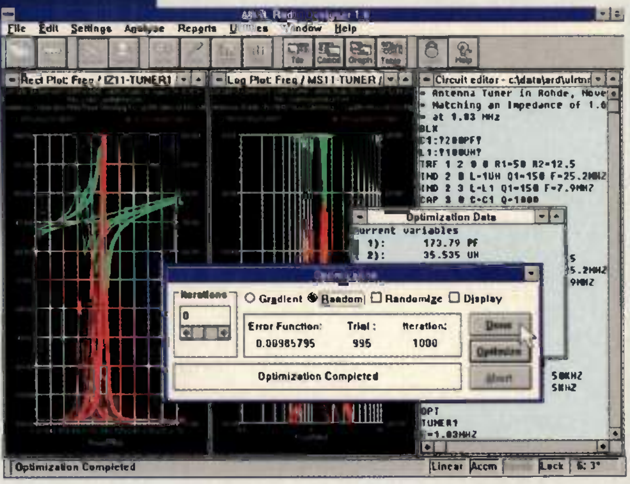
Global Positioning System: Principles and Practice
September 11-14, 1995, Washington DC
PCS: A Telecommunications Revolution
October 16-20, 1995, Washington, DC
Antennas and Antenna Systems: Practical Design, Implementation, and Testing
October 23-26, 1995, Washington, DC
Wireless Telecommunications: An Introduction
November 13-15, 1995, Washington, DC
Digital Transmission Systems
November 13-17, 1995, San Diego, CA
Video Transmission and Broadcasting Via Satellite
November 20-21, 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 Communication Networks
August 24-25, 1995, Berkeley, CA
Advanced Metallization Conference
October 3-5, 1995, Portland, OR
October 24-25, 1995, Tokyo, Japan
Information: Continuing Education in Engineering, University Extension, University of California, 2223 Fulton St., Berkeley, CA 94720. Tel: (510) 642–4151. Fax: (510) 643–8683.

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 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)**

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 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—

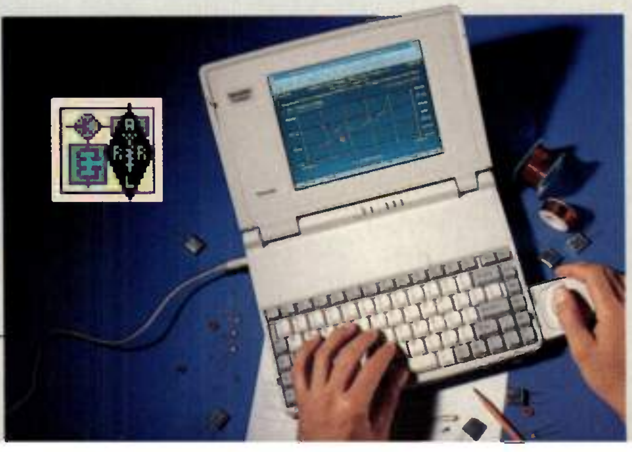
- Rectangular and polar graphs—onscreen and via any *Windows*™ compatible printer, in the colors, fonts and line weights you specify
- Tables—onscreen, in file form and via any *Windows*™ compatible printer

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

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).



ARRL 225 Main St. • Newington, CT 06111-1494
Phone (203) 666-1541
INFO/CARD 18

NIST Seeks Input for Standards Directory

The National Institute of Standards and Technology is updating its popular directory, *Standards Activities of Organizations in the United States*, for the first time in four years. The 1995 edition will feature information on groups outside the formal framework, such as consortia, user groups and ad hoc task forces. Standards groups may contact the publication contractor, R.B. Toth Associates, at (703) 329-0658.

Commercial Remote Sensing Satellite System Planned

Geophysical & Environmental Research Corporation (GER) has announced its GEROS project, a system of up to six remote sensing satellites that will provide on-line images and analysis for agricultural production, environmental protection, forestry and land management, disaster response , surveillance and other uses. GER satellites and ground systems will be built by various contractors using the company's technology and proprietary analysis algorithms. The satellites will obtain data in the visible and invisible light ranges, radar and emitted heat. SpaceVest of Reston, Virginia, is providing the startup capital for the GEROS project.

Solar Car Race Uses Satellite and Cellular Technology

Hughes Network Systems (HNS), Delco Electronics and Electronic Data Systems (all General Motors companies), have developed a location and communication system that was used in Sunrayce 95. The race is a biennial collegiate competition held this year on June 20-29, with teams racing 1150 miles from Indianapolis, Indiana to Golden, Colorado. 40 schools qualify for the race, out of approximately 65 applicants. EDS maintains the Sunrayce Communications Center, Delco is providing audio and navigation systems for location information (based on support vehicle location), and HNS' dual-mode cellular phones and DirecPC™ high speed digital service provide communications.

Conference News

Call for Papers: European Frequency and Time Forum — Precise measurement of time and frequency is the focus of the European Frequency and Time Forum (EFTF), to be held March 5-7, 1996 in Brighton, U.K. Papers are invited which address important topics in time measurement and precise time and frequency applications: piezoelectric materials, oscillators, filters, frequency standards, synchronization systems, frequency synthesis, metrology, navigation, telecommunications and instrumentation. Authors should submit their intention to submit a paper immediately, and will receive instructions for a one-page summary. Send the proposal to: 10th European Frequency and Time Forum, Attn: Mrs. L.J. Hudson, EFTF Secretariat, IEE Conference Services, London WC2R 0BL, U.K. The conference language is English.

GaAs Man Tech Conference Drops U.S. Citizenship Requirement — Beginning with the 1996 conference in San Diego, the Conference on Gallium Arsenide Manufacturing Technology will be open to participants from around the world and U.S. citizenship will no longer be required to attend. The 10-year-old organization sponsoring the event will also expand its governing committees to include international representation. For more information, contact Publicity Chair Dave Miller at (201) 539-5500, Technical Program Chair James Oakes at (508) 470-9779, or Conference Chair Neal Mellen at (505) 822-8801, ext. 236.

ARFTG Call for Papers — Papers are invited for the Testing for Fall 1995 Automatic RF Techniques Group conference. The conference theme is: Testing for Wireless Applications. Topics sought include methods for reducing testing time, testing cost and high confidence. This includes on-wafer testing, fixture characterization and correlation of large signal RF to DC test parameters. Presentations are informal, 20 minute talks. Authors are requested to submit two copies each of a one-page abstract and a 500 to 1000 word summary, including illustrations, by August 28, 1995. Proposals should be sent to the Technical Program Chairs: Dr. Mike Golio and Dr. Dave Halchin, Motorola, MS EL-609, 2100 E. Elliot Road, Tempe, AZ 85284. Tel: (602) 413-5947, fax: (602) 431-4453, email: m.golio@ieee.org.

Grocery Warehouse Benefits from Wireless Inventory Management

Smart and Final, the West's oldest and largest grocery retailer, reports increased operator productivity and a 10 percent increase in warehouse space utilization, accomplished by installing a RF inventory management system called Priya, from Motek Information Systems. Replacing a mainframe inventory system that could only be updated every 12 hours, the RF system provides real-time information on availability of slots for newly-delivered pallets of goods. Smart and Final estimates that it will get two or three more years' service from a warehouse that was previously considered to be at capacity.

NASA Develops Simplified Digital Down-Converters

NASA researchers at the Jet Propulsion labortory have developed a technique where the high-speed number controlled oscillators (NCOs) and mixer-multipliers used in a typical digital downconverter are replaced with multiplication coefficients of finite-impulse-response (FIR) filters. This simplification depends on particular choices of operating frequencies.

The combined functions of NCO and mixers are equivalent to multiplication of the input signal samples by time-varying coefficients. Implementation of the FIR filter solution in the general case would require updating coefficients on every clock cycle. However, if the local oscillator frequency is restricted to integer multiples of the output clock frequency ($f_L = nf_0$), then the local oscillator coefficients that must be incorporated into the FIR coefficients are constants, each successive cycle representing the same phase of the signal.

The technique is less restrictive if the FIR filter has coefficient memory. In this case, a series of repeating coefficients can effectively multiply the number of usable frequencies ($mf_L = nf_0$), where m is the number of available coefficient memories.

Business Briefs

Varian's Electron Devices Business Sold, Becomes Communications & Power Industries — Varian Associates has agreed to sell its Electron Devices business to Leonard Green & Partners, L.P. for approximately $200 million in cash and assumption of certain liabilities. The Electron Devices operation has net assets of approximately $120 million and annual sales of about $250 million. Varian's other businesses are not involved in the sale. The group manufactures vacuum tubes, amplifiers and power supplies.

Dynair Acquired By Osicom Technologies — Dynair Electronics, a privately held company, has been acquired and will become a subsidiary of Osicom Technologies, joining other Osicom communications-related subsidiaries Meret Optical Communications and Catel Telecommunications. Dynair manufactures digital and analog switching and distribution systems for video, broadcasting, imaging, surveillance and information displays.

AMP and M/A-COM Close Merger — Shareholders of M/A-COM Inc. approved a merger proposal with AMP Incorporated on June 30, 1995, and the merger has been completed. Under the terms of the merger, M/A-COM stockholders will receive 0.280 shares of AMP common stock for each M/A-COM share. Richard P. Clark has been named as both president of M/A-COM and as divisional vice president of AMP Global Wireless Products Group, under which M/A-COM operates as a subsidiary.

Merix to Buy Hewlett-Packard PC Board Operation — Merix Corporation, formerly the printed circuit board division of Tektronix, and Hewlett-Packard Company have signed a memorandum of understanding for purchase of HP's Loveland, Colorado circuit board fabrication operation for a price estimated at $23.6 million. Initially, Merix will lease the 120,000 square foot facility for five years, and will produce boards for HP as its major customer.

Dover Acquires AT&T Division — Vectron Technologies, Inc., a subsidiary of Dover Technology International, has acquired all of the assets of the AT&T Microelectronics Frequency Control Products group. The AT&T group has supplied piezoelectric based oscillators to various divisions of AT&T for more than 40 years, and has recently expanded its markets to include OEM sales to other telecommunications companies. The operation will be moved from its current location in Andover, MA to a new 43,000 sq. ft. facility in Hudson, NH.

Telxon and The Shams Group in Medical Partnership — A joint marketing agreement has been announced between Telxon and The Shams Group (TSG), which will integrate Telxon's pen-based wireless computers into TSG's MEDITECH healthcare information systems. Wireless connectivity allows real-time updating of patient records and transmission of data directly to the point of care.

COMET Has New Address — COMET North America is moving to larger offices, to cope with its substantial growth. The new address is 89 Taylor Avenue, Norwalk, CT 06854, tel. (203) 852-1231, fax. (203) 838-3827.

PTI Adds Manufacturing Space — Piezo Technology, Inc. announces an expansion of its manufacturing facility with 5000 additional square feet of space. PTI makes filters, crystal oscillators and resonators.

RF Industries Completes Move — RF Industries, Ltd. has moved to a new location at 7610 Miramar Road, San Diego, Calif. 92126. Telephone and fax numbers remain the same, (619) 549-6340 and (619) 549-6345, respectively.

Richardson Signs Up Huber+Suhner — Richardson Electronics has been named national distributor in the U.S. for Huber+Suhner's line of coaxial connectors, adapters, EMP protectors, antennas and RF components.

NEC Moves NEPOC™ Product Sales to California Eastern Laboratories — Sales of the NEPOC line of photocouplers, interrupters, fiber optic links, photo transistors, photo diodes and detectors has been transferred from NEC Electronics, Inc. to California Eastern Laboratories.

LNY Sales is U.S. Agent for Plessey Tellumat — Plessey Tellumat, South Africa, has signed an agreement with LNY Sales, Inc for exclusive sales of their low noise amplifiers for cellular, paging and satellite applications.

Spinner Coaxial Connectors Marketed by Precision Tube/Coaxitube — Exclusive U.S. importing and marketing rights for Spinner GmbH connectors have been assigned to Precision Tube Co./Coaxitube Division of Salisbury Md. The Spinner line features the Spinner-originated 7-16 connector,along with HN, N, C, SC and other types.

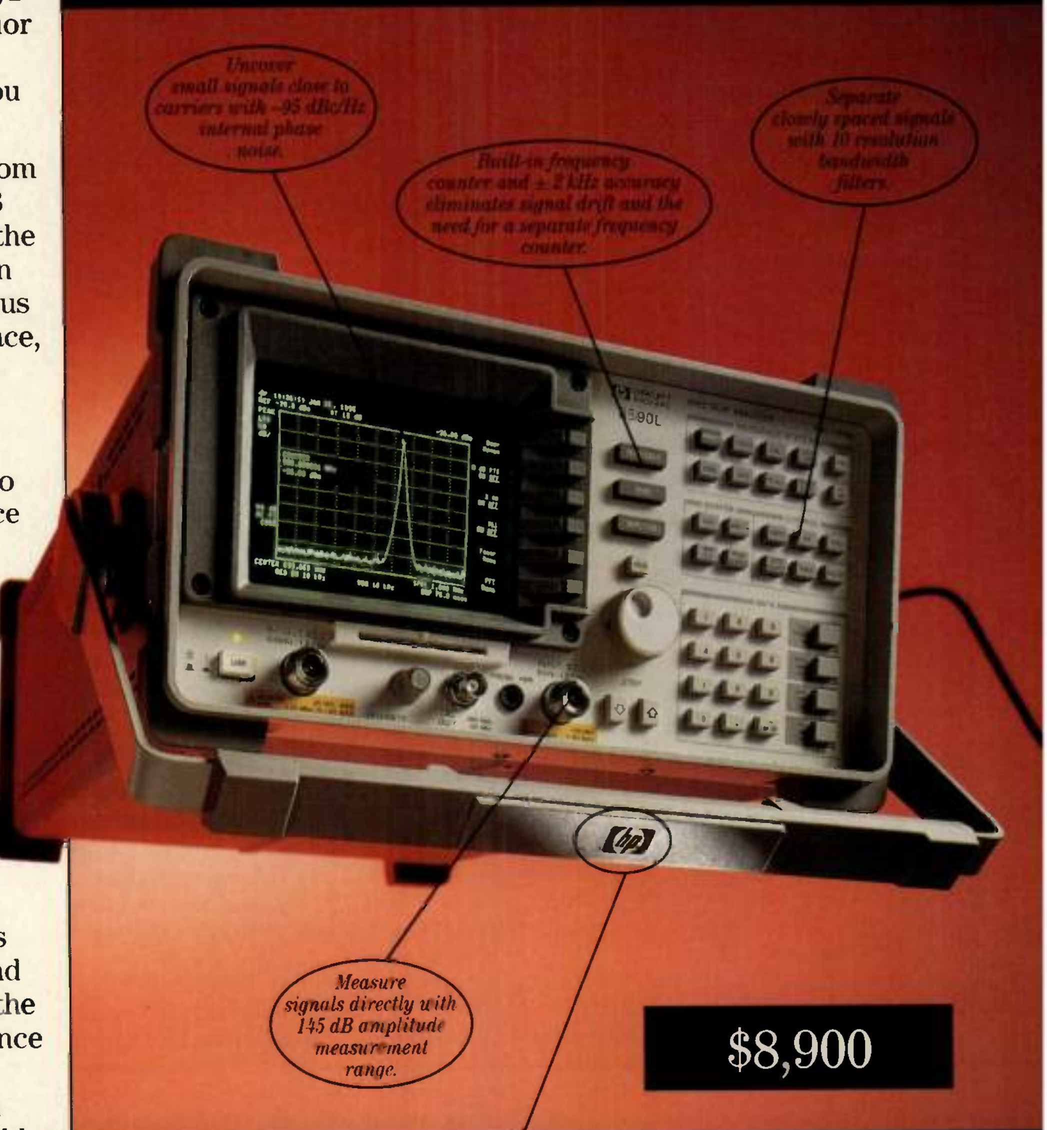
Femtosecond Systems Relocates — Femtosecond Systems, a manufacturer of precision oscillator noise measurement equipment, has a new address: 690 Arbutus St., Golden, CO 80401, tel: (303) 462-0799, fax: (303) 462-0766.

Contracts

RF Power Products Announces $1.3M Contract — RF Power Products has received a one-year agreement for its RF power generators from Mattson Technology valued at approximately $1,300,000. Mattson will use the power generators in their photoresist strippers, rapid thermal processing and chemical vapor deposition systems used in the semiconductor industry. RF Power Products makes power generators and peripheral products for the semiconductor, analytical instrument, commercial coating and flat panel display industries.

Microdyne to Supply Telemetry Receivers to the Navy — Microdyne Corporation, Aerospace Telemetry Division, has announced a major contract to provide nearly 100 of its new VMR-2000 VME bus controlled telemetry receivers and VMC-2001 Pre-Detection and Post-Detection diversity combiners, plus several telemetry signal simulators, to be used in an unidentified U.S. Navy program. The VME bus equipment will reduce the space requirements of previous rack-mount equipment. *RF*

Four believable features of this RF spectrum analyzer.



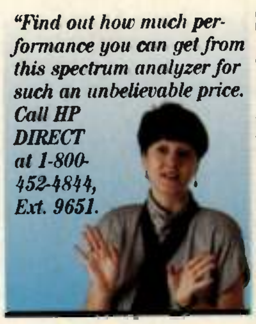
And one that's unbelievable.

The HP 8590L spectrum analyzer family gives you the superior performance you probably expect from HP. At a price you probably don't.

With a frequency coverage from 9 kHz to 1.8 GHz and a ±1 dB frequency response, you get the added confidence you need in amplitude measurements. Plus you get an easy-to-use interface, color print capability, and an optional built-in tracking generator.

Discover just how easy it is to afford all this HP performance by calling HP DIRECT at **1-800-452-4844, Ext. 9651***.

The engineers of HP DIRECT will give you all the specifications you need to choose the model that's right for you. And you can learn more about our entire HP 8590L spectrum analyzer family.



So give us a call. And discover the performance you can get for an unbelievable price.

*In Canada, call 1-800-450-2271, Dept. 147.

There is a better way.

HEWLETT® PACKARD

INFO/CARD 20

High-End Test Equipment Reflects New Communications Activity

By Andy Kellett
Technical Editor

If you haven't started seeing advertisements and new product releases for test equipment designed for installation and repair of systems such as GSM, various PCS systems and the new cable services, you soon will. While thousands of specialized test-sets will be manufactured to assist the armies of technicians it will take to install and maintain these new systems, the test equipment used in research and development is also changing to fit the new systems.

Complex Measurements

The new systems are complex. Complex (literally) modulation schemes such as π/4 DQPSK and GMSK have replaced modulations such as plain old FM; and channels are assigned both in time and frequency – the Digital European Cordless Phone (DECT) system assigns users to one of eight time slots, in addition to assigning them a frequency. "Along with complexity comes the need for more sophistication in test equipment," says Lynn Stewart, Market Development Manager for Wireless Communications at Hewlett-Packard's Microwave Instruments Division, "we look at signals in different ways than we have in the past."

According to Stewart, some of the most important measurements, particularly in the new wireless communications systems, are power measurement in both the frequency and time domain, and transmitter on/off times. Tom Brinkoetter, Marketing Manager at Tektronix pointed to those two measurements as important as well. Brinkoetter says looking at adjacent channel power is very important to manufacturers of multi-channel wireless systems, particularly digital systems. Brinkoetter adds that measuring transmitter on/off times is important to ensure transmitters in time-multiplexed systems don't interfere with each other, but also to make sure they follow the correct on/off profile to minimize sidebands, "again it's back to the adjacent channel power issue," says Brinkoetter.

The complex interplay of frequency domain and time domain specifications has prompted equipment manufacturers to make boxes capable of quickly and easily looking at signals in both domains.

Measurement Precision

While complex communications systems have caused equipment manufacturers to make their equipment more complex, the steadily improving performance of individual components has pushed up the basic performance of test equipment as well.

Customers are requesting lower noise in signal sources and improved performance from analyzers as the devices they test become more linear, have lower loss and have higher dynamic range. Brinkoetter points to measuring the response of diplexers for PCS use. A diplexer may see a +30 dBm transmit signal and a –130 dBm receive signal at its input, says Brinkoetter, "...so the rejection has to be well over 100 dB, and that requires the network analyzer to have that kind of sensitivity."

Customers for the Rohde & Schwarz FSE series spectrum analyzers, (distributed by Tektronix in the U.S.), have found the instrument's high dynamic range very useful says Brinkoetter, "they can see sidebands below specs, at levels close to the noise, without having to use a long sweep time."

Good calibration practices are becoming more important. The effect of bad adapters, connectors and terminations can be ten percent or more of a device's measured return loss, particularly if the device has low insertion loss, says Ken Harvey, Product Marketing Manager at the Wiltron Company. "I can find on almost every bench a connector or adapter that will cause a measurement to be out of spec," he says. To make it easier to calibrate all the connectors, adapters, etc. in a test set-up, Harvey says Wiltron's 54100 scalar analyzers include a precision return loss mode for use with a piece of precision air-line, which allows the person performing the test to find bad components and calibrate out their effects.

Manufacturing Measurements

Changes in manufacturing are also reflected in test equipment. ISO 9000 has prompted manufacturers to get the uncertainty of their measurements under control says Harvey, which is another reason to be sure of system calibration.

The manufacturers who use RF test equipment want to test as many devices as possible, so test speed is also important. "What we've seen in manufacturing is they tend to wrap R&D equipment in software," says Tektronix' Brinkoetter. The purpose of this software is to automate the testing process. With the software available with many instruments, procedures which took an hour to perform can be set-up and performed at a touch of a button.

Not only set-up times, but the times of the measurements themselves are being reduced. The IEEE-488.2 control bus standard is a speedier version of the old IEEE-488 standard, and using this bus, Wiltron has demonstrated analyzers capable of sending data to a computer in almost real time. Wiltron's Harvey says demand for fast test times helped drive their design for a very fast-stepping phase-locked synthesizer.

Conclusion

New communications systems are prompting test equipment manufactures to include more complex measurements in their boxes, tighter specs cause them to increase precision, and manufacturing is encouraging faster, easier testing procedures. RF

You never thought you needed the extra performance and expense of HP.

How about just the extra performance?

Like all of our signal generators, the HP 8648 series offers the superior performance you probably expect from HP, but thought you couldn't afford. At $5,865, however, can you really afford to do without it?

The HP 8648 family gives you uncompromised performance, with clean +10 or +13 dBm output power, and a simple user interface that lets you tackle a variety of applications. And the HP 8648A offers an electronic attenuator that reduces the risk of failure.

To find out about all the features the HP 8648 signal generator family has to offer, call HP DIRECT. It's the fast, easy way to get all your questions answered. With one simple call, you can get quick product specifications or any technical literature you may need to make the right decision. Or, if you want one-on-one technical support, you can speak to an engineer who has first-hand experience with HP products. And, of course, if you're ready to order, we can help you do that, too.

So give us a call. And get higher performance. At a lower price.

*In Canada, call 1-800-450-2271, Dept. 148.

There is a better way.

HEWLETT® PACKARD

INFO/CARD 21

Dual PLL IC Achieves Fastest Lock Time With Minimal Reference Spurs

By William O. Keese
National Semiconductor

The LMX233XA dual PLLs are designed for use in dual-synthesizer wireless designs. With a maximum frequency of 2.5 GHz, the series supports designs where fast frequency lock times and minimal reference spurs are crucial.

PLL frequency synthesizers are a vital component in wireless applications such as digital cellular phones, pagers, and set-top boxes. Applications that include dual down converters with an RF and IF stage make use of two PLL frequency synthesizers to generate separate frequencies for each stage. Full duplex systems, such as AMPS, need two RF synthesizers to generate both receive and transmit local oscillators simultaneously. Dual PLL chips, which supply both the RF and IF or two RF LOs, excel in dual synthesizer designs because of their reduced parts count, lower power consumption, and smaller board space requirements. The block diagram for the dual PLL chip is shown in Figure 1.

Like single PLL ICs, dual PLLs ICs must offer fast switching times and a minimum of spurious output and phase noise. The LMX233XA series ICs, the newest members of the PLLatinum family from National Semiconductor (Santa Clara, CA), offer a frequency lock time that's the fastest in the industry, minimal reference spurs, and no dead-zone.

The LMX233XA cuts lock time by 35 percent by using its patented Fastlock® technique. Fastlock shifts the loop filter's pole and zero corner frequencies while maintaining the PLL's gain/phase margin characteristics, using only one external resistor.

Fastlock Implementation

Figure 2 shows a conventional PLL configuration consisting of a high-stability crystal reference oscillator, a frequency synthesizer, a voltage controlled oscillator (VCO) and a passive loop filter. (A passive filter is preferred over a higher order filter because of its simplicity, low cost, and reduced phase noise.) The frequency synthesizer includes a phase detector, a current mode charge pump, and programmable reference (R) and feedback (N) frequency dividers.

In conventional PLL design, the tuning resolution of the PLL is set by the R counter dividing the crystal reference signal down to some reference frequency f_r, which is input to the phase detector. The phase detector compares it with f_p, the feedback signal, obtained by dividing the VCO frequency down by the N counter. The phase detector's current-source feeds into the loop filter, which converts the charge into the VCO's control voltage. The phase/frequency comparator's function is to adjust the voltage presented to the VCO until the feedback signal's frequency and phase match the reference signal. When this "phase-locked" condition exists, the VCO's frequency will be N times that of the comparison frequency.

Increasing the value of the N counter by one will cause the phase comparator to initially sense a frequency error between the reference and feedback signals The feedback loop responds by shifting the VCO frequency to N+1 times the reference signal. The VCO's frequency has in effect increased by the

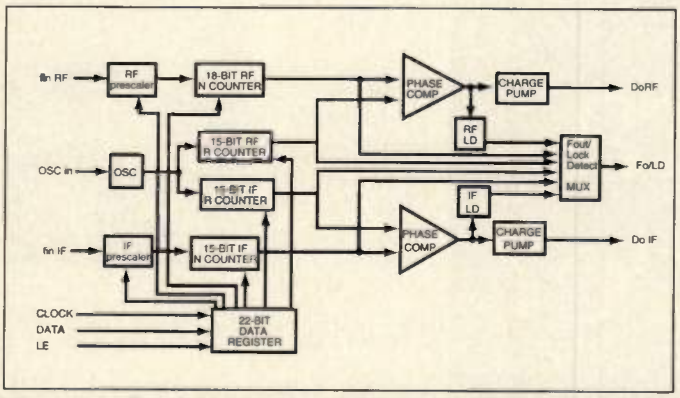


Figure 1. Dual PLL chips, which supply both the RF and IF stage frequency synthesizers.

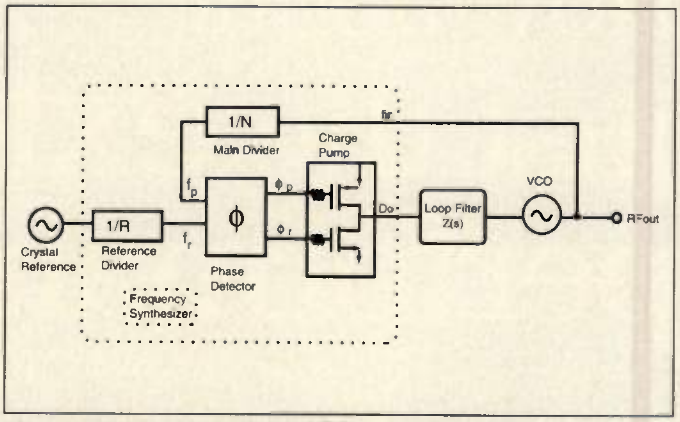


Figure 2. A conventional PLL configuration.

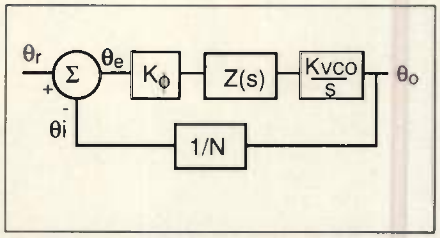


Figure 3. A linear control system model of the phase feedback for a PLL in the locked state.

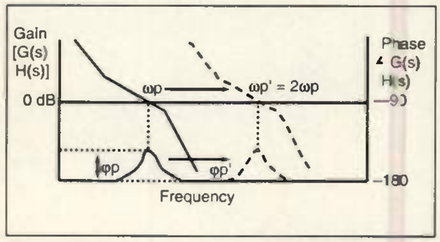


Figure 4. A Bode plot of the magnitude and phase of G(s)H(s) for a stable loop is shown by the solid trace.

minimum tuning resolution of the PLL. The transition rate to the new operating frequency is determined by the closed loop gain and the stability criteria:

$$\text{Open Loop Gain} = H(s)G(s) = \frac{\theta_i}{\theta_e} \tag{1}$$

$$= \frac{K_{pd} Z(s) K_{vco}}{Ns}$$

$$Z(s) = \frac{s(C2 \cdot R2) + 1}{s^2(C1 \cdot C2 \cdot R2) + sC1 + sC2} \tag{2}$$

$$T1 = R2 \cdot \frac{C1 \cdot C2}{C1 + C2} \tag{3a}$$

$$T1 = R2 \cdot C2 \tag{3b}$$

$$G(s) \cdot H(s)\big|_{s=j\omega} = \tag{4}$$

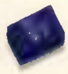
$$\frac{-K_{pd} \cdot K_{vco}(1 + j\omega \cdot T2)}{\omega^2 C1 \cdot N(1 + j\omega \cdot T1)} \cdot \frac{T1}{T2}$$

$$\phi(\omega) = \tan^{-1}(\omega T2) \tag{5}$$

$$- \tan^{-1}(\omega T1) + 180°$$

A linear control system model of the phase feedback for a PLL in the locked state is shown in Figure 3. The open loop gain is the product of the phase comparator gain (K_ϕ), the VCO gain (K_{vco}/s) and the loop filter gain Z(s) divided by the gain of the feedback counter modulus (N) (equation 1). The complex impedance of the passive loop filter used is given in equation 2. The time constants which determine the

Monolithic Chip Caps
Ultra-miniature sizes — all the way down to 0402. Temperature ranges from -55°C to +150°C.

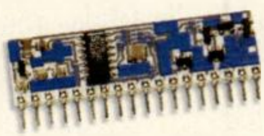


455KHz - 10.7MHz Filter
Offers excellent sensitivity, optimum stop band attenuation and high stability for wireless applications.

Compact VCO
Small size, low power consumption. 400MHz-2.5GHz. Stability of ±2MHz from -35°C to +80°C.

SMD Trimming Capacitor (TZV02) Series
Smallest size available – just 2.3mm x 3.2mm x 1.45mm. Excellent stability, rugged construction. Designed for auto placement.

SMD Inductor
Ultra-small, tight tolerance inductor with low DC resistance and outstanding high frequency characteristics.



Circuit Module (Hybrid IC)
Excellent HF and heat dissipation characteristics. The result of Murata's 25 years of thick film technology.

SAW Filter
Smaller, thinner design with high performance, even above 1GHz. Zinc oxide printed on sapphire substrate.

Microwave Filters (GIGAFIL®)
Low insertion loss for high Q-value dielectric resonators, excellent out-of-band rejection.

A few of the important components of a happy conversation with Grandpa.

A clear mountain lake, a grandson with his first fish and a cellular phone with as many as 140 Murata components. A simple combination that makes a nice surprise for Grandpa. And here's a surprise for you: For wireless devices from pagers to PDAs, you can use Murata components for 70% of any RF front end — components that range from multilayer VCOs and high frequency filters to chip monolithic hybrid couplers and RF diode switches. You see, we not only want to be an important component of a call to Grandpa. We also want to be the call you make when you specify components for your newest design.

For a free wireless poster, as well as Murata catalogs, call 1-800-831-9172, ext. 449.

muRata®
Innovator in Electronics

INFO/CARD 25

See us at RF EXPO EAST Booth# 311

pole and zero frequencies of the filter transfer function are defined in equations 3a and 3b. The third order PLL open loop gain can be calculated in terms of frequency, ω, T1 and T2 and K_ϕ, K_{vco}, and N (equation 4). From equation 4 , the phase term will be dependent on the single pole and zero such that the phase margin is determined in equation 5.

A plot of the magnitude and phase of G(s)H(s) for a stable loop is shown by the solid trace in Figure 4. The parameter ϕ_p shows the amount of phase margin that exists at the point the gain drops below zero (the cutoff frequency ω_p of the loop). In a critically damped system, the amount of the phase margin would be approximately 45 degrees. To minimize lock time, the cutoff frequency of the loop ω_p should be just wide enough to suppress the PLL's reference frequency spurs to a tolerable level.

In Fastlock, the cutoff frequency is redefined as $\omega_p' = 2\omega_p$, the loop response time would be approximately halved. Because the filter attenuation at the comparison frequency also diminishes, the spurs would have increased by approximately 6 dB. With Fastlock, however, the higher spur levels and wider loop filter conditions exist only during the initial lock-on phase, which is just long enough to realize the faster lock-on time. In effect, the curve of Figure 4 slides over to the cutoff frequency illustrated by the dotted line, without affecting the relative open loop gain and phase relationships.

To maintain the original gain/phase relationship at twice the original cutoff frequency, other terms in the gain and phase equations 4 and 5 will have to compensate by the corresponding $1/\omega$ or $1/\omega^2$ factor. Examination of equations 3 and 5 indicates the damping resistor variable R2 could be chosen to compensate the w terms for the phase margin. This implies that another resistor of equal value to R2 will need to be switched in parallel with R2 during the initial lock period. In addition, the magnitude of the open loop gain, G(s)H(s) must be set equal to zero at $\omega_p'=2\omega_p$. K_{vco}, K_ϕ, N, or the net product of these terms can be changed by a factor of 4, to counteract the ω^2 term present in the denominator of equation 3. While altering K_{vco} would be difficult at best, both K_p and N are readily available in a PLL IC. K_ϕ was chosen to complete the transformation because it can be readily switched between 1× and

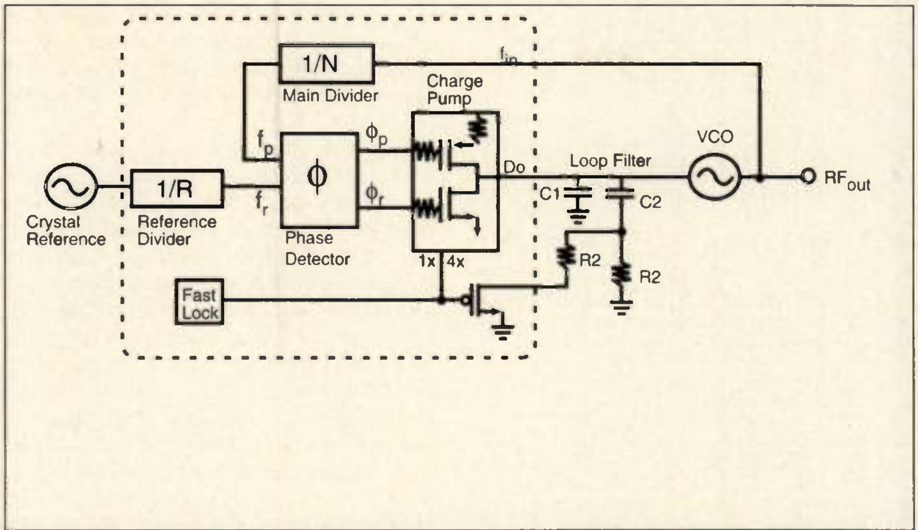


Figure 5. Fastlock architecture - an LMX2335 was used in an IS-54 design.

4× values by increasing the charge pump current from 1 mA in the standard mode to 4 mA in Fastlock.

(Changing the N gain term could also have been chosen to accomplish our objective. In fact, doing so causes the PLL's reference frequency to be pushed over in the reference domain along with the loop cutoff frequency. However, changing N also means changing the R counter value by the same factor, and while this is feasible, it introduces fractional counter techniques along with all the associated problems of the approach, as N/4 may no longer be an integer.)

Circuit Implementation

The LMX2335's Fastlock scheme is shown in Figure 5. When a new frequency is loaded the charge pump receives an input to deliver four times the normal current per unit phase error while an open-drain NMOS on-chip device switches in a second R2 resistor to ground. The user calculates the loop filter component values for the normal steady-state considerations. The device configuration ensures that as long as a second identical damping resistor is wired in appropriately, the loop will lock faster without any additional stability conditions. Once locked onto the correct frequency, the PLL returns to standard low noise operation. This transition does not affect the charge on the loop filter capacitors and is synchronous with the charge pump output, creating a virtually seamless change between Fastlock and standard mode.

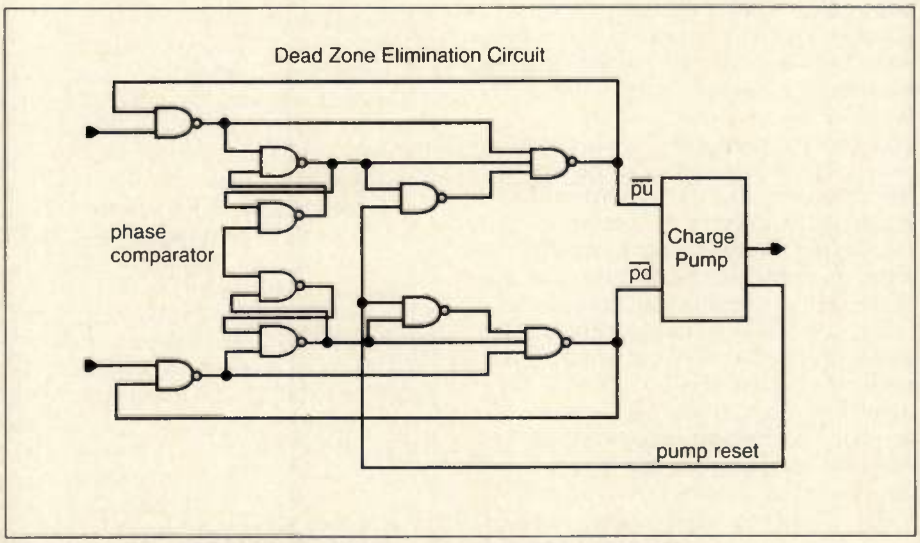


Figure 6. The LMX233XA deadzone elimination circuit.

	LMX2330	LMX2331	LMX2332	LMX2335
Type	RF/IF Dual	RF/IF Dual	RF/IF Dual	RF/IF Dual
RF input - Main PLL	2.5 GHz	2.0 GHz	1.2 GHz	1.1 GHz
RF Input -Aux PLL	510 MHz	510 MHz	510 MHz	1.1 GHz
Prescaler -Main PLL	32/33 or 64/65	64/65 or 128/129	64/65 or 128/129	64/65 or 128/129
Prescaler -Aux PLL	8/9 or 16/17	8/9 or 16/17	8/9 or 16/17	64/65 or 128/129
IDO Leakage	2.5 nA @ 85°C	2.5 nA @ 85°C	2.5 nA @ 85°C	5 nA @ 25 °C
Opr. Temp.	–40 to +85 °C	–40 to +85 °C	–40 to +85 °C	–40 to +85 °C
Vcc range	2.7 to 5.5 V	2.7 to 5.5 V	2.7 to 5.5 V	2.7 to 5.5 V
Icc (typ)	15 mA @ 3V	14 mA @ 3V	8 mA @ 3V	9 mA @ 3V
Icc pwrdown (typ)	1 µA @ 3V	1 µA @ 3V	1 µA @ 3V	1 µA @ 3V
Package	TSSOP 20	TSSOP 20	TSSOP 20	SO 16 - JEDEC
Typ. Applications	ISM (2.4 - 2.45) DECT, CATV WLAN	DECT, DCS1800 RCR-28, RCR-27 CATV	GSM, IS-54 RCR-27 ISM (902-928)	AMPS, NMT ETACS, CT-1 CT-1+, CT-2 ISM(902-928)
Order # ("X"=tape & reel)	LMX2330TM LMX2330TMX	LMX2331TM LMX2331TMX	LMX2332TM LMX2332TMX	LMX2335M LMX2335MX
Production avail.	now	now	now	Q2CY95

Table 1. The LMX233x family

IS-54 Application Example

An LMX2335 was used in an IS-54 design with the following constraints: F_{vco}=900 MHz, K_V=20 MHz, and channel spacing=30 kHz. The PLL's device attributes were: K_ϕ=1mA/2π, N= 30,000, F_{ref}=30 kHz, and F_o=3 kHz. The loop filter values used were: C1 = 1800 pF, R2 = 12 k, C2 = 0.012 µF.

The circuit locked within 1 msec (± 1 kHz) for a frequency jump of 50 MHz, compared with 1.6 msec for the standard PLL lock time. A small frequency disturbance can result when switching back to normal operation after reaching steady-state. By switching out of Fastlock mode when the PLL has settled near the desired frequency tolerance, almost the entire 2× increase in lock time can be achieved.

Minimal lock time is not the only requirement for a PLL - low phase noise and low reference spurs are also necessary. A deadzone elimination circuit and an almost perfectly balanced charge pump allow the LMX233x to meet these requirements.

A deadzone can occur in certain PLL implementations as the error becomes infinitesimally small. The PLL circuit reaches the point, called the deadzone, where the current source pulse width becomes too narrow to control and collapses to zero. A zone of phase error corrections will result which receive no responding current flow.

The LMX233XA deadzone elimination circuit (Figure 6) ensures that the charge pump current sources have actually responded to the phase comparator output signals (PU and PD) before activating the phase comparator reset logic. Both the pump up and pump down circuit always turn on, so the net difference, not the width of the pulses themselves, is the error correction signal. Because of the deadzone elimination circuit, the current pulses never collapse to zero allowing vanishingly small error correction pulses into the PLL loop filter in a controllable fashion. When the signal is out of lock, the corresponding pump-up or pump-down pulse width increases. As the frequency error is minimized, the difference between the correction pulses becomes smaller, until the PLL becomes "phase-locked," where the sink and source currents are equal, and zero net charge is injected into the loop filter. The circuit is therefore able to make minimal error corrections, without having to generate a narrow pulse which is dominated by the turn-on time of the charge pump output transistors.

Reference spurs are minimized by virtue of the charge pump being almost perfectly balanced. The LMX233XA's manufacturing process yields physically identical current-generating structures for the pump-up and pump-down circuits, which ensures that the magnitudes of their current sources, as well as matching their turn-on and turn-off times. This matching minimizes the momentary pump up or down excursions on the charge pump line which are a major contributor to reference spurs.

Like the balanced charge pump currents, the deadzone elimination circuitry also works to minimize the spurs because the charge pump feedback signals allow the generators to be on only long enough to eliminate potential deadzone, without contributing any excess active pump time. Excess pump time adds directly to the up or down excursions on the charge pump line by the amount the absolute magnitudes of the current generators differ. Coupled with the balanced source and sink currents, the circuitry can be tuned to exactly the same magnitude for a minimal period of time and the reference spurs are correspondingly minimized. At less than –74 dBm, the LMX233XA's reference spurs are the lowest in the industry.

Lower reference spurs means less filtering is needed at the board level. The PLL loop filter bandwidth can be increased for the same amount of spurious rejection, which means faster lock times. Similarly, because the charge pump has negligible leakage current, no "sawtoothing" occurs in the VCO control voltage, which could also contribute to spurs. The loop filter can often be implemented with a second order filter, instead of more exotic filters, resulting in fewer components, and fewer headaches.

For more information on the LMX233x family of dual PLLs call (800) 272-9959. *RF*

About the Author

William O. Keese is a Senior Applications Engineer at National Semiconductor Corporation in Santa Clara. Keese is head of phase-locked loop applications in the Wireless Communications division and has designed synthesizers for a variety of cellular and cordless communications standards, such as GSM, IS-136, DECT and PHS. Keese received a double major in Electrical Engineering and Materials Science from the University of California at Davis. He is currently completing his MSEE at UCD in RF and Microwave Engineering. He can be reached at 2900 Semiconductor Dr., M/S A-1500, Santa Clara, CA 95052-8090

Low Dropout Current Source Protects Silicon MMICs and Transistors

By John V. Bellantoni
Watkins-Johnson Co.

This 1994 RF Design Contest entry solves a problem often faced by RF designers concerned with both cost and power dissipation: is there a way to use low cost silicon devices over a wide temperature range without incurring any additional power dissipation in the bias circuitry? Here is a design that makes large voltage drops in amplifier bias circuits a thing of the past.

Silicon transistors and MMIC amplifiers are widely used in RF applications where cost and simplicity are paramount concerns. Figure 1 summarizes the most popular biasing schemes for Si MMIC amplifiers [1]. Directly connecting the MMIC to the supply, as shown in Figure 1(a), is suitable only under laboratory conditions. The bias resistor shown in Figure 1(b) is a more practical method.

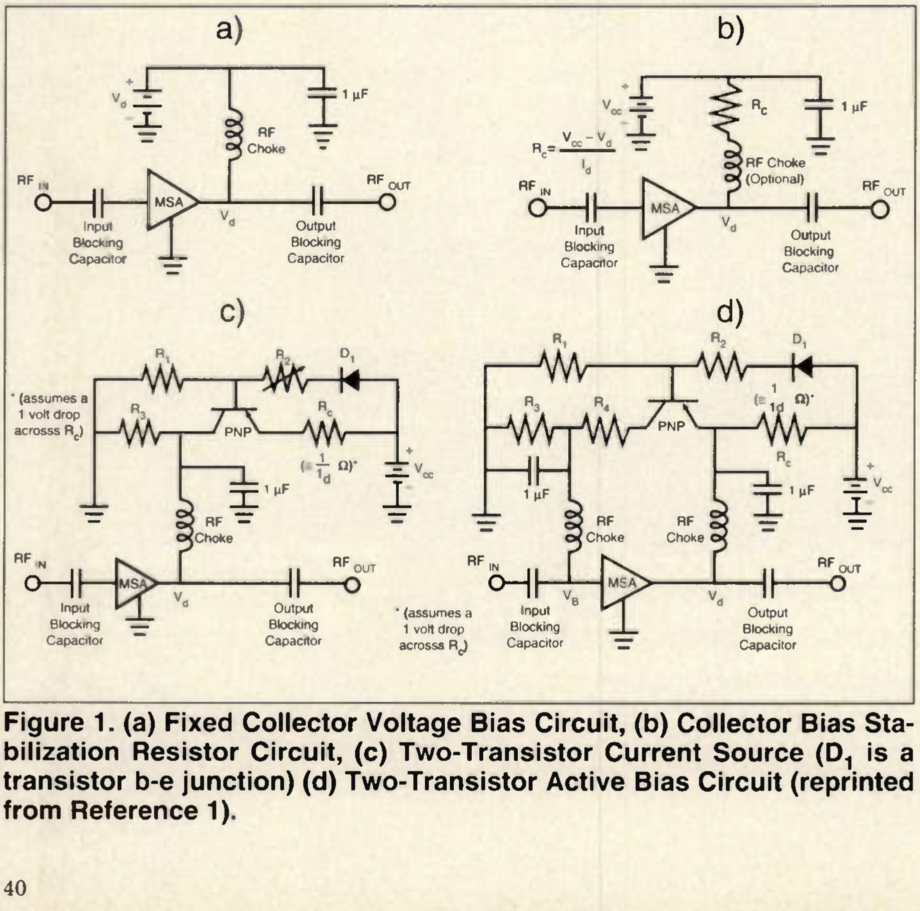


Figure 1. (a) Fixed Collector Voltage Bias Circuit, (b) Collector Bias Stabilization Resistor Circuit, (c) Two-Transistor Current Source (D_1 is a transistor b-e junction) (d) Two-Transistor Active Bias Circuit (reprinted from Reference 1).

However a minimum of 3 volts is needed across the resistor to maintain stability over temperature. That voltage drop can be reduced to 1.7 volts with the two-transistor designs given in Figure 1(c) and 1(d). The two-transistor circuits still increase power dissipation of a 5 volt Si MMIC amplifier circuit by 30 percent. In addition, the current supplied by the two-transistor design is sensitive to variations in the supply voltage.

The literature doesn't seem to contain any schemes for safely biasing transistor circuits close to their operating voltages. What's needed is a simple way to provide a constant current – something that works over temperature, power supply, and load variations, without any significant voltage drop from supply line to device. Figure 2 is the author's low dropout current source (LDCS) that meets these requirements; it provides a constant current regardless of load impedance.

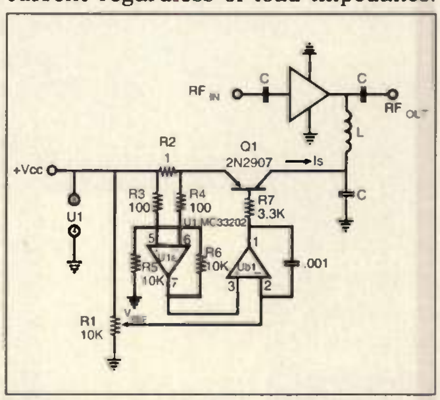


Figure 2. Low Dropout Current Source (LDCS) Circuit.

...MORE NEW 3 VOLT RF ICs FOR YOUR HANDHELD WIRELESS PRODUCTS

3V

Dozens of 3 Volt Amplifiers, Prescalers, Up & Downconverters, IQ Mods & Demods, and Transistor Arrays, including:

UPC8104GR new
IQ Modulator
with Up Converter
800 MHz to 2.4 GHz
2.7 to 5.5 V Supply Voltage

UPC8106T/09T
Up Converters
800 MHz – 2.4 GHz
7 dB CG @ 1.9 GHz
2.7 to 5.5 V Supply Voltage

UPC2758T
Downconverter
100 MHz – 2.4 GHz
17 dB CG @ 2.0 GHz
+6 dBm IP3

UPC2762T/63T
Driver Amplifiers
100 MHz – 1.9 GHz
14 or 20 dB Gain and
+7 dBm P1dB @ 1.9 GHz

UPC2768GR new
Downconverter
DC – 450 MHz
80 dB Conversion Gain
On-chip Oscillator

UPC2771T new
Wideband Amplifier
100 MHz – 2.1 GHz
21 dB Gain and
+11.5 dBm P1dB @ 900 MHz

5V

...plus a wide variety of Silicon Devices for 5 Volt applications, including:

UPC2709T
Wideband Amplifier
100 MHz–2.3 GHz
23 dB Gain
+8 dBm P1dB @ 900 MHz

UPC2766GR new
IQ Demodulator
35 dB AGC Dynamic Range
Flat Response to 1 GHz RF
DC–100 MHz I/Q Output

UPC2721GR
High Compression Point
Downconverter
900 MHz – 2.0 GHz
21 dB Conversion Gain

UPB1505GR new
Prescaler
÷64/128/256
3 GHz Guaranteed RF Input
High Input Sensitivity

NEC's 3 Volt ICs not only reduce power consumption in your wireless designs, they help reduce your parts count, improve the reliability, and simplify assembly.

We're committed to 3 Volt Silicon technology. These parts are just a sampling of the wide variety of the semiconductors we stock.

We also stock 5 Volt ICs — plus NEC's huge family of discrete devices. Many of these transistors are characterized at 1 to 3 Volts, and most are available in a number of package styles, including the new ultra-miniature 0.8 X 1.6 mm NEC "19" package.

For a FREE Product Selection Guide, call your nearest CEL Sales Office. Or circle the number below.

...plus dozens of discrete transistors including three new small signal bipolar series:

new

PART*	NF (dB)	GA (dB)	V/IC	fTEST(GHz)
NE68619	1.7	10.0	2V/3mA	2.0
NE68719	1.5	8.0	1V/3mA	2.0
NE68819**	1.6	8.0	3V/7mA	2.0

* AVAILABLE IN SIX DIFFERENT PLASTIC PACKAGES, INCLUDING THE ULTRAMINIATURE NEC "19" PACKAGE
** LOW PHASE NOISE DEVICE

See us at BOOTH 301 RF Expo East

CEL California Eastern Laboratories

NEC

CEL Headquarters 4590 Patrick Henry Drive, Santa Clara, CA 95054-1817; (408) 988-3500 FAX (408) 988-0279 Santa Clara, (408) 988-7846 Los Angeles, CA (310) 645-0985
San Diego, CA (619) 450-4395 Bellevue, WA (206) 644-3307 Richardson, TX (214) 437-5487 Olathe, KS (913) 780-1380 Woodridge, IL (708) 241-3040
Timonium, MD (410) 453-6600 Middleton, MA (508) 762-7400 Hackensack, NJ (201) 487-1155 Snellville, GA (404) 978-4443

INFO/CARD 32

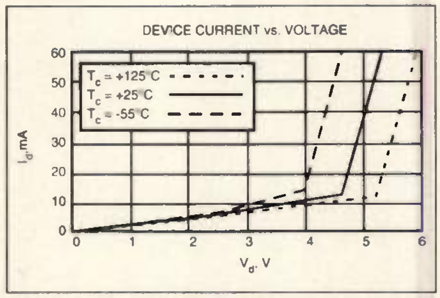


Figure 3. MSA-0300 I-V characteristics (reprinted from Reference 2).

The current is sampled by R2, amplified by U1a, and then compared to a reference voltage by U1b. The feedback loop is closed by Q1. Equilibrium occurs when the voltage drop across R2, multiplied by the gain of U1a, equals the reference voltage. Since R5 = R6 and R3 = R4, the gain of the differential amplifier is R6/R4, and the current will be:

$$I_s = V_{ref}\frac{R4}{R2 \cdot R6} \quad (1)$$

where V_{ref} can be set by potentiometer R1, or by some other means. The potentiometer is a good choice to continuously vary the operating point, while fixed resistors or voltage references are best for specific bias points.

For proper circuit operation while operating from a single supply, the dual op amp must have an input common mode range that includes the positive rail. Suitable devices in this category are the Motorola MC33202, Maxim MAX492, and National LMC6482. Substituting other op amps can be tricky. For example, the common mode input range of a JFET device includes the positive rail, but a negative supply is required. On the other hand, low cost single supply op amps, such as the LM358, will not operate with input voltages near their positive supply voltage.

Performance of the LDCS is consistent and predictable. The prototype circuit, set to 35 mA, doesn't even move a tenth of a mA when the load is shorted out. Stability over temperature is essentially a function of V_{ref}, derived from V_{cc}. If V_{cc} is not stable over temperature or time, use an inexpensive adjustable shunt regulator, such as the LM431, to produce the reference voltage. An added advantage to using a shunt regulator is that a battery-derived V_{cc} can vary over a wide range without a significant change in

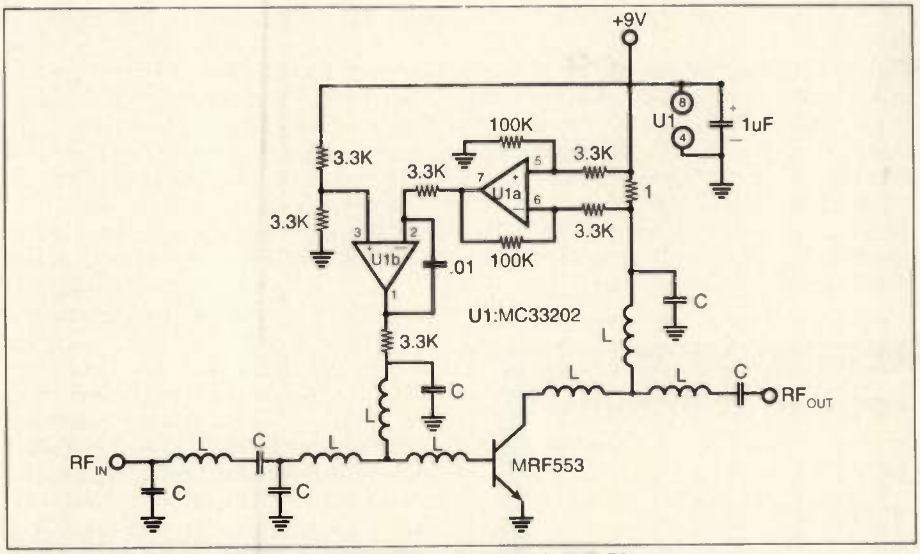


Figure 4. Low Dropout Active Bias Circuit (LDBC).

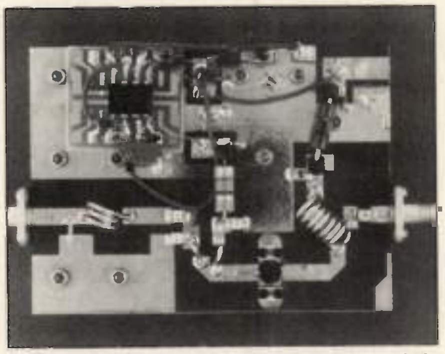


Figure 5. VHF amplifier with LDBC.

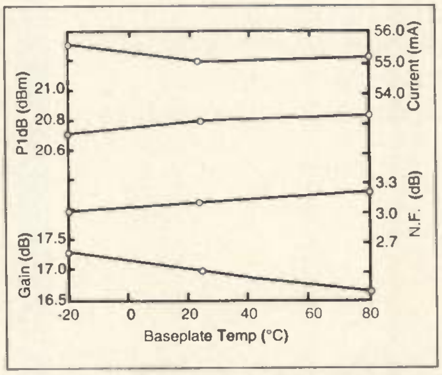


Figure 6. Performance over temperature of the VHF amplifier with LDBC. f_0=160 MHz, V_d=6 Volts.

current. Using an LM113 voltage reference, the current changed 9 percent – from 38 mA to 35 mA, when V_{cc} was decreased 50 percent, from 11.5 to 5.75 volts. Be careful not to set the supply voltage above 11.5 volts, since the MC33202 maximum rating is 12 volts (15 volts for the LMC6842).

The voltage drop across the circuit is due to R2 and Q1. At room tempera-

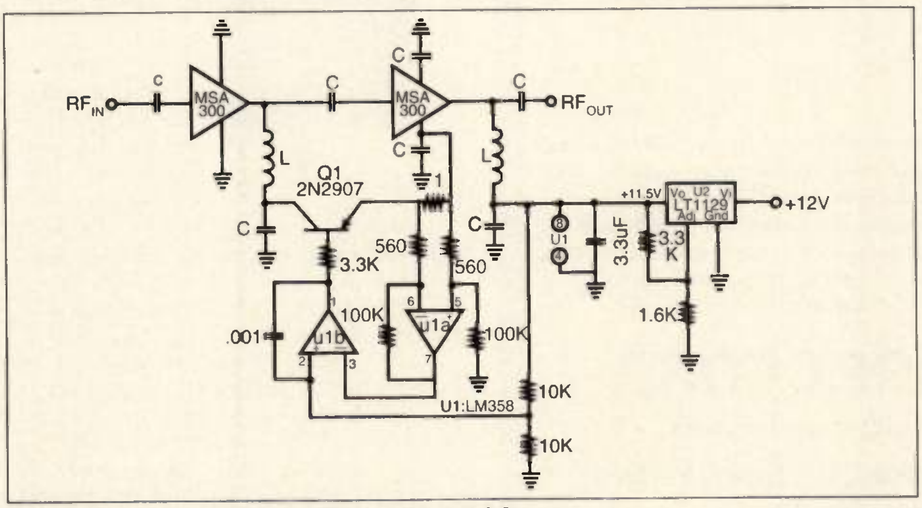


Figure 7. Two stage amplifier with LDCS.

ture, dropout was 160 mV at 35 mA, 250 mV at 75 mA, and 400 mV at 150 mA. Most of the dropout is due to Q1; a more expensive device such as a 2N4276 will result in even lower dropout performance. To determine the minimum V_{cc}, add the dropout to the maximum device voltage. The maximum device voltage usually occurs at cold temperatures. An example is shown in Figure 3, which is the I-V characteristic of a MSA-0300 device [2]. From the –40°C curve in Figure 3, the device voltage at 35 mA is 5.5 volts. Adding 160 mV for the LDCS, and an extra 100 mV for design margin, only 5.76 volts is needed to bias the device over temperature.

For active bias of MMICs or discrete devices, switch the input pins at U1b, as shown in Figure 4. The MRF-553 VHF amplifier pictured in Figure 5 uses the design given in the data book [3]. However due to the added low dropout bias circuit (LDBC), performance over temperature, plotted in Figure 6, is rock solid, and efficiency for the entire circuit is just 1.5 percent less than the efficiency of the transistor.

Nearly endless variations to the LDCS circuit are possible. One of the author's favorite is the design shown in Figure 7, where two Si MMIC amplifiers are biased in series. The LT1129 in Figure 7 is a low dropout voltage regulator that provides over-voltage and reverse-bias protection, a temperature stable voltage reference for the current source, and requires only 3.3 µF for stability. The LDCS is placed between the MMICs. That way, the op amp inputs are well below V_{cc}, so generic op amps, which are typically one third the cost of a rail-to-rail op amp, will work well. Whatever the application, the LDCS will keep a design on the road when low overhead clearance stops the rest. *RF*

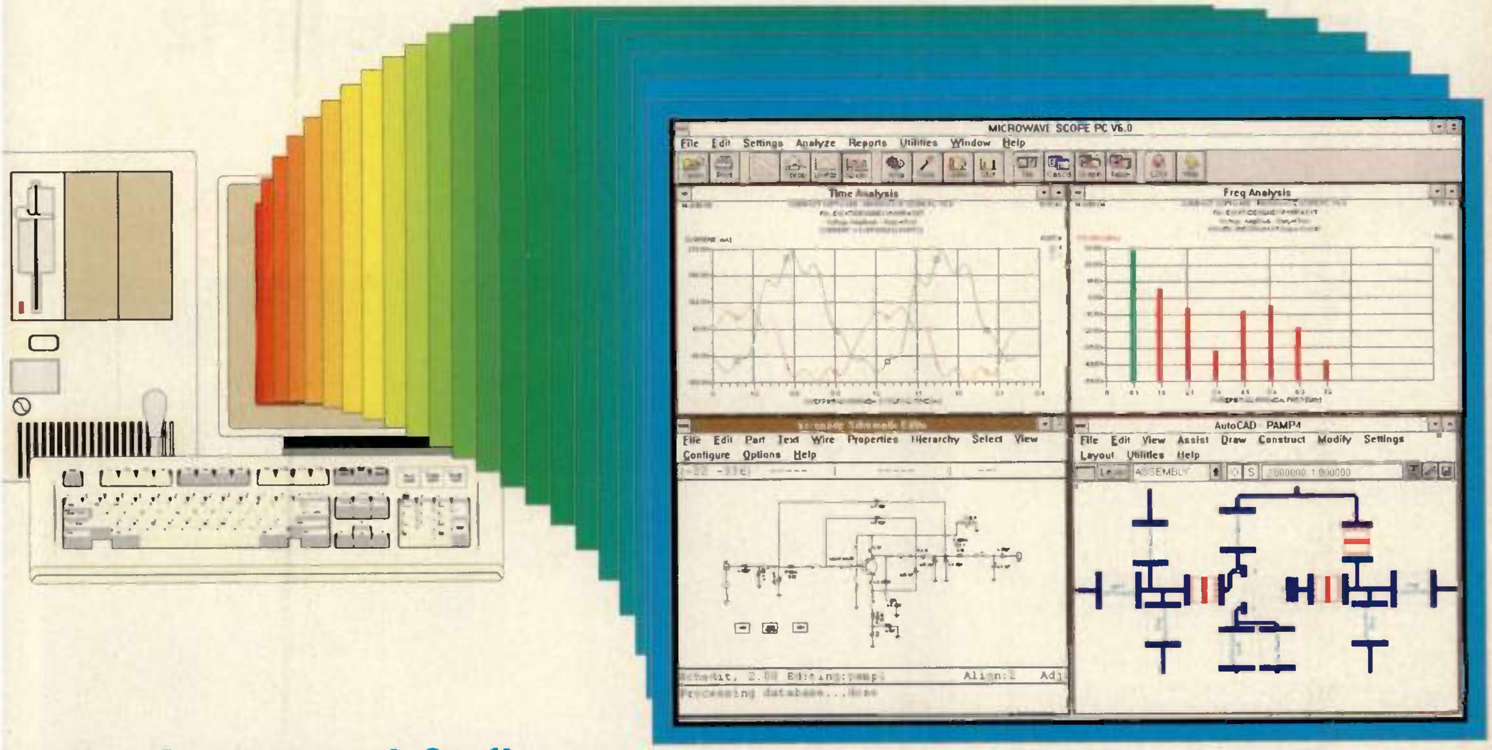
References

1. Mueller, William, "Biasing MODAMP MMICs," AN-S003, No.5091-6489E Hewlett-Packard, 1986
2. *Communications Components GaAs & Silicon Products Designers Catalog*, Hewlett-Packard, 1993, pp. 8-96 to 8-97
3. *Motorola RF Device Data*, Motorola, 1994, Rev. 5, pp. 2-374 to 2-377

About the Author

John V. Bellantoni is a Member of the Technical Staff at Watkins - Johnson Company, where he designs RF and microwave products for commercial wireless applications and also for high performance military systems. He earned a BSEE from Worchester Polytechnic Institute and MSEE and Ph.D. from Cornell University. He can be reached at Watkins-Johnson Company, 3333 Hillview Ave., Pal Alto, CA 94304-1204. His e-mail address is john.bellantoni@wj.com, and he can be found on 80 through 10 meters CW as WB1ALZ.

Unleash the power of your PC!



Only Compact Software offers a complete family of RF and microwave design tools for Windows!

Frequency-Domain Simulation - Compact Software offers a complete family of linear and nonlinear circuit simulation tools for the PC. **The Super-Compact** linear simulator offers accurate analysis and optimization of circuits from DC through millimeter-wave frequencies. The **Microwave Harmonica** nonlinear simulator builds on this foundation by adding harmonic-balance nonlinear analysis and optimization. **Microwave Scope** completes the family by adding models of optoelectronic devices including laser diodes, detectors, and fiber-optic links.

Time-Domain Simulation - Compact's **Super-Spice** simulator combines the traditional capabilities of SPICE with high frequency models for active devices and microstrip discontinuities. A unique electromagnetic field solver provides accurate modeling of inter-trace coupling effects.

Schematic Capture - Compact's **Serenade Schematic Editor** makes capturing RF and Microwave designs quick and easy. Complete symbol libraries are included for both device and layout features, allowing designers to drive the complete capture-simulate-layout process.

Physical Layout - **Serenade Layout**, based on AutoCAD, uses information from the designer's schematic to automatically generate a finished layout. Data is quickly post-processed to popular manufacturing formats.

System Simulation - The **Microwave Success** system simulator allows entire systems to be simulated and optimized.

Device Modeling - Compact's **Netcom** and **Scout** programs allow data to be acquired from popular vector network analyzers and fitted to popular device models for simulation.

Best of all, Compact's entire family of high-performance PC CAD software is available NOW!

New Releases Now Available!

Compact Software®

MICROWAVE, RF and LIGHTWAVE CAD SOLUTIONS

201 McLean Blvd. • Paterson, New Jersey 07504
TEL: (201) 881-1200 • FAX: (201) 881-8361

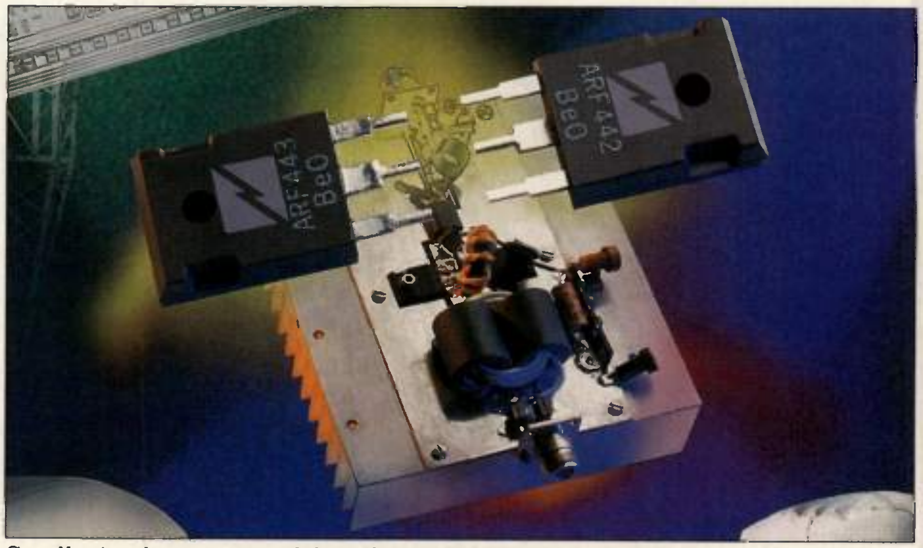
See us at RF EXPO EAST Booth# 400

INFO/CARD 29

Low Cost 1000 Watt, 300 Volt RF Power Amplifier for 13.56 MHz

By Kenneth Dierberger, Advanced Power Technology,
Bobby McDonald, UNI-WEST ENGINEERING
Lee B. Max, Consultant

This article details the design, development, assembly and performance of a low cost, high-efficiency, 1000 watt, 13.56 MHz RF power amplifier (PA) operated from a 300 VDC supply, with an efficiency of 80 percent The PA is built around a "symmetric pair" of low cost RF power MOSFETs from Advanced Power Technology (APT). The transistors are from a new generation of high quality, commercial, HF/VHF, silicon, 900 V breakdown RF power MOSFETs in TO-247 packages.



Small, simple power amplifiers for 13.56 MHz and other HF applications can be built with the APT "symmetric pair" MOSFETs, provided in low-cost standard TO-series packages. The ARF442/ARF443 units are pictured here.

Most transistorized RF power amplifiers operate from a DC to DC converter. This supply is usually low voltage, about 50 V, and requires a down regulator when operated from AC mains. This converter is a significant portion of the overall cost of the RF amplifier system.

As a result of IEC 555-2, all electronic equipment sold in Europe with a power draw of greater than 250 W will require power factor correction (PFC). The addition of a PFC preregulator to the system could add 50 to 100 percent to the cost of the power supply portion. The requirement for PFC is soon to follow in the USA and the rest of the world.

The use of new high voltage RF MOSFETs from Advanced Power Technology (APT) makes possible a new RF amplifier design which can be operated at 300 V, allowing for the direct use of a PFC regulated output, thus eliminating the DC to DC converter, reducing the cost of the RF amplifier system.

The new devices, like their predecessors, utilize the high performance of APT's Power MOS IV® technology and the "symmetric pair" package.

Amplifier Description

The amplifier is a 1000 Watt, 13.56 MHz design operating in class C with a 300 VDC power supply. Efficiency of the amplifier is 80 percent. The power amplifier is built around two "symmetric pair" of ARF444/ARF445 900 V RF power MOSFETs provided in TO-247 plastic packages. The devices are electrically identical, except that they are packaged in "mirror image" pairs to facilitate a symmetrical layout that helps maintain the electrical symmetry required for push-pull operation. Figure 1 shows the circuit diagram of the amplifier, with the parts list given in Table 1. The amplifier is a classical push-pull configuration, using a simple L-C network for impedance matching and transformer-coupling to obtain complementary gate drive signals. A wideband wire-wound transformer output circuit is used, with a conventional bifilar-wound RF choke for DC power supply isolation.

Short, low inductance interconnections are easily made using the ARF444/ARF445 devices, because they can be mounted symmetrically in a common source configuration. In particular, the gate circuit should minimize inductance to avoid instability and losses when that inductance is combined with the high capacitance of the gates. Similarly, the frequency response of the output circuitry is improved with minimum stray inductance due to interconnections [1].

The amplifier is operated directly from the PFC 300 VDC power supply, eliminating the DC-DC converter, and is constructed on a heat sink sized for proper dissipation at the expected power levels. Figure 2 shows the component placement on the PC board and heat sink. The common source design of the package allows the device mounting to be accomplished without an insulator, thus allowing good heat transfer to the heat sink with the use of thermal grease.

Input Network

The input network provides a 50 ohm impedance to the driver source and transformation of the MOSFET

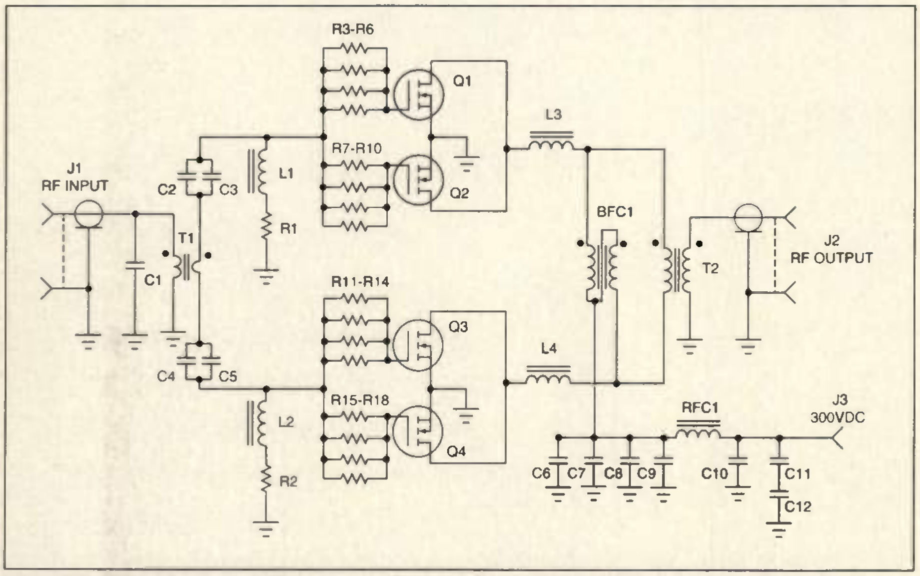


Figure 1. Schematic diagram of the 1 kW 13.56 MHz power amplifier.

Part Number	Description
R1, R2	10Ω 1W
R3-R18	4.7Ω 1W
C1	200 pF Chip Capacitors
C2-C5	0.1 µF Chip Capacitors
C6-C10	0.1 µF Disk Ceramic
C11, C12	0.01 µF Disk Ceramic
Q1, Q3	ARF444
Q2, Q4	ARF445
L1, L2	VK200-19/4B
L3, L4	0.37 µH: 6T, #18AWG, ID=0.438 in.
RFC1	2T, #14 PTFE insulated twisted pair on a Fair-Rite shield bead, #2643665702, $\mu_i = 850$
T1	9:1 conventional transformer; 3:1T, #18 stranded PTFE insulated wire on two Fair-Rite #2643540002, $\mu_i = 850$
T2	1:1 conventional transformer; 2:2 T, #14 stranded PTFE insulated wire on two stacks of three Fair-Rite shielded bead, #2643102002, $\mu_i = 850$
BFC1	6T, #18 twisted pair stranded PTFE insulated wire on three stacked Indiana General toroids, #F624-19-Q1, $\mu_i = 125$

Table 1. Parts list for the 1000 W power amplifier.

gate impedance, as well as balanced drive for push-pull operation. The input network comprises capacitor C1, plus the input capacitance of the power MOSFETs and the series gate resistors, both transformed by T1. The proper selection of C1 tunes the input network for minimum input return loss at maximum power output [2].

Transformer T1 provides a 9:1

impedance transformation of the MOSFET input impedance. It is constructed using two Fair-Rite cores #2643540002, $\mu_i = 850$, with 3 turns of stranded PTFE coated #18 wire on the primary and 1 turn of stranded PTFE coated #18 wire on the secondary. The secondary is coupled through the DC blocking capacitors C2-C3 and C4-C5 and resistors R3 through R18 to the gates of the MOSFETs. The resistor-inductor combinations R1-L1 and R2-L2 stabilize the push-pull amplifier at low frequency and provide the MOSFETs with a DC ground reference to insure the gates do not float to an unwanted DC potential, thus unbalancing the amplifier bias points. The parallel resistors R3-R6, R7-R10, R11-R14 and R15-R18 are placed in series with the gates of the MOSFET to prevent high frequency oscillation, common when paralleling MOSFETs [3].

Output Circuit

The 300 VDC power input is delivered through a balanced feed choke [4]. The choke is designed to create a zero DC magnetic bias in the core when both transistors draw the same average current. With the devices operating 180 degrees out of phase, the construction of the windings presents a high impedance at 13.56 MHz to the drain of each MOSFET. The choke is constructed by winding 6 turns of #18 stranded PTFE coated twisted pair around three stacked Indiana General toroids #F624-19-Q1, $\mu_i = 125$.

The output of the power devices is coupled to the output transformer T2 through two 0.37 µH inductors. The transformer is a wideband 1:1 conventional transformer. No output filtering was used in the test amplifier, which has the third harmonic 30 dB down and the second harmonic 55 dB below the 1000 watt output power level.

The transformer is constructed by winding 2 turns of #14 stranded PTFE coated wire for the primary and 2 turns of #14 stranded PTFE coated wire for the secondary around two stacks of three Fair-Rite #2643102002 shield beads, $\mu_i = 850$.

Performance Measurements

The test amplifier was operated under two conditions. First the amplifier was driven with a 13.56 MHz RF signal, modulated by a 1 kHz square wave, at a 50 percent duty cycle, up to a peak power out of 1200 W. Next, the amplifier was driven with a 13.56 MHz CW RF signal up to a continuous power out of 1000 W. Due to the close correlation of the modulated data and the CW data it was concluded that there is significant thermal margin when using four 300 W devices at 1000 W CW.

Figures 3 through 6 show the performance data for this amplifier. Figure 3 is a plot of P_{out} versus P_{in} and Figure 4 shows gain versus P_{out}. The curves show the classical class C characteristics, with low gain at low power output, improving as the output power increases. The gain peaks at 16.9 dB when the amplifier output is 800 W, with a roll-off to 15.9 dB at 1200 W.

Efficiency versus P_{out} is shown in Figure 5. As would be expected in

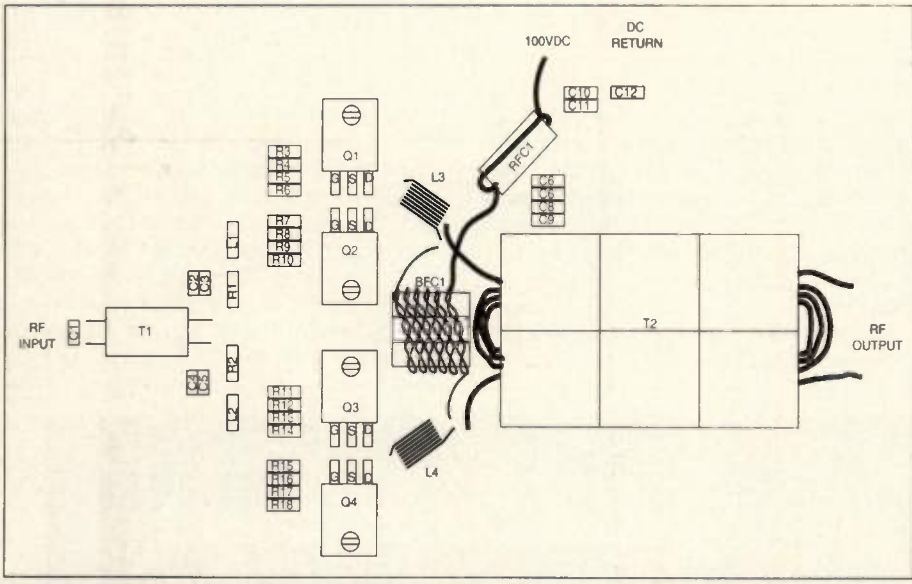


Figure 2. Layout of the amplifier, showing placement of major components and positions of input and output transformers.

class C, the efficiency is over 50 percent at power output above 300 W. The efficiency rises to an outstanding 80.4 percent at 1000 W, continuing upward to 84.4 percent at 1200 W output. Figure 6 is total amplifier power dissipation versus P_{out}.

300 Volt Power Supply

The topology chosen for the 300 volt PFC power supply is the commonly used continuous mode boost converter. This topology is the most popular where power requirements are greater than 750 W. Figure 7 is a simplified schematic of the regulator which is implemented using an APT5012JNU2 and a Unitrode U3854 controller IC [5, 6, 7].

The regulator operates by the controller sensing the rectified DC input and controlling the ON and OFF time of Q1 such that the current in L1 closely follows a sine wave which is in phase with the AC line voltage. During the OFF time of Q1 the inductor fly back transfers some of the stored energy in the inductor to the output storage capacitor. The controller senses the output voltage and adjusts the average current in the inductor such that the regulated voltage on the output capacitor is maintained at 300 V.

Conclusion

This paper has descibed a recent advance in commercial solid state RF power device and circuit technology. The high quality, low cost, components and circuits described here now make it possible to deliver solid state, 10,000 watt (or more), 13.56 MHz power supplies costing less than an equivalent

AN900
S E R I E S

REDEFINING PERFORMANCE & VALUE

THE AN900 SERIES PORTABLE SPECTRUM ANALYZERS

With frequency coverage of 9 kHz to 2.9 GHz for the AN920, 9 kHz to 22 GHz for the AN930A, and 9 kHz to 26.5 GHz for the AN940, the AN900 series of spectrum analyzers can match your RF and microwave testing requirements.

In addition to being full-featured, portable spectrum analyzers, each AN900 series model provides unique measurement features never before available on any spectrum analyzer.

A wide 30 MHz resolution bandwidth filter provides unequalled measurement capability on wideband or spread spectrum signals. When used in combination with the built-in FM/AM receiver and modulation measurement scales, direct measurement of wideband signal modulation components, including frequency agile signals, is possible.

A 25 MHz digitizing rate enables zero span measurements on pulsed RF and digital signals at sweep rates as fast as 200 ns/div. Pretrigger and posttrigger delay allow precise time interval or gated measurements.

An automatic trace limits test function performs unattended monitoring and detection of erroneous signal conditions. Captured signals can be automatically stored in memory with time and date stamp for later recall and analysis or sent directly to a plotter via the standard RS-232 or IEEE-488 interfaces.

A logical front panel control layout that avoids the use of menus or shift keys simplifies operation and enhances user productivity.

Other optional built-in features, including a 2.9 GHz tracking generator, quasi-peak detector, and 0.02 ppm time base, expand each model's possible uses.

Contact IFR for more information or to arrange for a demonstration of the AN920, AN930A or AN940.

IFRent/Lease Plan
An easy way to operate the best in test equipment.
Call 1-800-835-2352

CRAFTED WITH PRIDE IN USA

IFR SYSTEMS, INC.
10200 West York Street / Wichita, Kansas 67215-8999 U.S.A.
Phone 316/522-4981 / 1-800-835-2352 / FAX 316/522-1360

INFO/CARD 42

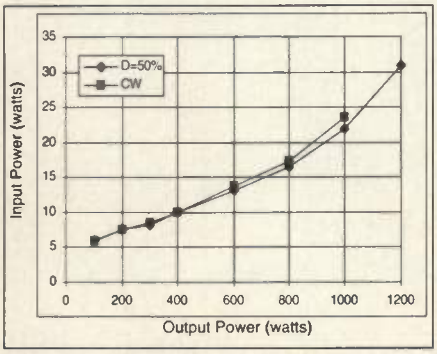


Figure 3. Input power versus output power for the test ampliifer.

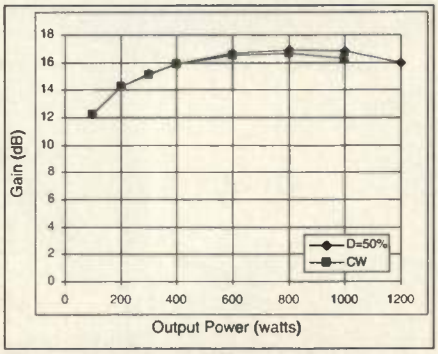


Figure 4. Amplifier gain versus output power.

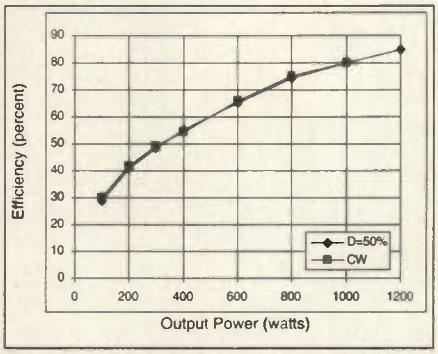


Figure 5. Efficiency versus output power.

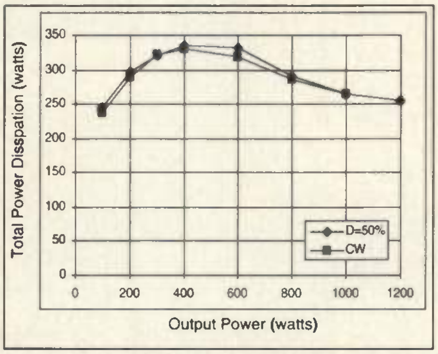


Figure 6. Total amplifier power dissipation versus power output.

tube-type RF power supply.

The combination of high voltage operation, high gain, and efficiency of 80 percent make this technology exciting just for performance alone. Combine that performance with component costs that allow for multi-kilowatt, 13.56 MHz amplifiers to be built at less than $0.25 per watt and you now have the first real breakthrough in commercial HF, RF power technology in over a decade.

This is only the beginning. The commercial technology detailed in this paper will be evolving quickly into solid state devices and circuits for higher frequency, higher power, and even higher operating voltages.

To obtain more information on these MOSFETs, contact the author at (503) 382-8028, or circle Info/Card #251. ***RF***

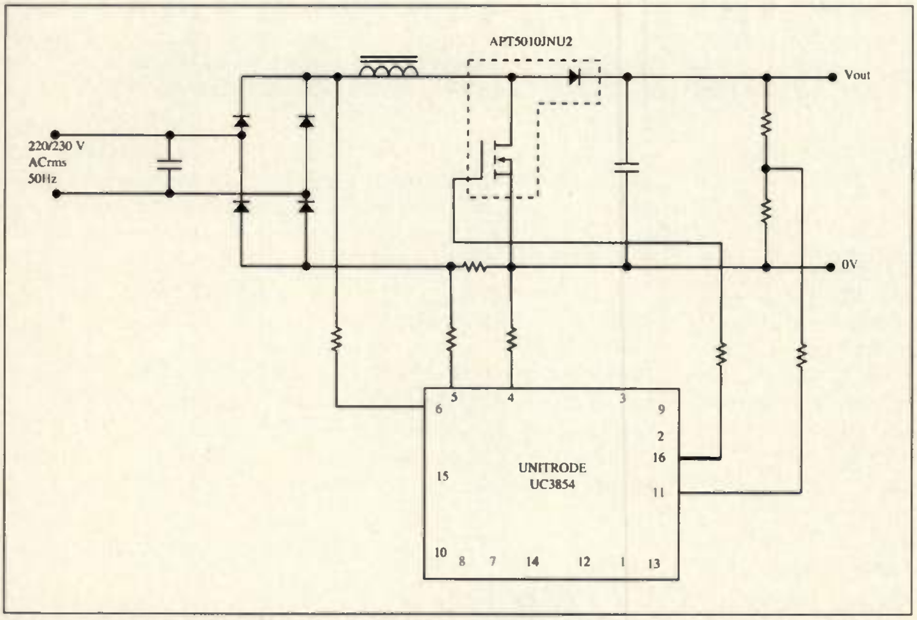


Figure 7. Simplified circuit diagram of the power factor correction power supply.

References

1. H.O. Granberg, "Good RF Construction Practices and Techniques," Motorola Application Note AR164, *Motorola RF Device Data*, Volume II, DL110 rev 4.
2. H.O. Granberg, "Broad band Transformers and Power Combining Techniques for RF," Motorola Application Note AN749, *Motorola RF Device Data*, Volume II, DL110 rev 4.
3. Rudy Severns, et al, "Parallel Operation of Power MOSFETs" "Anomalous Oscillation and Turn-Off Behavior in a Vertical Power MOSFET," *MOSPOWER Applications Handbook*, Siliconix Inc., 1984.
4. William E. Sabin, Edgar O. Schoenike, et al, *Single Sideband Systems and Circuits*, McGraw-Hill 1987.
5. Phill Todd, "UC3854 Controlled Power Factor Correction Circuit Design," Unitrode Application Note U-134, *Product and Applications Handbook* 1993-94.
6. Ken Dierberger, Denis Grafham, "Design of a 3000 Watt Single MOSFET Power Factor Correction Circuit," APT Application Note APT9303.
7. Ken Dierberger, Denis Grafham, "Customized ISOTOP® Module for High Power Boost Converters and Related Topologies," APT Application Note APT9401.

About the Authors

Kenneth Dierberger is Applications Engineering Manager for Advanced Power Technology Inc., 405 SW Columbia St., Bend, Oregon 97702. He can be reached by telephone at (503) 382-8028.

Bobby McDonald is an engineering consultant with UNI-WEST ENGINEERING, 6329 Bethel Island Rd., Bethel Island, CA 94511.

Lee B. Max is an independent consultant, located at 6284 Squiredell Dr., San Jose, California 95129.

The biggest news in RFIC amplifiers comes in the smallest package.

Erase your design problems with the industry's smallest 3V and 5V Si and GaAs RFIC amplifiers.

When it comes to cost effective RFIC amplifiers for your wireless applications, we've got your size.

Our ultra-miniature SOT-363 (SC-70) package requires half the board space of the next smallest package on the market–and only 15% of the space of an SO-8 package. Making it ideal for compact, handheld designs.

Extend battery life with these low-current 3V and 5V gain blocks for applications to 6 GHz. All backed by HP's reputation for quality and our track record of shipping millions of building block RFICs per month.

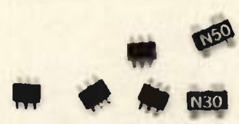
And Penstock has 20 offices nationwide staffed with engineers to help you design-in these products with free samples.

Call HP at 1-800-537-7715, ext. 9007 for a Selection Guide and Data Sheets.
For immediate *free samples*, call 1-800-PENSTOCK.
In Northern California, (408) 730-0300
In Canada, (613) 592-6088

PENSTOCK
RF/MICROWAVE DISTRIBUTION
AN AVNET COMPANY

Typical Performance

Part Number	Frequency Range	Voltage (V)	Current (mA)	NF (dB)	Gain (dB)	IP3 (dBm)	Package (IEC)
INA-30311	DC-1000	3	6.3	3.5	13	- 2	SOT-143
INA-50311	DC-1000	5	17	3.6	19	+10	SOT-143
INA-51063	DC-2400	5	12	3.0	20.5	+ 6	SOT-363
INA-52063	DC-1600	5	30	3.5	20	+17	SOT-363
MGA-86563	500-6000	5	15	1.6	20	+15	SOT-363
MGA-87563	500-4000	3	4.5	1.6	14	+ 8	SOT-363



HEWLETT PACKARD

HP Europe, fax 31-2503-52977
HP Canada, call 1-800-387-3154 ext 9007

CGCM9501

Signal Simulator

Microdyne Corporation's Aerospace Telemetry Division has unveiled its new general purpose signal simulator, TSS-2000, for use in test and measurement research. The unit offers both internal and external modulation capabilities, acting as a signal simulator, signal generator and sweep generator. It provides +20 dBm maximum output power, multiple modulation formats, narrow and wide range deviation, and data rates up to 20 MHz. Sweeping capabilities are from 10 to 600 MHz (optional frequency range) and continuously in 200 MHz segments in the 1400 MHz to 2500 MHz range. Doppler simulation can reach up to 100 kHz with triangular or sawtooth patterns. Modulation formats include: AM, FM, PM, PCM/FM, PCM/PM, PCM/BPSK, TV/FM (ext.). External I and Q modulation inputs are also included. When simulating a PCM data stream, the pseudo-random data is 1023 or 2047 bits, NRZ-L or Bi-Phase L and is fully compatible with major BER test sets. The TSS-2000 is phase locked to an internal reference in order to achieve the necessary frequency stability and low phase noise. An external 5 or 10 MHz reference signal can be applied to the unit to obtain even higher stability. Remote control is via IEEE-488, RS-232C, or RS-422 interface ports on the rear panel.

Microdyne Corp.
INFO/CARD #250

Transmitter/ Receiver Pair

RF Monolithics has introduced two new members of its Virtual Wire™ product family. The HX2000 transmitter and companion RX2010 receiver operate at 916.5 MHz, within the 902 to 928 MHz ISM band. The HX2000 is a miniature, surface mountable, transmitter module with self-contained RF functions that shorten development time. The transmitter

employs on-off keyed modulation and is designed to be driven from a 3V CMOS logic signal. The carrier signal is quartz SAW stabilized, and a SAW filter is used to suppress output harmonics. The RX2010 receiver incorporates RFM's amplifier-sequenced hybrid (ASH) receiver architecture. The receiver supports a 10 kb/s baseband data rate and has low external parts count. North American unit pricing in 1,000-piece quantities is $8.02 for the HX2000 transmitter and $20.84 for the RX2010 receiver.

RF Monolithics, Inc.
INFO/CARD #249

622 MHz VCXO

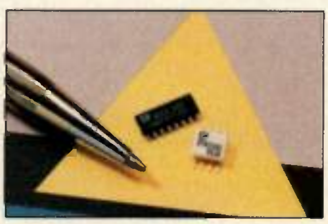
Raltron Electronics announces a high speed voltage controlled crystal oscillator (VCXO) for use in 622 MHz

phase locked loops for SONET and SDH data concentrators and other high frequency, wide bandwidth PLL applications. Model VH-7126 VCXOs are available in both traditional negative-going ECL outputs and also new positive-going PECL outputs. The standard center frequency is 622.08 MHz, but other frequencies in the 250 to 750 MHz range are also available. Basic frequency stability is specified at ±15 ppm maximum over the temperature range of 0 to +70 °C. Input control voltage range of 0.5 to 4.5 V yields a standard frequency control range of ±70 ppm. Output jitter is held to 50 psec pp. Pricing for the VH-7126 is less than $80 in OEM quantities.

Raltron Electronics Corp.
INFO/CARD #248

Amplifier Chip Set

Celeritek's CCS1933 is a two-chip set designed to provide a compact, 2W, RF power amplifier for North American PCS base stations, Japanese PHS base stations, and many industrial applications in the 1.85 to 2 GHz band. The chip set operates from a 5 V power supply and consists of Celeritek's CMM1301 integrated driver amplifier and CFK2162 matched power stage. The CCS1933 delivers at least 35 dB of gain, +33 dBm minimum output power, and achievable efficiency of greater than 45 percent. Because of its high linearity, the chip set fully complies with stringent Bellcore requirements for PI/4 DQPSK modulation of minimal spectral



regrowth in adjacent channels. Production quantities of 500 are available in 30-45 days ARO and are priced at $40.50 per chip set.

Celeritek
INFO/CARD #247

High Dynamic Range Mixer

Watkins-Johnson's HDM11 high dynamic range FET mixer is intended for cellular applica-

tions. The surface-mount mixer operates with an LO range of 800 to 1000 MHz, RF range of 800 to 1000 MHz, and IF range of 10 to 100 MHz. Typical 3IIP is +37 dBm and nominal LO drive is +17 dBm. Typical minimum port-to-port isolation is 25 dB and 50 dB for LO-RF and LO-IF isolation, respectively. Typical maximum SSB conversion loss is 7.0 dB for an IF at 10 MHz and 7.5 dB for an IF at 100 MHz. Typical 1 dB compression occurs at +23 dBm. At 5 VDC, the FET mixer typically consumes 25 mA.

Watkins-Johnson Co.
INFO/CARD #246

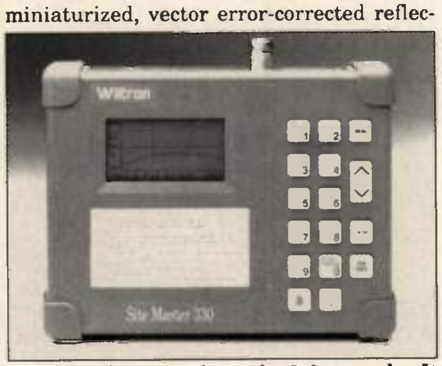
TEST EQUIPMENT

VNA Software

A new radio-measurements personality from Hewlett-Packard simplifies the user interface for HP 894000 series vector signal analyzers. The personality sets up the analyzer to automatically measure adjacent channel power, occupied bandwidth, modulation accuracy, frequency tolerance and 10-burst average error-vector magnitude on burst or continuous signals. The HP 89451A is available for $510.
Hewlett-Packard Co.
INFO/CARD #245

Antenna System Tester

The Wiltron company announces the Site Master VSWR/return loss and fault location tester. Site Master is a hand-held, miniaturized, vector error-corrected reflec-



tometer that weighs only 2.2 pounds. It incorporates a synthesized source, directional bridge and "smart" synchronous measurement technology that is immune to interference. The Site Master has a starting price of $3,950.
Wiltron Co.
INFO/CARD #244

Capacitance Meter

Boonton Electronics' family of capacitance meters features the ability to resolve and display minor component losses in the presence of a large reactive component in capacitors, inductors, and resistors at 1 MHz. All the meters make true three-terminal measurements that shunt stray capacitance and yield true end-to-end capacitance of the device under test. Model 7200 is microprocessor controlled and has programmable test levels, internal and external bias. Price for the Model 7200 is $5,475.
Boonton Electronics Corp.
INFO/CARD #243

Spectrum Analyzer

The PA2500 spectrum analyzer from DKD Instruments turns your PC into a full featured spectrum analyzer. Consuming less than 10 W, it covers the 100 kHz to 2.4 GHz range. Spurious free dynamic range is 80 dB, and with the optional internal programmable 50 dB step attenuator, it can accurately measure signals from –135 to +20 dBm. Internal gain compensation and power calibration give power accuracy to ±2 dB. The software supports marker functions, trace math, overlays, autologging and hard copies to a printer. Price is $6995.99.
DKD Instruments
INFO/CARD #242

Arbitrary Waveforms

Wavetek's model 296 is a 50 MHz multichannel arbitrary waveform generator with advanced waveform sequencing capability. Model 296 contains up to four independent 50 MHz channels and can link up to 4,096 waveform segments. Output signals can have 15 Vpp amplitude (80 Vpp with optional high voltage module) and 2 ppm frequency accuracy. Operation is via a mouse-controlled graphical user interface. U.S. list price is $7,245.
Wavetek Corp.
INFO/CARD #241

Antenna Tester

Bird Electronics announces the AT-800, a hand-held antenna tester for cellular and other 800-960 MHz services. The AT-800 uses a built-in RF source to measure VSWR, match efficiency, and return loss at single frequencies, or automatically sweeps over a user-specified frequency range. The display shows numeric measurements and high resolution graphic plots .
Bird Electronic Corp.
INFO/CARD #240

SEMICONDUCTORS

Receiver Amplifier

The MPS-0924A9-88 is a low noise high dynamic range amplifier module designed for ultra-linear applications. Paired amplifier stages in a surface mount package are externally hybrid combined to produce a balanced amplifier which has 1.5 dB noise figure and +38 dBm IP3 while consuming 1.2 W from a single positive voltage supply. Gain is 18 dB with ±0.5 dB flatness over the operating bandwidth.
Microwave Technology
INFO/CARD #239

Spread Spectrum IC

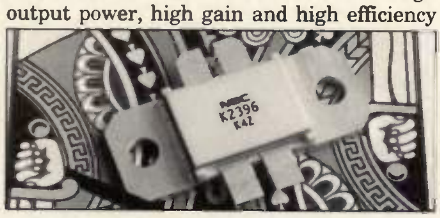
The S20043 direct-sequence spread-spectrum transceiver IC is highly programmable, providing users with thousands of possible programmable pseudo noise code words in lengths up to 2047 and data rates from 100 bps to 4 Mbps. The receiver and transmitter are completely independent, allowing either full-duplex or half-duplex operations. Samples are priced at $85 each and are delivered in a 68-pin PLCC. Pricing for quantities of 10,000 or more is projected at $23.50 each.
American Microsystems, Inc.
INFO/CARD #238

RF Power MOSFET

Motorola's MRF182 and MRF183 RF power transistors offer a bottom side source that eliminates DC isolators and reduces common mode inductances. At 1 GHz, the MRF182 delivers 30 W P_{out}, 13 dB gain, and 55 percent efficiency; the MRF183 delivers 45 W P_{out}, 12 dB gain, and 55 percent efficiency. Price in low volumes is $93.00 for the MRF182 and $108.50 for the MRF183.
Motorola Semiconductor
INFO/CARD #237

Linear, 100 W MOSFET

California Eastern Labs introduces a 100 W power MOSFET for Band IV and V TV linear transmitters. Designed for broadcast transmitters in the 470 to 860 MHz band, NEC's new 30 V, class AB push-pull NEM0899F01-30 Si MOSFET delivers high output power, high gain and high efficiency



under a variety of drive conditions. At 860 MHz, V_{DD} = 30 V, and I_{dg} = 300 mA, the MOSFET typically produces 100 W with 12 dB gain and 50 percent drain efficiency.
California Eastern Laboratories
INFO/CARD #236

Micro Diodes

M-pulse Microwave's family of Micro SMT™ diodes includes PINs, Schottkys, and mixer-ring-quad families. The diodes are packaged using Micro SMT technology, which allows devices to be packaged while still in wafer form. The devices have a package inductance in the range of 0.1 to 0.2 nH and a package capacitance in the range of 0.02 to 0.03 pF. Micro SMT is a trademark of ChipScale, Inc.
M-pulse Microwave
INFO/CARD #235

PHEMTs

Stanford Microdevices has announced a line of pseudomorphic high electron mobility transistors (PHEMTs) which achieve up to 50 percent power added efficiency from 500 MHz to 26 GHz. At 2 GHz these FETs have 16 dB of gain with 0.25 noise figure. The SPF-2298 has typical output power of +24 dBm at 1 dB compression when biased at +5 V and 100 mA. Typical IP3 is +33 dBm.
Stanford Microdevices
INFO/CARD #234

SUBSYSTEMS

Upconverter

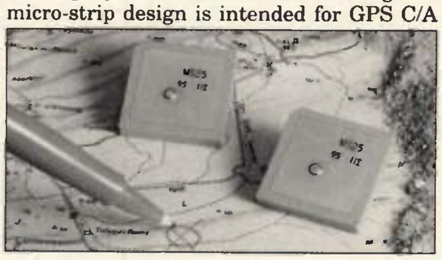
Mu-Del model MUCM-10 is a multi-module, independently removable five channel upconverter unit. The modules are fully enclosed and isolated from each other. Input frequency of the main chassis is 10 MHz ±3, output frequency is 1435.5 to 1535.5 MHz, tunable in 1 MHz step size at the front panel of each module. Image rejection is at least 60 dB below output and spurious response is –60 dB.
Mu-Del Electronics, Inc.
INFO/CARD #233

Telephone Interface Unit

Stanford Telecom announces the release of the STel model 2700 telephone interface unit (TIU), providing the interface between the single channel per carrier VSAT equipment and external telephone equipment. The voice compression algorithm used is compatible with the present ITU G. 728 standard 16 kbps and the future G .279 for 8 kbps. The TIU can switch between 19.2 and 9.6 kbps and can operate at multiple data rates.
Stanford Telecommunications, Inc.
INFO/CARD #232

GPS Patch Antenna

Toko America has introduced the DAK series of miniature dielectric ceramic antenna elements for use in Global Positioning Systems (GPS). The rectangular micro-strip design is intended for GPS C/A



right-hand circular polarization wave reception. Its 25 mm^2 surface and 4mm height makes this product approximately one quarter the size of a traditional antenna element without sacrificing sensitivity.
Toko America, Inc.
INFO/CARD #231

HF Receiver/Translator

Interad Ltd. introduces model 9450, an eight-channel, wideband HF receiver with input frequency range from 0.5 to 32 MHz and output range from 1.0 to 11 MHz. The unit has eight channels – one independent and seven others sharing a common LO. Receiver bandwidth is 10 MHz and nominal gain is 53 dB. Synthesizer tuning speed is better than 1 ms and synthesizer step size is 500 kHz. Minimum output IP3 is +44 dBm.
Interad Ltd.
INFO/CARD #230

Airborne Transmitter

Aydin Vector's T-300 S/L series subminiature airborne UHF, video/telemetry transmitters are available in 2, 5 and 10 W power output. The transmitters measure 1.50 × 2.50 × 0.75 inches and weigh less than 4 oz. The transmitter complies with IRIG-106-93 and MIL-STD-461 EMI requirements.
Aydin Vector Division
INFO/CARD #229

SIGNAL SOURCES

Phase Locked Source

Communication Techniques has introduced a low cost, low phase noise, high performance, phase locked coaxial resonator oscillator available from 750 MHz to 3000 MHz. Typical phase noise for an 860 MHz unit is –108 dBc at 1 kHz offset, –115 dBc at 10 kHz offset, and –130 dBc at 100 kHz offset. Spurious levels are typically –100 dBc. Output power is normally +13 dBm.
Communication Techniques, Inc.
INFO/CARD #228

Ultra-Stable OCXO

MTI - Milliren Technologies, Inc. introduces their next generation of ultra high stability / high reliability oven-controlled crystal oscillators. The 260-0536 (10 MHz) utilizes an SC-cut resonator to offer thermal stability of $\pm 1.0 \times 10^{-9}$ from –30 to +70 °C. Aging is specified at 3.0×10^{-10} per day (5.0×10^{-8} per year). Phase noise is –125 dBc/Hz at 10 Hz offset, with a noise floor of –160 dBc/Hz. The device measures 2.0 × 2.0 × 1.5 inches and is priced at $480.00 each in quantities less than 100.
MTI - Milliren Technologies, Inc.
INFO/CARD #227

Miniature OCVCXO

Oak Frequency Control Group's 4598S OCVCXO, available from 10 to 25 MHz, features a package outline of 38.0 × 26.5 × 15.0 mm. The 4598S meets a temperature stability spec of $\pm 5 \times 10^{-9}$ over 0 to 70 °C and features aging of ±0.1 ppm per year. The OCVCXO operates from a +5 V supply. Typical pricing with standard options is $165 each in 1000-piece quantities.
Oak Frequency Control Group
INFO/CARD #226

Miniature OCXO

Reeves-Hoffman has introduced the Model 105 miniature OCXO. Housed in a standard 1.5 × 1.5 × 0.53 inch TCXO package, the Model 105 offers high stability for small size, rack mounted or portable applications. The 105 is able to drive TTL and CMOS loads for more design flexibility. A variety of temperature and stability options are available.
Reeves-Hoffman
INFO/CARD #225

Low Phase Noise Oscillator

Model 2930201 from Piezo Crystal utilizes Piezo's SC-cut crystals. The frequency range is from 5 to 12 MHz. Typical phase noise at 10 MHz is –110 dBc/Hz at 10 Hz offset. The aging rate at shipment is 5×10^{-10}/day. Fre-

quency stability is $\pm 1 \times 10^{-8}$ from –20 to +60 °C. Size is 2.00 × 2.00 × 0.75 inches, and price is $190 each in quantities of 500.
Piezo Crystal Co.
INFO/CARD #224

TCXOs

Vectron Laboratories' series of PC board mount, temperature compensated crystal oscillators are available in frequencies from 500 kHz to 75 MHz. Models CO-511 and CO-557 provide aging rates of less than 1×10^{-6}/year and temperature stabilities ranging from $\pm 5 \times 10^{-7}$ from 0 to 50 °C and $\pm 2 \times 10^{-6}$ from –55 to +85 °C. The CO-557 series measures 1.4 × 1.06 × 0.50 inches, and the CO-511 series measures 1 × 1 × 0.50 inches, with an alternate European CO-15 package.
Vectron Laboratories, Inc.
INFO/CARD #223

OCXO

Frequency Electronics' model FE-101 is a rugged, compact, ultra-stable subminiature crystal oscillator with temperature stability of 1×10^{-8} from –55 to +85 °C. The OCXO warms up to stabilized frequency in less than two minutes and has g sensitivity of 3×10^{-10}/g. Steady state power consumption is 1.75 W at 25 °C. Model FE-101A measures 1.27 × 1.33 × 1.33 inches.
Frequency Electronics, Inc.
INFO/CARD #222

DISCRETE COMPONENTS

SMT Porcelain Capacitors

North American Capacitor Company's MPR Series of micro-porcelain multilayer capacitors operate at microwave frequencies up to 30 GHz. Proprietary porcelain materials enable typical minimum Q factors of 10,000 at 1 MHz and 25 °C. The MPR Series capacitors are available with capacitances ranging from 0.2 pF to 0.1 µF and are available in chip and pellet configurations; each in both 1.4 × 1.4 × 1.45 mm and 2.79 × 2.79 × 2.59 mm case sizes.
North American Capacitor Co.
INFO/CARD #221

Expanded Trimmer Lines

Voltronics has added higher capacitance values to its J lines of ceramic chip trim-

mers. The JZ line now has a 40 pF part, the JZ400, in addition to its 3.0 through 30 pF

max. ranges, and the smaller JR line now has 30 and 40 pF parts in addition to its 3.0 through 20 pF max. ranges. Prices are well under $1.00 each.
Voltronics International Corp.
INFO/CARD #220

SIGNAL PROCESSING COMPONENTS

Attenuator

Mini-Circuits has introduced a low cost, surface mount fixed attenuator with a very wide DC to 7 GHz bandwidth. The PAT-1 is a miniature 0.21 × 0.21 × 0.053 inch, 50 ohm unit housed in a ceramic package and exhibits excellent input/output matching throughout the entire frequency range with a maximum VSWR at 1.3:1 at midband. The device offers a 1 W rating at 25 °C case temperature. This attenuator is priced at $2.95 each in quantities of 10 to 49.
Mini-Circuits
INFO/CARD #219

High Isolation Mixer

MITEQ's DM0052HA2 and DM0052LA mixers are constructed using a new microwave balun (patent pending) operating from 0.5 to 2.0 GHz with an IF response from DC to 500 MHz. This design produces unusually high port-to-port isolation and the "h" version performs as an up- or down converter covering most PCN and communication applications requiring high input signal levels. Both designs can also be used as biphase modulators or phase detectors with low DC offset voltages.
MITEQ
INFO/CARD #218

Delay Lines

MICRO-COAX has introduced a family of compact custom delay lines. Standard delay times range from 1 to 200 ns with insertion loss ranging from 1.2 to 5.9 dB at 900 MHz. Dimensions of standard models range from 0.75 inch high × 1 inch diameter to 2.25 inch high × 2.75 inch diameter. Each delay line is engineered to the specific requirements of a customer's application.
MICRO-COAX
INFO/CARD #217

1 GHz+ SAW Filter

Three patents are pending on an RF SAW filter designed by Murata Electronics. Murata's SAW filter is based on zinc oxide printed on a sapphire substrate and delivers high performance, even above 1 GHz. This new design provides a larger electromechanical coupling coefficient, higher propagation velocity and smaller wave propagation losses. Other design enhancements include a 50 ohm termination so that no external adjustment circuit is required. Pricing is approximately $3 to $4 each, depending on volume.
Murata Electronics North America
INFO/CARD #216

Lowpass Filters

RLC Electronics introduces its new line of lowpass filters with spurious-free operation up to 40 GHz. These units are designed

using a low-ripple Chebychev approach and offer excellent VSWR and rejection parameters, while maintaining an extremely small size. Prices start at $150.00 in unit qty.
RLC Electronics, Inc.
INFO/CARD #215

IF SAW Filters

The SWS Series SAW filters from Toko America are multimode resonator filters that feature narrow bandwidths of 30 kHz and insertion losses less than 5 dB. The use of temperature stable ST-quartz material allows for a broad operating temperature range of –30 to +80 °C. The series is available in six standard center frequencies: 83.16, 85.05, 86.85, 86.01, 90.0 and 130.0 MHz. Pricing in 100 piece quantities ranges from $15 to $20.
Toko America, Inc.
INFO/CARD #214

CABLES & CONNECTORS

Push-On Assemblies

Precision miniature semi-rigid and flexible cable assemblies featuring GPO™ connectors 1/5th the size and weight of comparable SMA connectors are offered by Storm Products. The GPO connectors offer a snap together system that provides excellent vibration performance. Connector and cable options are available for flight and space applications. Semi rigid cable diameters from 0.034 to 0.085 inches are available, and a 0.070 inch flexible cable is available.
Storm Products Co.
INFO/CARD #213

Field Replaceable SMA

COAXICOM has introduced a complete line of panel mounted (flange) field replaceable SMA connectors. The variety includes male and female versions, with square flanges ranging from 0.375 inches to 0.500 inches, and rectangular flanges from 0.375 × 0.500 to 0.223 × 0.625 inches. Right angle types are part of COAXICOM's standard line, with 45° flanges available.
Coaxial Components Corp.
INFO/CARD #212

Connectors

Times Microwave announces the availability of three connectors designed for LMR® series cables. N-male connectors, in crimp (TC-400-NM) and clamp (TC-400-NMC) designs and a TNC-male crimp (TC-400-TM) connector provide VSWR of less than 1.2:1 up to 1 GHz. They are priced at $8.00 each.
Times Microwave Systems
INFO/CARD #211

AMPLIFIERS

Amplifiers w/Power Supply

The amplifiers in the MSI-PS series feature an internal AC/DC power supply which will accept 105-125 VAC, 47 to 420 Hz supplied directly from your electrical outlet. They are available in common bands ranging from 100 MHz to 18 GHz. These amplifiers can be specified with RF output powers up to –33 dBm and with gain ranging from 20 to 50 dB.
Microwave Solutions, Inc.
INFO/CARD #210

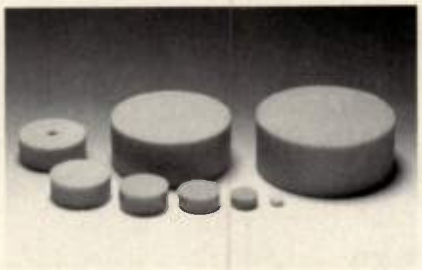
Thermally Compensated

The MRFA2604 offers thermal compensation which can be partially disconnected, and it operates in the frequency range of 470

to 860 MHz. The device is specified at 28 V with a minimum output power of 175 W and 8 dB small signal gain (minimum) at nominal power. U.S. pricing for the MRFA2604 RF amplifier is $1,430.13 in low volumes.
Motorola Semiconductor
INFO/CARD #209

100 W Amplifier

ENI's Model 2100L RF power amplifier produces 100 W of linear class A output over a frequency range of 10 kHz to 12 MHz. With a gain of 50 dB, the 2100L features front panel metering, low harmonic and intermodulation distortion, and complete protection against short and open loads. The amplifier is also unconditionally stable and has integral power supply and forced-air cooling.
ENI
INFO/CARD #208



Dielectric Resonators-400 MHz to 32 GHz

A variety of materials and characteristics allow Trans-Tech to satisfy a particular design need. Extremely

Standard materials	Nominal Dielectric Constant	Temperature Coefficient Range	Minimum Q	Recommended Frequencies (GHz)
8500	36.0	−3 to +6 ppm/°C	10,000 @ 4.5 GHz	1.4 to 13.5
8600	80.0	−6 to +9 ppm/°C	3,000 @ 3.0 GHz	0.7 to 3.5
8700	29.1	−4 to +4 ppm/°C	10,000 @ 10.0 GHz	5.6 to 32.1
8800	37.5	0 to +4 ppm/°C	6,000 @ 4.5 GHz	0.8 to 5.2
8300	36.0	0 ppm/°C	27,000 @ 850 GHz	0.8 to 1.0

High Q D8300 material has been developed especially for narrowband Cellular Base Station filtering. In DRO's for digital DBS lower phase noise can be achieved by using High Q dielectric resonators. Materials are available with high E' for smaller size and in a wide range of temperature coefficients to compensate for temperature drift.

INFO/CARD 98

Cost Effective VCO Solutions

For those engineers considering in-house VCO designs, Trans-Tech offers cost effective coaxial resonators. Miniature (3mm) and Sub-miniature (2mm) Coaxial Line Elements are excellent where circuit miniaturization is of utmost importance, such as in cellular telephones, PCS, and other wireless applications. They cover the UHF frequency range.

Performance benefits include: higher circuit Q and greater temperature stability, together with reduced microphonics, fewer environmental effects on frequency, and excellent solderability. Two materials are available to provide the designer with high unloaded Q and small size. Application Notes are available on request.

INFO/CARD 99

Application Notes Available:

Coaxial Resonators for VCO Applications

This 8-page application note outlines the use of coaxial resonators in VCO circuits.

CIRCLE 535

Dielectric Resonator Positioning for Low Phase Noise

Presents a circuit trick to quickly find the optimum DR position in a DRO circuit.

INFO/CARD 97

CARD (Computer Aided Resonator Design) and COAX (Coaxial Element Design Guide) are Windows™-based software design tools that assist in the selection of dielectric and coaxial resonators for oscillators and filters from UHF to Ku band frequencies.

- Complete (Coaxial/Dielectric) Resonator Selection – From Initial Concept Specification to Recommended Part Number
- Facilitates Sensitivity Analysis
- Equivalent Circuits for Computer-Aided Circuit Simulation
- Graphic Presentation of Frequency Response
- Relates Component Geometry to Predicted Performance

Free Software

For further information or a copy of CARD/COAX Software, circle reader no., call, or FAX.

Winner of the 1993 American Ceramic Society's Corporate Technical Achievement Award

Trans-Tech

Ceramic Solutions for a Wireless World

Tel: (301)695-9400 • FAX: (301)695-7065

Trans-Tech, Inc. is a Subsidiary of Alpha Industries Alpha

INFO/CARD 47

See us at RF EXPO EAST Booth# 512

Test Setups for Measuring Intermodulation Distortion

By Gary A. Breed
Editor

One of the fundamental performance measurements for RF circuits is intermodulation distortion (IMD). This test procedure and its results define the linearity of amplifiers and the performance of receiving systems in the presence of multiple signals. This article presents the typical test configurations for IMD testing, with some additional notes on test procedures and interpretation of results.

Intermodulation distortion, as its name implies, is the presence of unwanted signals that have been created by mixing action (modulation) among signals in circuits that are not ideally linear. The term mixing is exactly that same as is used for frequency conversion, since IMD products are defined in that manner:

$IMD_x = n f_1 \pm m f_2$

that is, a specific IMD product is the mixing product of a fundamental or harmonic of one one signal and a fundamental or harmonic of another signal. The expression is not resricted to two signals; it can be expanded to any number of individual signals which can create IMD.

From the above equation, it follows that IMD measurements require at least two signal sources, f_1 and f_2, along with some kind of detector that can observe the frequencies where the various IMD products are expected to appear. To determine where those frequencies will be, we need to know the expected range of n and m.

The order of the IMD product is defined as n + m. Therefore, a second-order IMD product can be either the sum or the difference of two frequencies. Third-order products are twice one frequency, plus and minus the other frequency, giving four possible IMD products. Without working out all the math, odd-order IMD products occur at intervals equal to the difference in frequency between f_1 and f_2. If those two frequencies are close together, the odd-order IMD products will be very close to the two fundamental frequencies, distributed in a distinctive pattern (Figure 1).

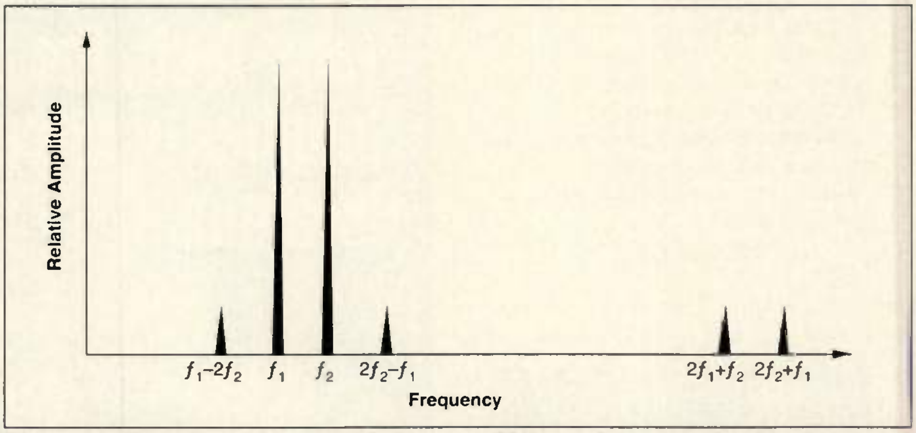


Figure 1. Relationships of third-order IMD products to the fundamental frequencies that caused them.

The most common types of IMD testing use this characteristic to advantage. First, the IMD products appear in the same receiver or transmitter tuning range as the fundamentals. This mimics the real world; in a receiver, two strong signals just outside a the IF filter passband may cause IMD that is detectable within the passband. In a transmitter, IMD generated within the transmitter, or involving other nearby transmitters, may create distortion products that are so close to the desired signal that they can not be filtered out, corrupting the transmitted signal.

IMD products that fall far away from the frequency of operation are of

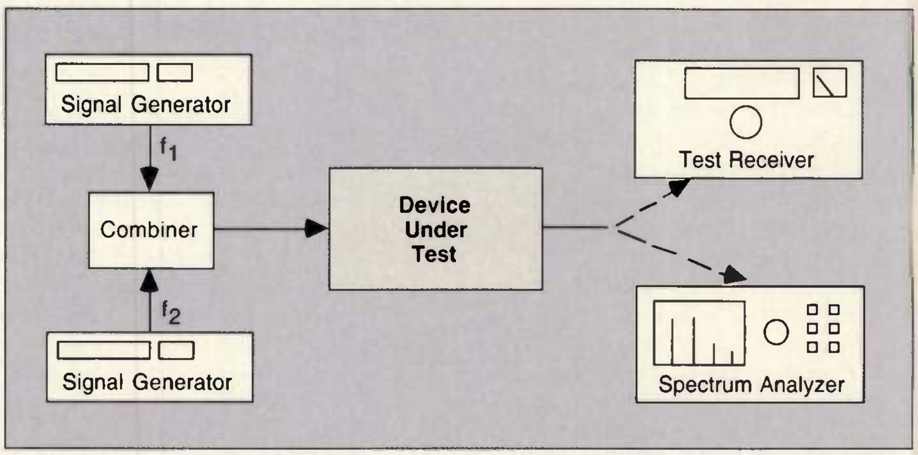
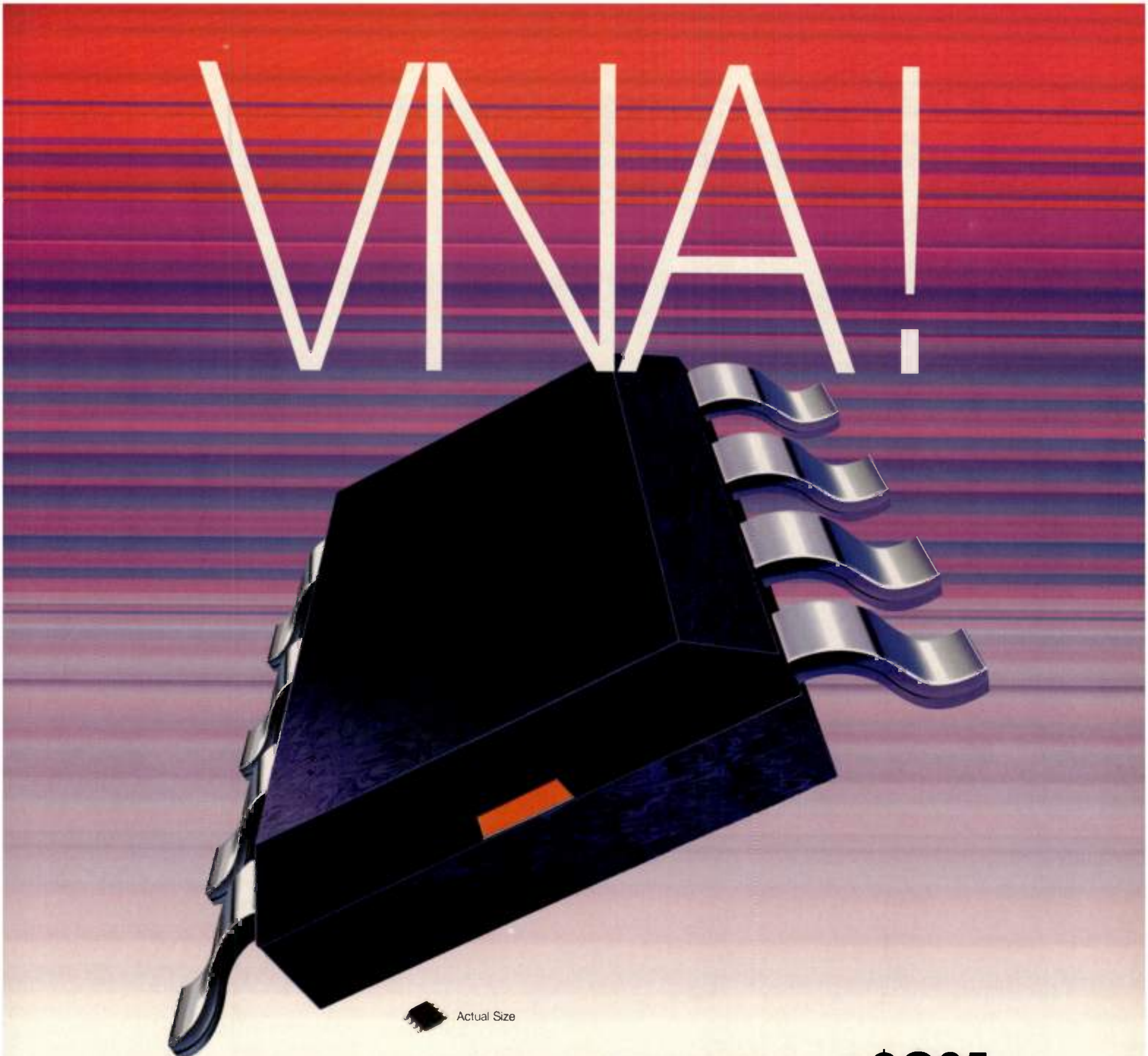
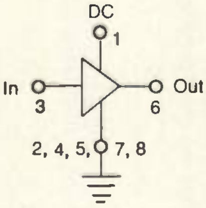


Figure 2. Basic test setup for testing a two-port device, typically an amplifier, filter, or perhaps a frequency conversion subsystem.



VNA Amplifiers +17.5dBm, 0.5 to 2.5GHz only $2.95 (1000 qty.)

Very New Amplifiers...at a very affordable price, from Mini-Circuits! Yes, VNA-25 RF amplifiers are very small, yet incredibly powerful (+17.5dBm typ. output at 1dB compression). The SOIC-8 pin surface mount units operate directly from a +3V to +5V single DC supply with 18dB typ. gain and cover the popular 0.50-2.50GHz wireless band. These units are very easy to use because all capacitors are internal and RF/DC connections are separate, eliminating the need for both external coupling capacitors and an RF choke. You can buy these very new amplifiers for the low price of just $2.95 ea., qty.1000. Development qty.10, only $4.95ea.! So, call Mini-Circuits today for immediate off-the-shelf availability and guaranteed 1 week shipment.



Freq.(GHz)	.5-.8	.8-1.0	1.0-2.0	2.0-2.5
Gain (dB) typ.	14.0	17.0	18.0	16.0
Max. Output (dBm) @1dB Comp. typ.	+18.0	+18.5	+17.5	+17.0
IP 3rd Order (dBm) typ.	+27	+27	+27	+27
VSWR Output typ.	1.5:1	1.7:1	1.7:1	1.5:1
VSWR Input typ.	6.4:1	2.8:1	2.0:1	1.4:1

DC Power.: +5.0V for specified performance.
Current,(mA): 85typ., 105 max.
Thermal Resistance. Junction-to-case: 125°C/W
Price ($) ea. : 2.95 (qty. 1000), 4.95 (qty.10).

- All specs at 25°C (case temp. 35°).
- Available in Tape and Reel.
- MTTF at 150°C max. junction temp.: 3×10^7 hrs.typ.
"Case" is defined as mounting surface of leads.

Mini-Circuits...we're redefining what VALUE is all about!

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

CUSTOM PRODUCT NEEDS...Let Our Experience Work For You.

F 180 Rev Orig

INFO/CARD 48

much less practical interest, since most radio systems include filtering that reduces potentially harmful IMD to insignificant levels. However, there are still plenty of systems with broadband front-ends and wideband amplification that may benefit from measurement of widely-separated IMD products. As a general rule, though, acceptable close-in IMD performance also means acceptable far-removed IMD performance, and is much easier to measure.

Test System Architecture

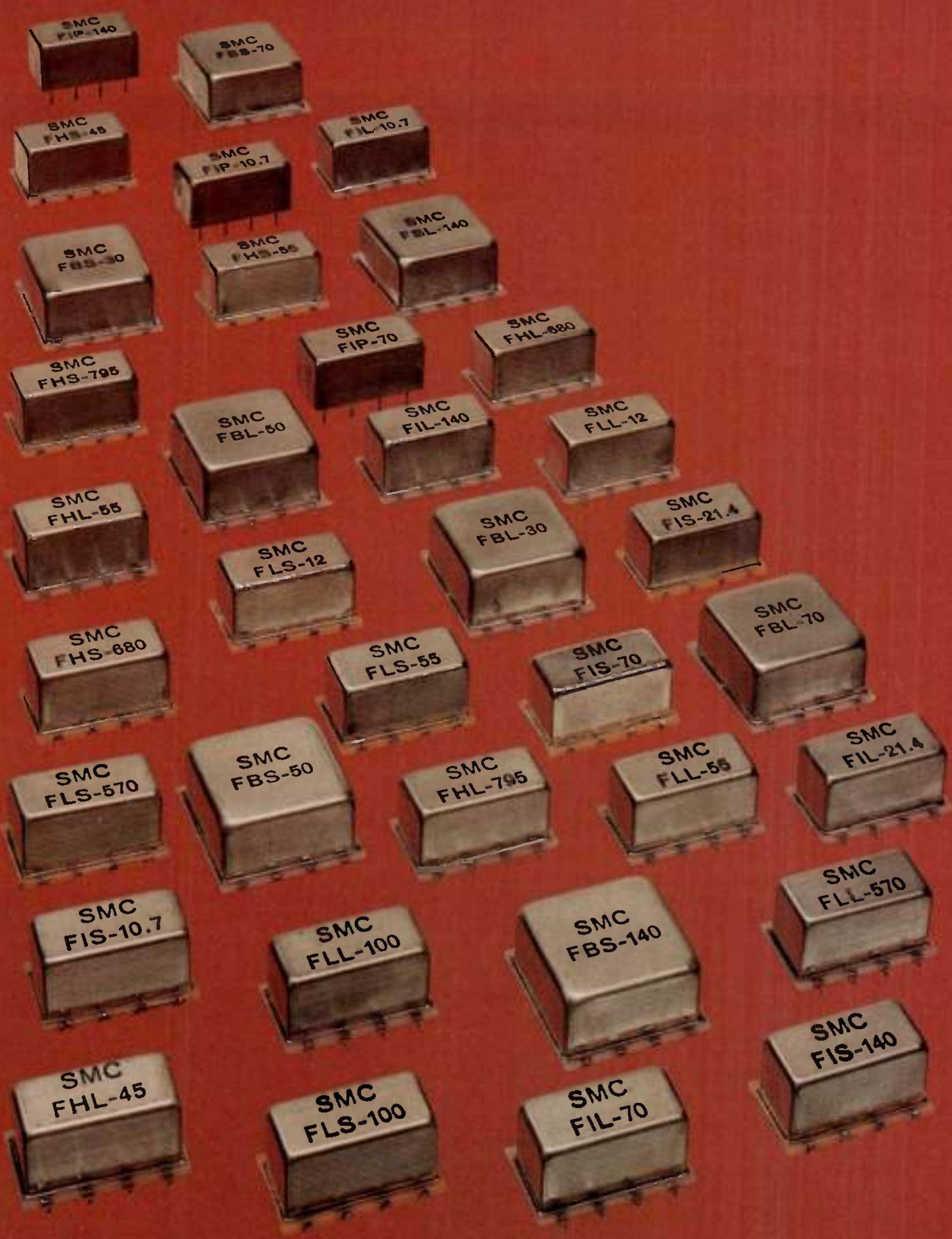
There are two basic test setups used for third order IMD measurements. The first and most common, shown in Figure 2, is for testing individual circuits, and consists of two signal sources, a combiner, the necessary interconnections to the device under test, and a receiver or spectrum analyzer to detect and measure the distortion products.

Although the arrangement is very straightforward, there are several important considerations that must be followed. First, the signal sources must be stable and accurate in frequency, with very low noise to avoid ambiguity when measuring very low levels of IMD. Also, the signal sources must be closely matched in amplitude to avoid variations due to the test setup. Unequal amplitude sources will create unequal amplitude distortion products. We want to measure the effects of the circuit under test rather than the characteristics of the test instrumentation!

Such test systems often include an attenuator between the combiner output and the device under test input. This allows the engineer to precisely balance the amplitudes of the signal generators at a fixed level, then separately adjust the input to the test circuit. This extra attenuator is unnecessary with a well-designed combiner and high quality signal generators.

Also, the receiver or spectrum analyzer must not contribute errors to the test results. Of particular concern is avoiding signal levels that may overload the input circuits of these instruments, creating a new set of distortion products that can confuse or even obscure the desired measurement. A typical test to see if internal distortion is a problem is to attenuate the input to the receiver or analyzer by 10 dB, and make sure that the measured results also change by exactly 10 dB.

FILTERS



Synergy has introduced a selection of high performance, low cost standard catalog and custom highpass, lowpass and bandpass filters covering passbands within the DC to 2000 MHz range. These filters are readily available in standard pin packages as well as the newest Synergy patented metal surface mount package with either leaded or flush mounting configurations.

Most importantly, when you specify Synergy, you benefit from our Sales and Applications team to assist you in the wide choices of available filters.

For a copy of our latest catalog, contact:
SYNERGY MICROWAVE CORPORATION,
483 McLean Boulevard,
Paterson, NJ 07504.
Phone (201) 881-8800 or
FAX (201) 881-8361.

SYNERGY
MICROWAVE CORPORATION

See us at RF EXPO EAST Booth# 402

INFO/CARD 51

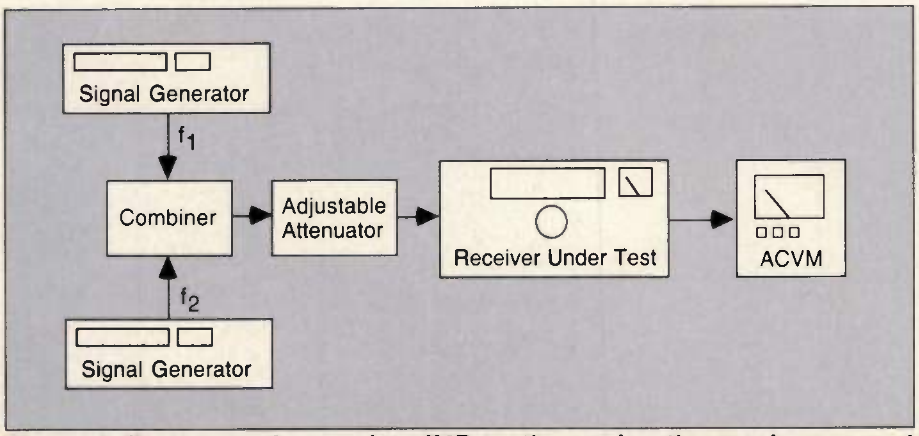


Figure 3. Test setup for receiver IMD testing, using the receiver as part of the test system, resulting an an overall performance measurement.

If not, further investigation is necessary to establish the proper signal level, or to locate the source of the problem if signal levels are within the instrument's specifications.

The second test setup is specifically for testing of receivers. The receiver becomes part of the test system, as shown in Figure 3. In this setup, f_1 and f_2 are again supplied by two signal generators through a combiner. Because receivers operate with very low level inputs, the attenuator mentioned earlier is used by most engineers for more precise control over test signal levels. The output of the receiver (audio or baseband) is measured using an AC voltmeter.

Test Procedures

Measurement procedures are similar for different types of circuits, but because the range of expected results can vary widely, there are some test procedure variations, as well. We'll use two examples to illustrate the process: a medium-power amplifier and a receiver.

The most common test for power amplifier linearity is a two-tone test with the test signals separated by 1 or 2 kHz. This represents the "real world" where modulation creates a composite signal with numerous frequency components, but within a normal passband that is rarely less than 2 kHz. The IMD products observed from this test would correspond to spurious signals generated by IMD among the components of the modulated signal. By establishing a standard test of 2 kHz spacing (or another representative spacing), a repeatable test can be performed, and meaningful comparisons of a "before and after" nature can be made, as well as comparisons of different amplifiers.

INFO/CARD 52

Marconi 4 microwave.

The new, fast, super-accurate **Marconi 6200B Microwave Test Set:** scalar analyzer, sweep generator, counter and power meter in one box.

The **Marconi 6200B** is still the only system to integrate a sweeper, scalar analyzer, power meter and counter into a single package. It's compact, easy to use, and exceptionally accurate, to accelerate and simplify the design and production of microwave components and systems.

The four-in-one design of the 6200B reduces set-up times, minimizes errors and speeds measurement across a wide range of applications. The user interface with its big full-color screen makes operation easy to learn, while a versatile macro facility allows complex test routines to be memorized and recalled at the touch of a button.

The performance and versatility of the Marconi 6200B can be extended still further with the **6210 Reflection Analyzer**: providing even more accuracy in measuring and analyzing return loss.

Find out more about Marconi's microwave test solutions: contact your local office for more information.

Marconi
Instruments

Marconi Instruments Inc. 3 Pearl Court, Allendale, NJ 07401 Tel: (201) 934 9050/1 800 888 4114 Fax: (201) 934 9229
In Mexico: Telegroup S.A. De C.V. Tel: 5 398 3889 Fax: 5 362 0273

INFO/CARD 53

The two test signals are set to the desired amplitude to drive the amplifier under test. This amplitude may be varied to examine amplifier performance at several power levels. This can be especially important for determining the power level at which the IMD passes the threshold of acceptable performance. (The threshold may be anywhere from 20 dB below carrier to 50 dB below carrier, depending on the application).

This test is almost always run with a spectrum analyzer as the detector. The frequency span of the analyzer is set to observe the two test signals along with a number of odd-order IMD products. Thus, a complete picture of the amplifier output can be observed at once.

A receiver is often tested as a complete unit, when the overall input-to-ouput performance must be known. In this case, the test signals are set at a frequency separation that avoids any ambiguity due to receiver design, maintained for the same before-and-after and unit-to-unit comparisons noted above for amplifier testing.

The signal separation should be small enough that the test signals and the IMD products fall within the front-end passband of the receiver. A receiver with a front-end preselector will require a closer spacing of test frequencies than a wideband receiver. Typical test signal spacings are 20 kHz, 100 kHz and 1 MHz.

The signals must be spaced far enough apart so that the IF bandwidth of the receiver effectively attenuates the stronger signals when the IMD products are measured. For example, if 20 kHz spacing is used, the attenuation of the IF filter at 20 kHz from the center frequency must be much more than the amplitude difference between the test signals and the IMD products.

Once the test signals are applied to the receiver input, the baseband or audio output is monitored. A reference is set at the level of the received test signals, then the receiver is tuned to the frequency of the expected IMD products. The difference in amplitude is readily measured. Of course, all gain control functions must be disabled to avoid erroneous results.

Reference Levels

When comparing published measurement data, we must remember that there are two methods used for IMD specifications. One is to use the amplitude of each test signal as the reference point. In this case, the IMD will be specified as "*x* dB below either of the test signals."

The other common reference uses the peak amplitude of the composite two-tone test signal, which is 6 dB higher than either test signal. On a spectrum analyzer display, the attenuation will be set so that the test signals are displayed 6 dB below a reference line.

Both reference conventions are valid, but to make comparisons, we must remember to determine which one was used. Correlation is simple; the difference between the results is always 6 dB, with the peak amplitude measurement showing 6 dB better IMD performance than the equivalent individual test-tone referenced measurement.

Conclusion

This simple introduction to IMD testing is only a beginning, intended to outline equipment and methods used in IMD testing. In particular, testing with more than two tones is growing in importance, with the growth of cellular and PCS systems which have multiple channels amplified in a single transmitter, or captured in a single receiver. *RF*

Bibliography

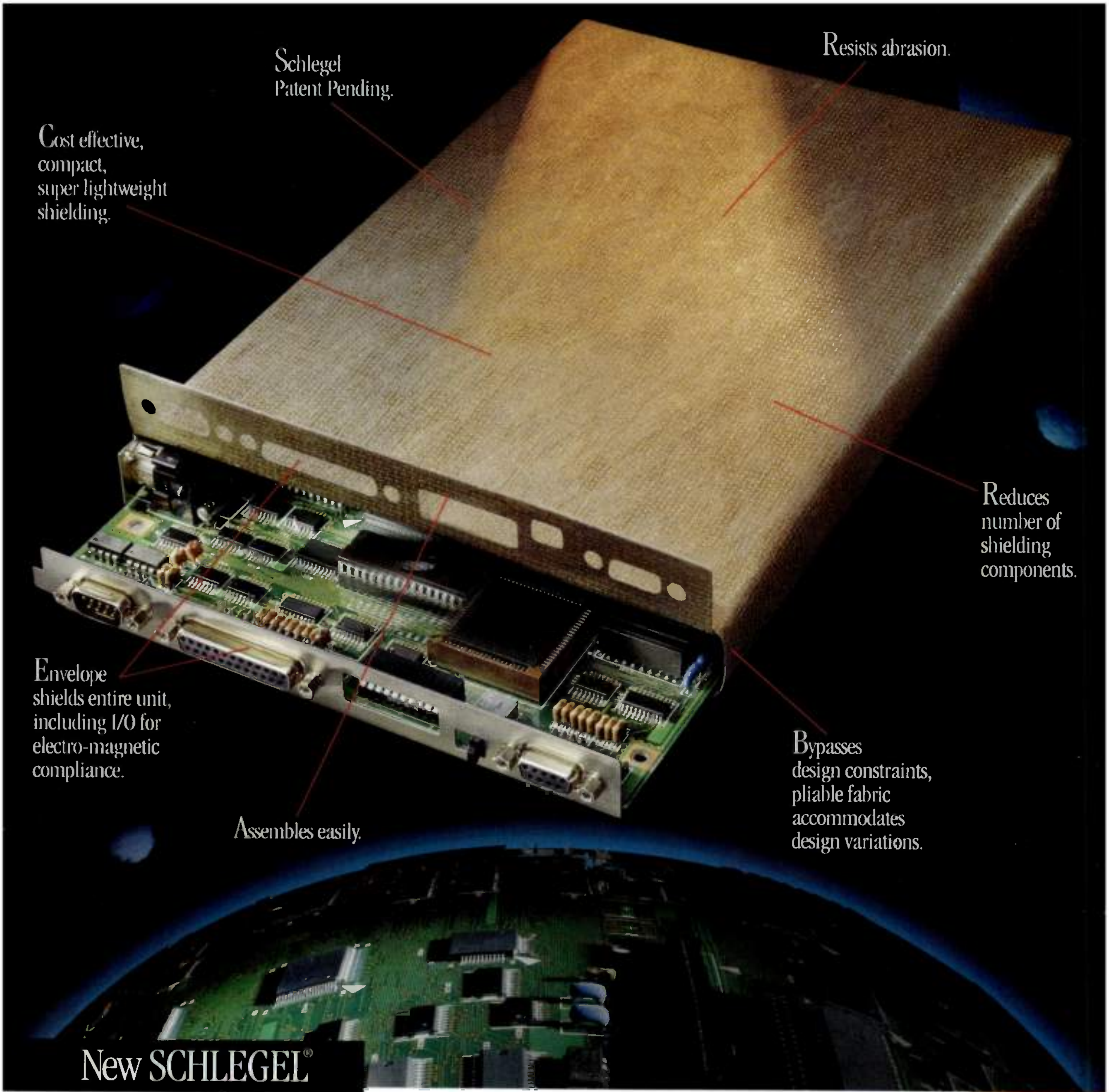
1. R.A. Witte, "Distortion Measurements Using a Spectrum Analyzer," *RF Design*, September 1992, p. 75.
2. M. Bartz, "Designing Effective Two-Tone Intermodulation Distortion Test Systems," *RF Design*, November 1987, p. 59.
3. M. Leffel, "Intermodulation Distortion in a Multi-Signal Environment," *RF Design*, June 1995, p. 78.
4. U. Rohde, T.T.N. Bucher, *Communications Receivers*, McGraw-Hill 1988, ch. 3.
5. W.E. Sabin, E.O. Schoenike, editors, *Single-Sideband Systems & Circuits*, McGraw-Hill 1987.
6. *ARRL Handbook*, American Radio Relay League 1994, pp. 26.42-26.51.
7. P. Vizmuller, *RF Design Guide*, Artech House 1995, Chs. 1, 3.
8. W. Hayward, *Introduction to Radio Frequency Design*, American Radio Relay League 1994, Ch. 8.
9. R.S. Carson, *Radio Communications Concepts: Analog*, John Wiley & Sons 1990, Chs. 5, 8, 9, 10.

August 1995

EMC®

TEST & DESIGN

- IEEE EMC Symposium Special Issue
- Design-for-Compliance
- EMC News and Products



Schlegel
Patent Pending.
Resists abrasion.
Cost effective, compact, super lightweight shielding.
Reduces number of shielding components.
Envelope shields entire unit, including I/O for electro-magnetic compliance.
Bypasses design constraints, pliable fabric accommodates design variations.
Assembles easily.
New SCHLEGEL®

A Soft Solution to a hard problem

Our cover features the new line of portable, battery-operated EMF meters introduced this month by Wandel & Goltermann. A product feature describing these meters can be found on page 18.

(Photo courtesy Wandel & Goltermann)

EMC TEST & DESIGN

August 1995

FEATURES

DEPARTMENTS

*Info/Cards can be found on page 130 of the accompanying issue of *RF Design*.

EMC Test & Design is published three times a year as a supplement to RF Design magazine. August 1995, Vol. 6, No. 5. *EMC Test & Design* is a registered trademark of Argus Inc. Copyright 1995 by Argus Business, a division of Argus Inc., 6151 Powers Ferry Road, N.W., Atlanta, GA 30339–2941, (404) 955–2500. Editorial and advertising offices are at 6300 S. Syracuse Way, Ste. 650, Englewood, CO 80111, (303) 220–0600. Printed in USA. For additional information, including subscription information, see the indicia on page 7 of RF Design .

Calendar

August

14-18 **IEEE EMC Symposium**
Atlanta, GA
Information: All About Meetings, Tel: (310) 371-3438. Fax: (310) 371-5268.

September

10-14 **EOS/ESD Symposium**
Phoenix, AZ
Information: ESD Association, P.O. Box 913, Rome, NY 13442; tel: (315) 339-6726; fax: (315) 339-6793.

24-27 **Advanced Technology for Electronic Packaging**
San Diego, CA
Information: International Electronics Packaging Society, Inc. (IEPS), P.O. Box 43, Wheaton, IL 60189; tel: (708) 260-1044; fax: (708) 260-0867.

October

16-18 **Minnesota EMC Event**
Bloomington, MN
Information: Kimmel Gerke Associates, 1544 North Pascal, St. Paul, MN 55108; tel: (612) 330-3728.

Courses

Electrostatic Discharge in Integrated Circuits
October 9-10, 1995, Burlingame, CA
Information: Continuing Edulation in Engineering, University Extension, University of California, 2223 Fulton Street, Berkeley, CA 94720. Tel: (510) 642-4151; Fax: (510) 642-0374.

Standards and Calibration Laboratories: Principles and Practices
October 23-27, 1995, Washington, DC
Electromagnetic Interference and Control in Modern Communications Systems
November 13-17, 1995, Washington, DC
Lightning Protection with Emphasis on Electrical and Electronic Equipment
September 7--8, 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.

EMC Workshop - Immunity Measurements
October 24-25, 1995, Surrey, England
EMC Diagnostics Workshop Emission Measurements
October 26-27, 1995, Surrey, England
Introduction to EMC
October 17, 1995, Surrey, England
EMC Testing
September 27, 1995, Surrey, England
November 21, 1995, Surrey, England
Information: Miss Nikki Hamann, Conference Group, Technical Services Division, ERA Technology Ltd., Cleeve Road, Leatherhead, Surrey, KT22 7SA England. Tel: 44 (0)372–374151 ext. 2595. Fax: 44 (0)372–377927.

EMC TEST & DESIGN

Established 1990

PRESIDENT/ARGUS INTEGRATED MEDIA
Stephen Stoneburn

VICE PRESIDENT/GROUP PUBLISHER
David J. Premo

EDITORIAL DIRECTOR
Gary A. Breed

TECHNICAL EDITOR
Andrew M. Kellett

ACCOUNT EXECUTIVE
Mike Henry

SALES/EDITORIAL OFFICE:
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111
(303) 220–0600 Fax: (303) 267–0234

VICE PRESIDENT/SPECIAL ADVERTISING
Drew DeSarle

CLASSIFIED ADVERTISING SALES
Wes Hudson

CREATIVE DIRECTOR
Brian Buxton

ART DIRECTOR
Pamela Bobe

STAFF ARTIST
Susumu Komatsu

VICE PRESIDENT/MARKETING RESEARCH
Tina D'Aversa-Williams

VICE PRESIDENT/PRODUCTION & PROMOTION
Cherryl Greenman

PRODUCTION MANAGER
Jenny Black

PROMOTION MANAGER
Marcie Bailey

VICE PRESIDENT CIRCULATION
Doug Florenzie

LIST RENTAL MANAGER
Etta Davis

REPRINTS MANAGER
Vivian Peterson

CORPORATE EDITORIAL DIRECTOR
Robin Sherman

A Publication of

ARGUS INTEGRATED MEDIA

A Division of Argus Inc.

Scott Smith President/Argus Inc.
Wayne Otterbourg, C.P.A. Vice President, Finance/Argus Inc.
Arthur E. Sweum Senior Vice President/Argus Inc.
Joe Randall General Manager/Argus Trade Shows

Argus Inc. Corporate Offices:
6151 Powers Ferry Road, N.W.
Atlanta, GA 30339–2941
Tel: (404) 955–2500
Fax: (404) 955–0400

News

Reverberation and Anechoic Chamber Operators Meeting

The Naval Surface Warfare Center in Dahlgren, VA is sponsoring the 1995 Reverberation Chamber & Anechoic Chamber Operators Group Meeting. The meeting will be held December 5-7, 1995 in Dahlgren. Topics will include military test applications, test standards, industrial and commercial testing, new test technologies, automotive testing, medical/biological testing, and others. For more information, contact: Naval Surface Warfare Center, Dahlgren Division, Attn: Michael O. Hatfield/Code F-52, 17320 Dahlgren Road, Dahlgren, VA 22448; email: MHATFIE@RELAY.NSWC.NAVY.MIL

Lindgren and Monsanto in Distributor Agreement

Lindgren RF Enclosures and the Metallized Materials Group of Monsanto Company have concluded an agreement making Lindgren the exclusive U.S. and Canadian distributor for Flectron metallized materials for architectural shielding products. Flectron materials use polyester nonwoven fabric coated with either copper or nickel-on-copper, and are available as 54 inch wide roll goods, and in roll tape form.

DoD Renews IITRI EMC Support Contract

IIT Research Institute announces that its contract to provide support to the Department of Defense in Annapolis, Maryland has been renewed for a minimum period of 39 months. The contract to provide technical support to the DoD Joint Spectrum Center (JSC) is for a maximum of $119 million, with an option for an additional two years. IITRI's JSC Support Group helps to guarantee the electromagnetic compatibility of military communications and electronic weapons systems. Its engineers are frequency called on to solve spectrum management and electromagnetic interference problems involving the military services, the DoD, or the civil sector. IITRI has managed the JSC Support Group (formerly known as the Electromagnetic Compatibility Analysis Center Support Group) for more than 30 years. IITRI is headquartered in Chicago and is affiliated with Illinois Institute of Technology.

D.L.S. Opens New Facility With 7 EMC Test Labs

On July 5, D.L.S. Electronic Systems opened its new 16,000 square foot EMC test facility in Wheeling, IL, with (2) FCC/CISPR pre-scan semi-anechoic chambers; (2) IEC 801-2 & 4 test rooms; (2) IEC 801-3 test rooms, including a 24 × 35 ft. semi-anechoic room capable of testing at 20 V/m at 3 meters; and (1) IEC 801-5, 6, 8, 11, 555-2 & 3 test room. D.L.S. continues to operate its two open field test sites in Genoa City, WI.

News

ESCO Subsidiaries Form EMC Test Systems Group

Rantec Microwave & Electronics, Inc. and the Electro-Mechanics Company (EMCO) have formed EMC Test Systems Group, a new business unit combining the product lines of Rantec Anechoic Systems, Rantec's Ray Proof North America and EMCO. The EMC Test Systems Group is headquartered in Austin, TX.

Listings Sought for NIST Product Certification Directory

NIST's Standards Code and Information Program has awarded a contract to The Marley Organization Inc. to revise and update NIST Special Publication 774, *Directory of U.S. Private Sector Product Certifications Programs*. the new directory will provide data on national, regional and local systems for certifying goods for sale. Information under each listing will include name and purpose of the certifying organization, types of products certified, steps involved in the certification scheme and a pictorial index of certification marks. Organizations wishing to be listed, or interested parties who can identify qualifying organizations should contact Charles W. Hyer, The Marley Organization Inc., 412 Main St., No. 3, Ridgefield, CT 06877; tel: (203) 438-3801; fax: (203) 438-2313. Expected publication of the updated SP774 is early 1996.

ESD Association to Update Mil-Std-1686

The ESD Association and its Standards Committee have accepted an invitation from the U.S. Department of Defense to update Mil-Std-1686, Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices). Originally produced by the military in 1980, the standard established the requirements for an ESD control program, and now is in its third revision. The update would become an ANSI standard and would be adopted by the military.

ANSI Publishes Report on Progress in Voluntary Immunity Standards

In a December 1994 report, ANSI committee C63 states that immunity efforts are having an increased effect on the ability of home entertainment electronics (mainly TVs and VCRs) to reject interference. As older equipment is replaced by new models that have incorporated improved designs, the number of interference complaints has continued to drop. The report also includes notes on design recommendations that would further improve immunity performance of these products.

Prediction Of Conducted Emissions In Switched-Mode Power Supplies

By Gregory A. Kyriazis
Inmetro

Gregory A. Kyriazis received his BSc degree in Electrical Engineering from the Universidade Federal do Rio de Janeiro in 1982 and his MSc degree in Electrical Engineering from Centro Federal de Educacao Tecnologica do Rio de Janeiro in 1995. His experience in engineering includes over 10 years as design engineer and test engineer. He can be reached at Rua Republica do Peru, 136/701, 22021-040 Rio de Janeiro, Brazil; Fax: +55 21 679 1507.

Switched-mode power supplies (SMPS) create large amplitude disturbances over a wide range of frequencies. Therefore it is important to predict the emission level of the equipment during the early design stage to optimize the filtering design and reduce the time to market.

The modeling of the disturbance sources in SMPS is done in the frequency domain. To convert the time domain switching waveforms into the frequency domain, the Fourier series of the waveforms are calculated. The model proposed in [1], although based on a buck converter, was used in the modelling of a flyback-type SMPS. This model is based on the equivalent disturbance generator applied to the switching transistors. The parameters used by this model were measured on a commercial SMPS sample. A SPICE simulator and a spreadsheet were used to predict the emission behavior of this SMPS.

It was evident that the model can predict the actual circuit behavior. A rationale is given for the differences between measured and calculated results.

Disturbance Voltage Types

There are basically two types of disturbance voltage present on a power bus [1]: differential mode (DM) and common mode (CM). DM disturbance voltage (V_{DM}) occurs between the leads of the intentional current path (phase- neutral or phase-phase). CM disturbance voltage (V_{CM}) occurs when the disturbance source is between ground and the phases, including neutral. The phase-ground (V_P) and neutral-ground (V_N) disturbance voltages are measured with a spectrum analyser (or EMI receiver) and a line impedance stabilization network (LISN) are: [3].

$$\begin{aligned} \left|\hat{V}_P\right| &= \left|\hat{V}_{CM} + \hat{V}_{DM}\right| \\ \left|\hat{V}_N\right| &= \left|\hat{V}_{CM} - \hat{V}_{DM}\right| \end{aligned} \qquad (1)$$

Modeling CM Emissions

The CM current path on a simplified schematic of SMPS is shown in Figure 1 (resistance values are in ohms). R1 and R4 are the equivalent LISN high frequency impedance. R3 and R5 are the diode bridge series resistance when forward biased. C2, R2 and L2 are respectively, the capacitance, the ESR and the ESL of the input ripple filter capacitor. V1 is the switched voltage waveform, and C1 is the parasitic capacitance to ground. This model assumes that the output filter inductor, reflected through the output transformer, is very much greater than L2, and therefore the current flows through the impedance of the input ripple filter capacitor [1]. This assumption is valid for the buck converter.

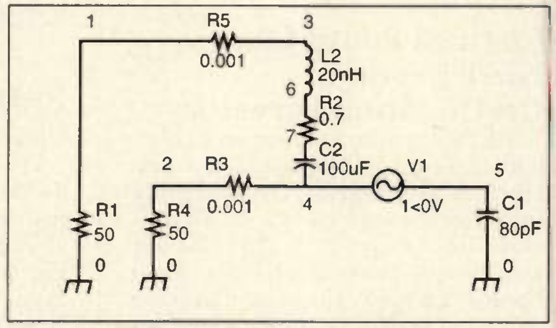


Figure 1. SMPS CM emission model.

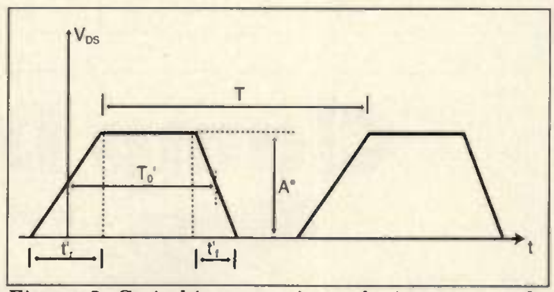


Figure 2. Switching transistor drain-source voltage waveform.

The measured values were taken from a flyback-type SMPS commercial sample without any EMI control measures. The voltage source V1 was measured with an oscilloscope (HP 1740A). C1, C2 and R2 were measured with an LCR meter (HP 4262A). L2 was estimated from manufacturer information. The values of R3 and R5 were taken from [1]. Special care was devoted to the guarding techniques used in the measurement of C1.

The switching-transistor drain-source voltage (V_{DS}) waveform was measured and approximated by a trapezoidal waveform (Figure 2), where A'' (= 400 V) is the amplitude, T_0' (= 12.4 μs) is the switching transistor cutoff time, t_r' (= 130

■ Conducted Emissions

ns) and t_f' (= 60 ns) are respectively the rise and fall times, and T is the period. The amplitude and phase of the Fourier expansion coefficients for the one-sided spectrum of this waveform were calculated using standard techniques [3].

In the SMPS sample tested, the parasitic capacitance to ground, C_p (= C1), was mainly due to the distributed capacitance between the primary and secondary windings of the output transformer (because the switching-transistor heatsink was well isolated from the chassis, its contribution to the parasitic capacitance was negligible). The current that flows in each elementary capacitance of the winding depends on the voltage level at each element. The potential, distance x along the winding, is $(x/l)^2 V_{DS}$. The total current is obtained integrating the effects of all the elements for the entire winding, i.e.,

$$I = \frac{jn\omega_0 C_P V_{DS}}{l}\int_0^l \frac{x^2}{l^2}dx \qquad (2)$$

$$= jn\omega_0 C_P \frac{V_{DS}}{3}$$

where ω_0 is the switching fundamental frequency and n is the harmonic number. The total current flows as if the capacitance C_p were connected to a voltage source of $V_{DS}/3$. Thus, in this case study, the value of A´´ to be inserted in the Fourier expansion of V_{DS} is one third of the measured value of the drain-source voltage waveform amplitude. This is a simplified approach; it assumes the windings are perfectly uniform, the secondary windings can be approximated by a conductive plane and the series capacitance down the winding is negligible.

The CM emission component (the voltage drop on R1 and R4 of Figure 1) was calculated using the PSPICE 5.0 circuit simulator (Microsim Co.). As this simulator gives only the first nine Fourier expansion coefficients, the circuit of Figure 1 was simulated with an AC analysis ranging from the third harmonic (192 kHz) to the 461th harmonic (29,504 MHz), assuming a voltage source with unity amplitude and null phase. Using the principle of linearity, the simulation results were then multiplied by the Fourier expansion coefficients of V_{DS} for each harmonic number to yield the predicted CM disturbance voltage (Figure 3).

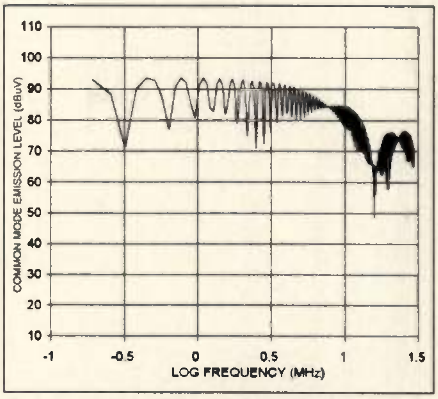


Figure 3. Predicted CM emission level.

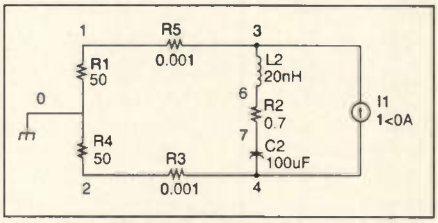


Figure 4. SMPS DM emission model.

Modelling DM Emissions

The DM current path on a simplified schematic of SMPS is shown in Figure 4, where I1 is the current waveform through the switching transistor. The current source I1 was measured with an oscilloscope (HP 1740A). The other components are similar to those of the CM model. This model addresses only the low impedance component of DM emissions [2].

The switching transistor current waveform, $I_{DS}(t)$, was measured and approximated by the addition of two triangular waveforms, $I_{DS1}(t)$ and $I_{DS2}(t)$, as illustrated in Figure 5, where A (= 1.79 A), t_r (= 3.1 μs) and t_f (= 100 ns) are respectively the amplitude, the rise and fall times of the $I_{DS1}(t)$ current component, T_0 (= T − T_0' = t_r + t_f) is the switching transistor saturation time, A´ (= 2.86 A) is the amplitude of the $I_{DS2}(t)$ current component, and T1 (= t_f' = 60 ns) is equal to the fall time of the drain-source voltage waveform. The amplitude and phase of the Fourier expansion coefficients for the one-sided spectrum of both $I_{DS1}(t)$ and $I_{DS2}(t)$ were calculated using standard techniques [3].

The DM emission component (the voltage drop on R1 and R4 of Figure 4) was calculated as described for the CM emission component, except that the simulation results from the analysis of the DM model were multiplied by the Fourier expansion coefficients of I_{DS}, for each harmonic number (Figure 6). Substituting the predicted CM and DM disturbance voltages in equation 1, for each harmonic number, gives the predicted conducted emission level (Figure 7).

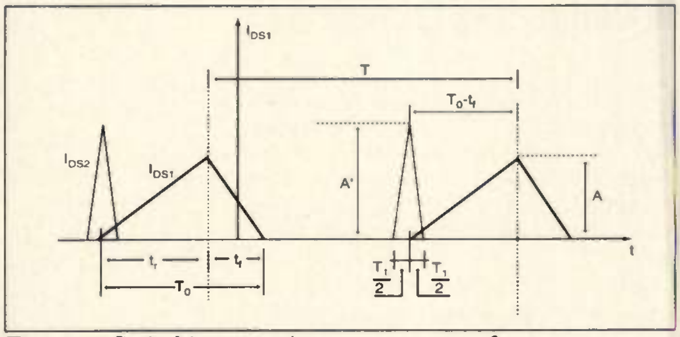


Figure 5. Switching transistor current waveform.

Shielded Output Transformer

A way of reducing primary to secondary capacitance is to provide an interwinding electrostatic shield connected to the DC supply line of the flyback converter [4]. The CM model (Figure 8) is based on the electrostatic shielding model proposed in [5] where C18 and C19 are the primary-to-shield and secondary-to-shield capacitances; C20 and C21 represent the leakage current that flows out of the shield due to the transformer and the circuit layout, respectively. These parasitic capacitances were measured using guarding techniques. The DM model is the same as presented above (tests from 100 Hz to 1 MHz indicate the shield has little or no effect for DM currents [6]). Figure 9 shows the predicted conducted emission after shielded output transformer insertion.

Experimental Validation

The measurement of the disturbance levels was carried out with a CISPR setup [7]. A computer controlled spectrum analyzer (HP330/HP8567A) was used for EMI measure-

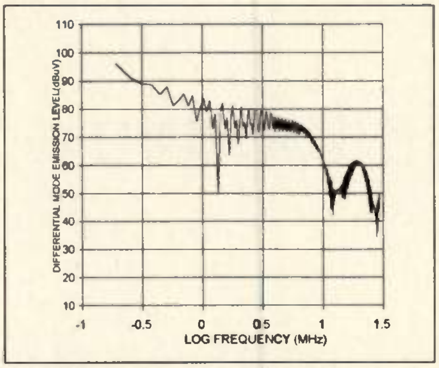


Figure 6. Predicted DM emission level.

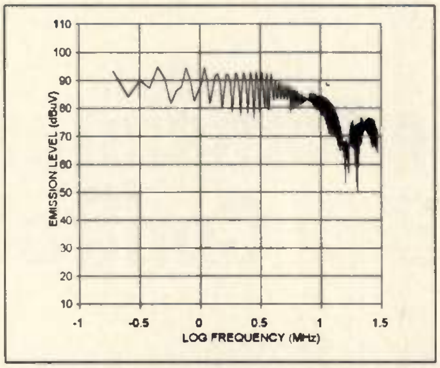


Figure 7. Predicted conducted emission level.

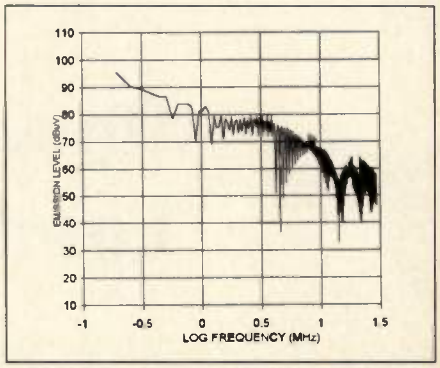


Figure 9. Predicted conducted emission level with shielded output transformer.

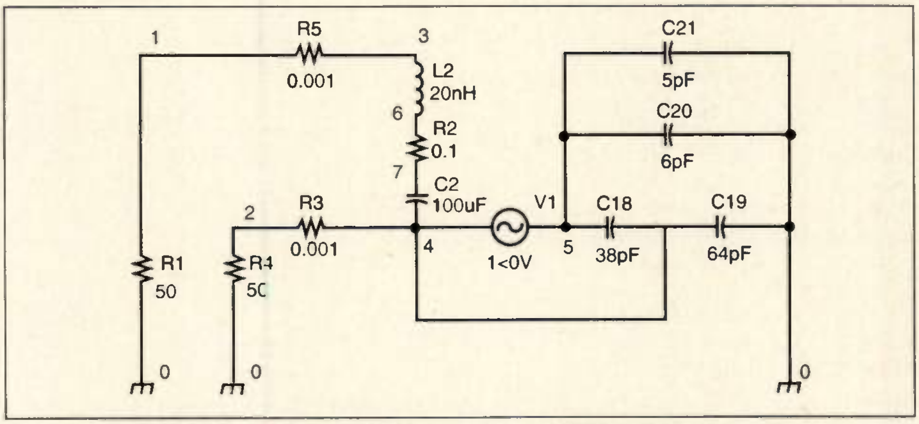


Figure 8. SMPS with shielded output transformer, CM emission model.

ment. A peak detector was used for all the tests, since quasi-peak is not available for this model. As the analyzer displays the RMS value of the sinusoidal harmonic, 3 dB was subtracted from the calculated peak values. A line impedance stabilization network (LISN - EMCO 3825/2) was used to supply the SMPS during the measurement. The author built the differential mode rejection network (DMRN) proposed in [2], and used it to measure the CM component of the conducted emission.

The measured CM emission level of the SMPS under test is shown in Figure 10. Part of the difference between the measured and predicted CM values (Figure 3) is explained by the insertion loss of the DMRN (≈ 4 dB). Another reason for the difference in the low frequencies (150 kHz - 450 kHz) is that in this range the LISN presents a lower impedance value than the assumed 50 ohms. The measured conducted emission level is illustrated in Figure 11. The effect of the shielded output transformer on the measured conducted emission level is reported in Figure 12. The predicted results (Figures 7 and 9) agree fairly well with the respective measured ones.

Although originally derived for the buck converter, the equivalent disturbance generator model proposed in [1] allows an effective prediction of the flyback-type switched-mode power supply conducted emission level.

The unexplained difference between the measured and calculated values points to the development of a model that could address the high impedance differential mode emission of a flyback converter.

Ackowledgements

The author thanks Marcelo Collona Rosman, Wilton Ney do Amaral Pereira and Marcio Antonio Sens for their helpful suggestions. The author is also indebted to Paulo Jacinto Pastor-Braga for providing the resouces for the work.

References

1. M.J. Nave, "Prediction of Conducted Emissions in Switched-Mode Power Supplies," *Proceedings of the IEEE International EMC Symposium*, San Diego, CA, August 1986, pp. 167-173.
2. M.J. Nave, *Power Line Filter Design for Switched-Mode Power Supplies*, Van Nostrand Rheinhold, 1991.
3. C.R. Paul, *Introduction to Electromagnetic Compatibility*, John Wiley & Sons, 1992.
4. L.E. Jansson, "Radio Frequency Interference Suppression in Swiched-Mode Power Supplies," *Mullard Technical Communications*, Vol. 12, No. 120, October 1973, pp. 2-6.
5. P.A. Chatterton and M.A. Houlden, *EMC Electromagnetic Theory to Practical Design*, John Wiley & Sons, 1992.
6. MIL-HDBK-241B, "Design Guide for EMI Reduction in Power Supplies," Defence Logistic Agency, VA, USA, September 1983, pp. 99.

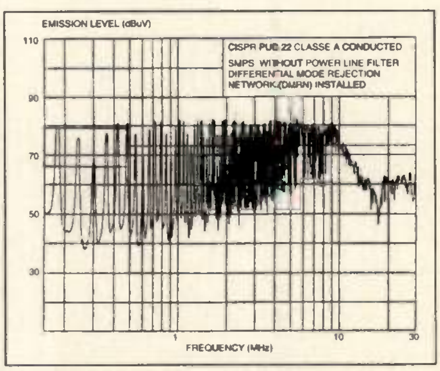


Figure 10. Measured CM emission level.

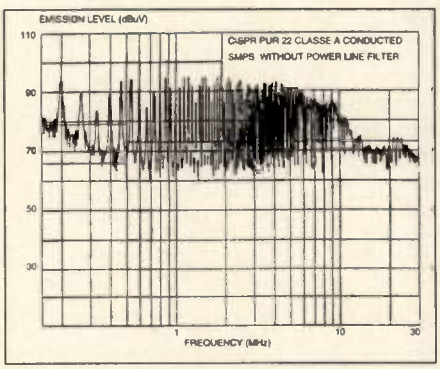


Figure 11. Measured conducted emission level.

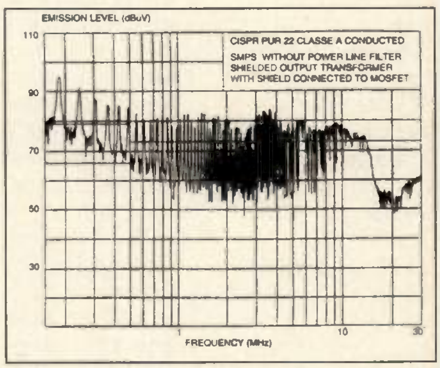


Figure 12. Measured conducted emission with shielded transformer.

Power Transistor Inductive Load EMI Control

By Richard Valentine and Tom Huettl
Motorola Semiconductor Products Sector

Richard Valentine is a member of the Technical Staff at Motorola and is the Technical group leader for the GENESIS advanced vehicular electronics team.

Thomas Huettl is a systems engineer and member of the GENESIS advanced vehicular electronics team. He has a BSEE from Arizona State University.

Both authors can be reached at Motorola, Phoenix Technology Center, 7755 S. Research Dr., Suite. 110, Tempe, AZ 85284. Tel: (602) 413-2537, or (602) 413-2518.

Controlling an inductive load such as a DC relay or low speed solenoid with a power transistor driven from a microcontroller or digital logic would seem fairly straightforward. A power transistor is selected to satisfy a few essential requirements: maximum voltage rating above supply voltage, current rating above solenoid's operating current level, a low on-voltage to keep power dissipation down (so no heatsink is required) and the ability to be driven from 5 volt logic. The solenoid's inductive "kickback" voltage is contained with an avalanche-rated power FET. Unfortunately, this design will also generate significant EMI.

There are two conditions in this switching circuit that contribute to EMI: the logic signal's high speed transitions which drive the power FET, and the inductive "kickback" voltage clamp's behavior. Figure 1 shows a relay control circuit to test various EMI reduction methods. The results are shown in Figure 2(a) for the previous straightforward design. Adding a free wheeling diode across the solenoid stops the power FET from avalanching, but does not eliminate EMI as shown in Figure 2(b).

Slowing the switching edges of the logic signal driving the power FET's gate will help minimize EMI because the power FET's switching times are no longer in the RF range. Logic signals usually exhibit switching edges of less than 1μs. If the power FET is switched at anywhere near this speed, serious EMI will result. One simple method to slow down the logic driving signal's edges is to add a series resistor and a gate-to-source capacitor. To minimize the chance of parasitic RF oscillations during switching the series resistor value should be 1kohm or less and the gate to source capacitor value should be fairly large, 0.01 to 1.0 μF, in order to slow the gate drive signal transition times. The gate drive source lines must be connected close to the source, and placed out of the source to common load current path. Figure 2(c) shows the effect of just adding

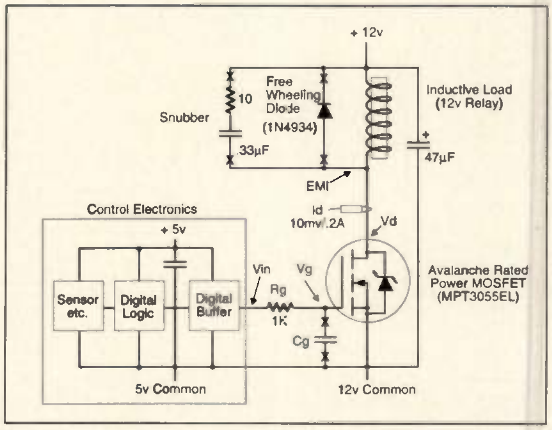


Figure 1. Inductive load control test circuit.

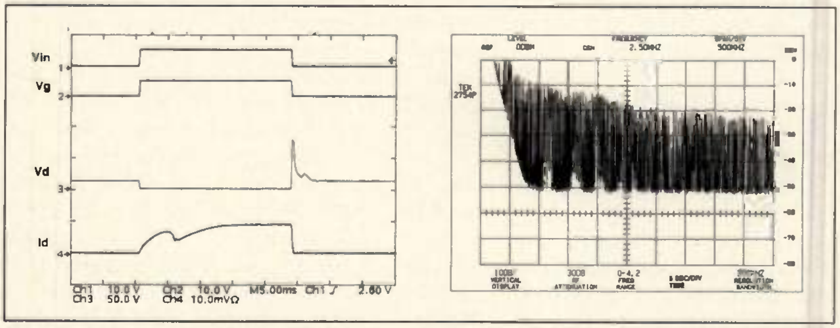


Figure 2(a). Drain voltage, V_d, avalanches power FET and contributes to EMI.

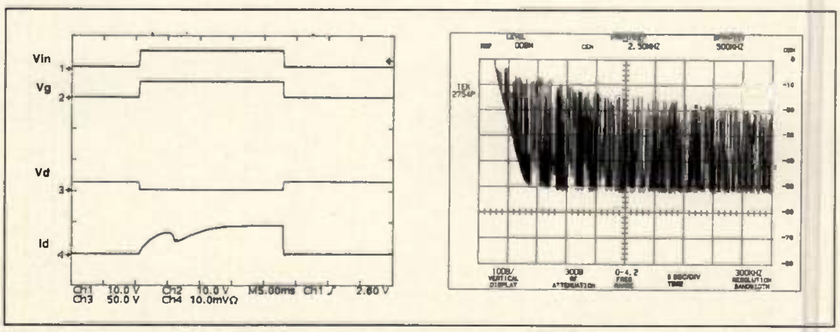


Figure 2(b). A free wheeling diode stops power FET from avalanching, but does not stop EMI.

Let The Creative Juices Flow, Not The EMI and RFI.

For any project where EMI and RFI are potential problems, custom gasketing and shielding produced with Monsanto's Flectron® Metallized Materials is the answer to letting your creative juices flow.

Flectron uses a patented technology for applying thin metal coatings of copper, silver or nickel on woven and non-woven fabrics. Our extensive fabricator network in the U.S. and Canada provides custom configurations with Flectron selectively laminated to low compression set foams and insulating materials.

Flectron is substantially more flexible than foils or other shielding laminates and allows you to utilize many material combinations and product designs never before possible. Flectron provides unique solutions to your most stringent shielding, grounding, ESD and packaging requirements. It's the cost-effective avenue for total creativity in design.

Flectron is currently being designed into telecommunications equipment, cellular phones, computer workstations, medical electronics, and direct broadcast television. For more information on Flectron and the Flectron fabricator nearest you, *contact Monsanto toll free at:* **1-800-843-4556.**

FLECTRON®
METALLIZED MATERIALS
By Monsanto

® Registered trademark of Monsanto Company

INFO/CARD 63

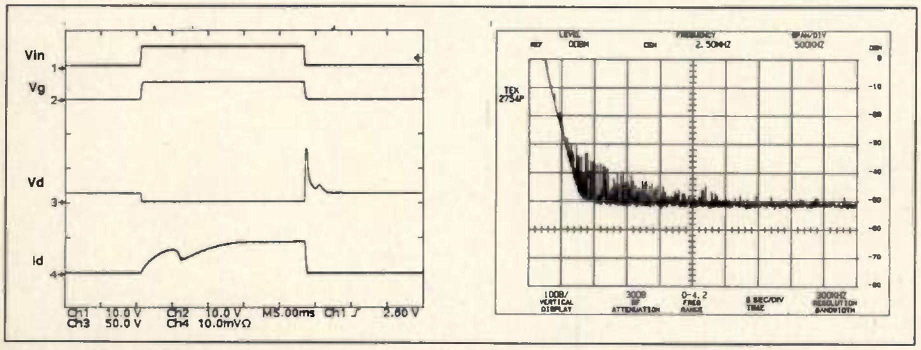


Figure 2(c). Adding a 0.1 μF gate capacitor slows down the FET and lowers EMI.

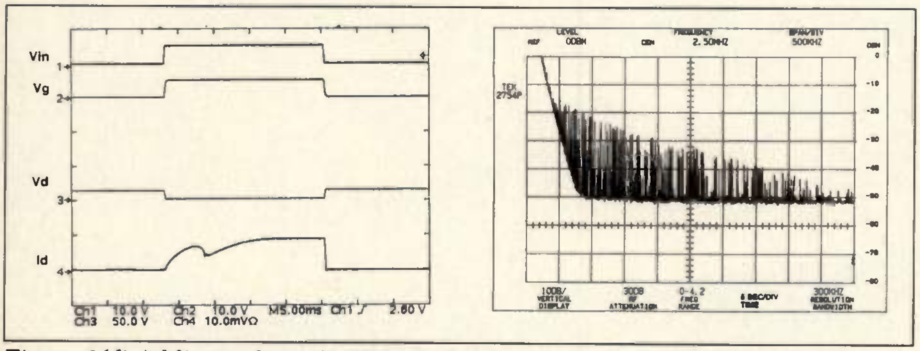


Figure 2(d).Adding a free wheeling diode along with the gate capacitor increases EMI levels.

a 0.1 μF gate capacitor which reduces EMI by slowing down the power FET's switching speed. Figure 2(d) is the same except the free wheeling diode across the load has been added. The gate RC network is a low cost fix, but does introduce a timing delay, and extra power dissipation in the power FET. The extra power dissipation occurs because of the power FET's slow turn off. The extra power dissipation may require a larger FET. Graph 1 shows the delay effect for different gate capacitor values. Generally a 50 to 100 μs delay time should not effect the application since the operating frequency for relays or solenoids is usually less than 10 Hertz.

One other point about the gate voltage switching behaviour is that power FETs exhibit high transconductance, which means it only takes a small gate voltage variation to turn the load on or off. The gate voltage variation can be determined by dividing the load current by the FET's forward transconductance. For example, an MTP3055EL's forward transconductance (g_{FS}) is 5.0 mhos minimum. If the load current is 0.2 amperes, then

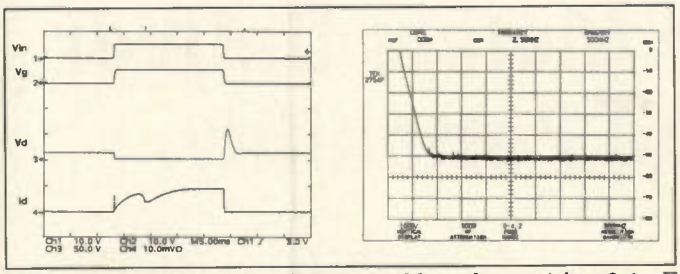


Figure 2(e). Adding a 1 μF 10Ω snubber along with a 0.1 μF gate capacitor minimizes EMI.

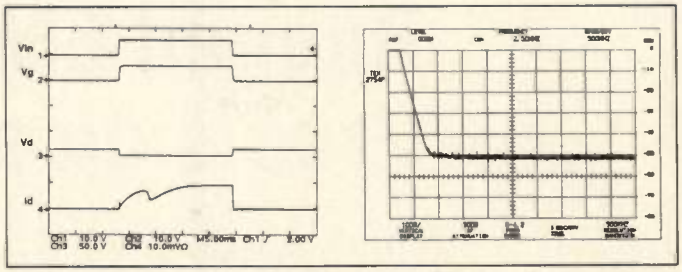


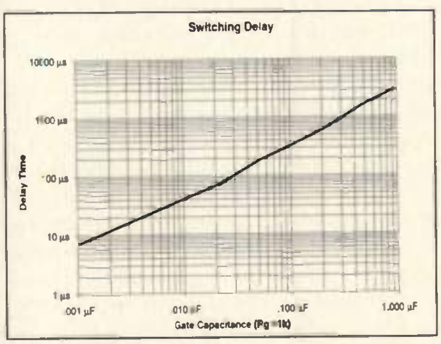
Figure 2(f). Adding a 0.33 μF 10Ω snubber to the free wheeling diode along with 0.1 μF gate capacitor minimizes EMI.

the ΔV_{gs} is only 0.04 volts. (ΔV_{gs} = 0.2/5). Therefore only a small portion of the gate's voltage transition time affects the switching times of the load. This is why a large gate-to-source capacitor has to be used to slow down the gate voltage transition time.

The other EMI source is from the inductive "kickback" voltage clamp. When this device (either a free wheeling diode or zener) is activated, it generates EMI. The free wheeling diode also slows down the solenoid's or relay's mechanical turn-off performance. Replacing the free wheeling diode with a RC snubber can reduce EMI and still allow good turn-off mechanical response. The snubber capacitor value should be large enough to prevent the power FET from avalanching. The exact value of the RC snubber is determined by the specific application. A 0.3 μF metallized film capacitor and 10 ohm resistor are good starting values for the snubber. Figure 2(e) shows the effects of adding a snubber and Figure 2(f) shows a snubber plus free wheeling diode.

Summary

EMI can be minimized in low speed relay or solenoid control designs by adding a RC filter to the gate drive to slow down the power transistor's switching times and a RC snubber across the load to contain the inductive "kickback" voltage. ⏚



Graph 1. Switching delay from adding gate capacitor

Rugged EMF Meters Deliver Precision and Portability

This article describes the new line of EMF meters from Wandel & Goltermann, as featured on the cover of this issues. For more information, contact Wandel & Goltermann at 2200 Gateway Centre Blvd., Morrisville, NC 27560-9228; Tel: (804) 491-5047, Fax: (804) 491-3163; or circle Info/Card 182.

Wandel & Goltermann's new line of EMF meters: Model EFA-1 and EFA-2 have the case style on the left; the EMR-10 and EMR-11 style is shown in the center; the EMR-20 and EMR-30 are as pictured on the right.

Safety in electromagnetic fields (EMF) is an issue which has carved out a place of its own in the news, with a particular focus on workplace safety. In response to growing concern, Wandel & Goltermann has introduced a family of EMF meters that can be used to make quick, precise measurement of fields in nearly any workplace.

Dealing With "Electrosmog"

Although an artificial term, the term *electrosmog* is becoming commonly used to describe the environmental impact of being constantly exposed to electromagnetic fields. Although blown out of proportion in the press, research of the late 1970s brought legitimate concerns to light regarding the effects of omnipresent fields on man and the environment.

It has been determined that electromagnetic fields have an effect on the human organism. Thermal effects are relatively straightforward, relating to the heating of the water in our bodies. One danger of this type of temperature rise is that the human temperature control mechanisms are normally triggered by sensors in the skin. EMF-induced heating occurs internally, where the water content is highest. As a result, sweating and other protective reactions do not occur.

Non-thermal effects have also been noted, in particular, experiments show changes in the permeability of cell membranes and changes in the phagocytic activity of lymph nodes. It is likely that high frequency radiation of a given intensity and modulation weakens the immune system, affects the hormone balance, and may even have psychological effects.

Although debate continues on exactly what field intensities cause what degree of harm, standards have been developed that address the dangers as we understand them. Studies are ongoing, and these standards will undoubtedly change in future as more research is completed.

Sources of EMF

Low frequency EMF appears mainly as magnetic fields where large currents flow and conductors are separated or magnetic operation is involved. Devices include electric arc welding equipment, motors and power supplies. Low frequency electric fields occur in open multi-plug installations and extension cables. Measurements can determine whether hazardous fields are present at a given location.

High frequency EMF (radio waves) occurs in many places. The highest levels will be found near radio and television stations and satellite earth stations. Safety zones and limited exposure times are part of a protection plan. Also of concern are the many low power radio devices, such as cellular telephones, which can have high field intensities very close to the units. Precision measuring instruments are needed to identify areas to avoid, and to verify that protected areas are indeed safe.

In addition to communications equipment, radio energy is commonly used in industry for lo-

New EMF Meters

calized heating and plasma generation (sputtering or vaporizing). Some medical equipment makes use of high intensity radio energy, as well. Employee safety is especially important, since workers are near the equipment for long periods of time. Monitoring the fields created by electronic equipment with accurate, reliable instruments is an essential part of an EMF safety program.

EFA-1 and EFA-2 — Magnetic Field Analyzers

Covering magnetic fields from 5 Hz to 30 kHz, the Wandel & Goltermann EFA-1 and EFA-2 analyzers are compact, battery-operated units. They use a built-in three-dimensional magnetic probe, or an optional precision H-field probe that conforms to IEEE and VDE standards. A miniature probe is available that can get into tight spaces. The probes have measurement range of 100 nT to 10 mT, and provide either the RMS or peak values.

The fields can be analyzed by frequency. The units have a wide array of filters, including 5 Hz to 2 kHz, 5 Hz to 30 kHz, and 30 Hz to 30 kHz. The EFA-2 allows individual filter frequencies of 15 Hz to 2 kHz to be specified by the user. The EFA-2 also has datalogging capability for long-term measurements up to 24 hours, and it will store up to four complete measurement setups, with automatic selection of measurement range. The instruments measure 7.875 × 4.375 × 2.375 inches and weigh 2.2 lb.

EMR-10 and EMR-11 — High Frequency Monitors

The EMR-10 measures magnetic fields from 30 kHz to 30 MHz, and the EMR-11 measures electric fields from 100 kHz to 3 GHz. Each one is designed for rugged use in the field by non-technical operators. The measurement ranges and operating parameters of both instruments are optimized to conform to requirements of the International Radiation Protection Association (IRPA), World Health Organization (WHO), and national organizations such as IEEE/ANSI, IEC and NRPB. Both instruments will collect measurement data and transfer that data to a computer via the built-in RS-232C interface. The units have an alarm with user-adjustable threshold, instantaneous or average measurement, and automatic self-diagnostics. Measurements are displayed in V/m, A/m, mW/cm^2, or W/m^2. Instrument size is 3.5 × 1.75 × 9.5 inches, and the weight is 12 oz.

EMR-20 and EMR-30 — Precision Hand-Held Instruments

Models EMR-20 and EMR-30 are hand-held E-field radiation meters for 100 kHz to 3 GHz measurements. They are suited for applications such as servicing of RF communications equipment and use in RF radiation safety programs at industrial and manufacturing facilities. Measurement accuracy is exceptional, based on proprietary triaxial signal processing circuitry. The units come with an isotropic omni-directional probe providing 60 dB dynamic range. The units contain a built-in optical interface that allows easy calibration by the owner, or through the facilities of recognized calibration laboratories. The EMR-30 will internally story sets of measurements including value, time stamp and instrument setting. Both units measure 3.75 × 2 × 18 inches (including probe), and weigh 1 lb.

■ New Products

Components

High Permeability Magnetic Cores

Cobalt-based amorphous alloy MAGNAPERM® high permeability cores from AlliedSignal Amorphous Metals are designed with an extremely flat DC hysteresis loop. Permeability greater than 90,000 at 1 kHz makes these cores particularly effective for noise suppression applications. In addition to EMI common mode filtering, applications also include telecommunications and data communications interface transformers, pulse and current transformers.

AlliedSignal Amorphous Metals
Parsippany, NJ
Info/Card #168

Filtered D-Sub Connectors

Power Dynamics line of D-Sub connectors are designed to suppress EMI/RFI noise over a wide range of frequencies. The units include integrated ferrite plates to combine a filter/connector into a single space-saving unit. The connectors are available in 5.0 mm, 7.2 mm, 9.4 mm and 13.84 mm footprints, and meet EIA, RS-232C and RS449 standards. Terminations available include p.c.b., solder cup, crimp and I.D.C.

Power Dynamics, Inc.
West Orange, NJ
Info/Card #170

Suppressor Diodes

Semtech Corporation announces a new famiilty of transient voltage suppressor (TVS) diodes designed to protect sensitive ICs from damage due to ESD. The new devices are provided in low-cost SOT-23 packages. The diodes use a dual-junction, common anode configuration and can be used to protect two uni-directional lines or one bi-directional line, making them application to signal lines as well as the V_{cc} bus. Models are available in standoff voltages of 5, 12, 15 and 24 V. In 10,000 quantities, the price is $0.39 each.

Semtech Corporation
Newbury Park, CA
Info/Card #171

Custom Filters

Elpac Components announces a line of custom EMI filters. Filters can be tailored to specific filtering needs in high-reliability applications such as industrial controls, aerospace and mobile electronicc where high power and signal level curretns must operate independently without crosstalk.

Elpac Components
Irvine, CA
Info/Card #169

Shielding

PTFE Coated Shielding Foils

Custom fabricated PTFE coated foils have been introduced by Insul-Tab, Inc. for use as release liners in manufacturing, EMI/RFI shileds in electronics, and in food packaging applications. Aluminum, copper and stainless steel foils can be supplied, with foil thicknesses of 1 to 15 mils, and widths from 1/2 inch to 18 inches.

Insul-Tab, Inc.
Woburn, MA
Info/Card #172

Vacuum Metallization Capabilities

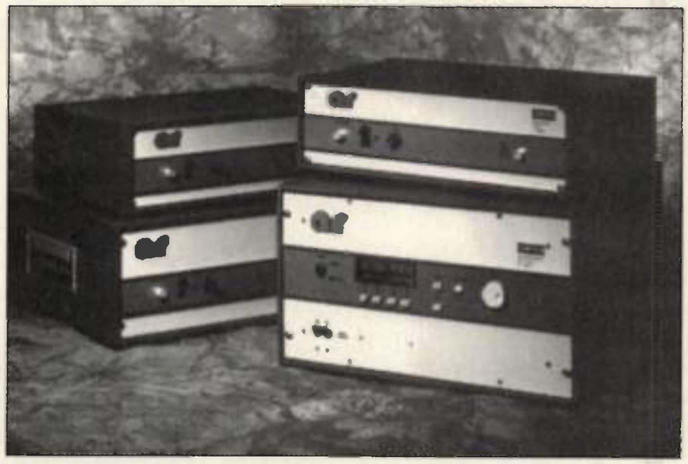
Rare Earth Coatings offers vacuum metallization for EMI/RFI shielding and reflective applications. Their Vacuglas® process deposits metal onto plastic materials with strong adhesion, providing a minimum 1 ohm per square and 72 dB continuous. Several different metals can be applied: copper, aluminum, silver, gold and others.

Rare Earth Coatings West
St. Paul, MN
Info/Card #173

Connector Gaskets

Connectors for control and communications systems are kept both physically and electromagnetically clean with precision die-cut gaskets using Shieldseal 106 sheet materials from James Walker & Co. The nickel-filled silicone elastomer gaskets meet military specifications, and can be provided for a wide range of commonly-used D-type and circular connectors, as well as custom configurations. The gaskets offer 120 dB shielding attenuation and EMP survivability.

James Walker & Co.
Woking, Surrey U.K.
Info/Card #174



Microwave Amplifiers

A new line of broadband microwave amplifiers have been introduced by Amplifier Research, intended for susceptibility and general laboratory applications in the L, S, C, X and IJ bands. Three solid-state models provide 1, 5 and 10 watts minimum output from 1.0 to 4.2 GHz, and four TWT amplifiers provide 200 watt output from 1-2 GHz, 2-4 GHz, 4-8 GHz, and 8-18 GHz, respectively. The amplifiers feature reduced power output under mismatch condition rather than shutoff, for uninterrupted testing. All amplifiers are rated at minimum power output at the output connector, rather than "typical" or "nominal" specifications. A complete set of protection features, gain control and and IEEE interface are provided.

Amplifier Research
Souderton, PA
Info/Card #176

Low Profile Shielding Vents

Tecknit offers their new Teck-cell-A (LP) panels, 0.25 inch thick aluminum honeycomb material, providing air flow and EMI shielding performance at a low cost for commercial applications. The vents are available with gasketing of beryllium copper fingers, oriented wires in silicone, or UL-rated nickel-plated fabric and neoprene rubber. Optional finishes include chromate conversion, tin & electroless nickel plating.

Tecknit
Cranford, NJ
Info/Card #175

Equipment

EMI Receiver

Messelektronik Berlin introduces a low-cost portable EMI receiver, featuring built-in PC with memory card and LCD graphic display. The unit operates for four hours on rechargeable batteries. The receiver uses a synthesized local oscillator, preselection, automated attenuators and CISPR Quasi Peak demodulation. IF bandwidths are 0.2, 9.0 and 120 kHz. IEEE interface and opto-coupled RS-232 interface provide convenient test configuration.

MEB Messelektronik Berlin
Berlin, Germany
Info/Card #177

Immunity Tester

the RF power generator system EMCG 230/B2 from Dressler is a complete unit for testing products to the IEC-1000-4-6 standard for conducted immunity. The EMCG 230 has all necessary modules to form a complete test system without requiring separate RF power amplifier, signal generator and

New Products

modulator. As required by the standard, the unit provides 8 watts and drives an integrated 6 dB attenuator to provide a stable 2 watts output. Test frequencies from 0.15 to 230 MHz can be set in 10 kHz increments by front panel thumbwheel switches. CW and the required 1 kHz, 80% AM modulation are provided.
Dressler Hochfrequenztechnik
Stolberg, Germany
Info/Card #178

Software

3-D EMI Simulation

QUIET™ Version 2.0 is introduced by Quad Design, providing prediction of electric and magnetic field intensities radiated from backplanes, motherboards and MCMs. the new model of this EMI analysis tool includes a 3-D simulation engine that permits the automatic simulation of complex system effects, including cable common mode current and radiation. Multiple board EMI shielding and scattering are also simulated, as is enclosure resonance. Understanding the behavior of these system characterstics is essential to meeting EMC specifications.
Quad Design
Camarillo, CA
Info/Card #179

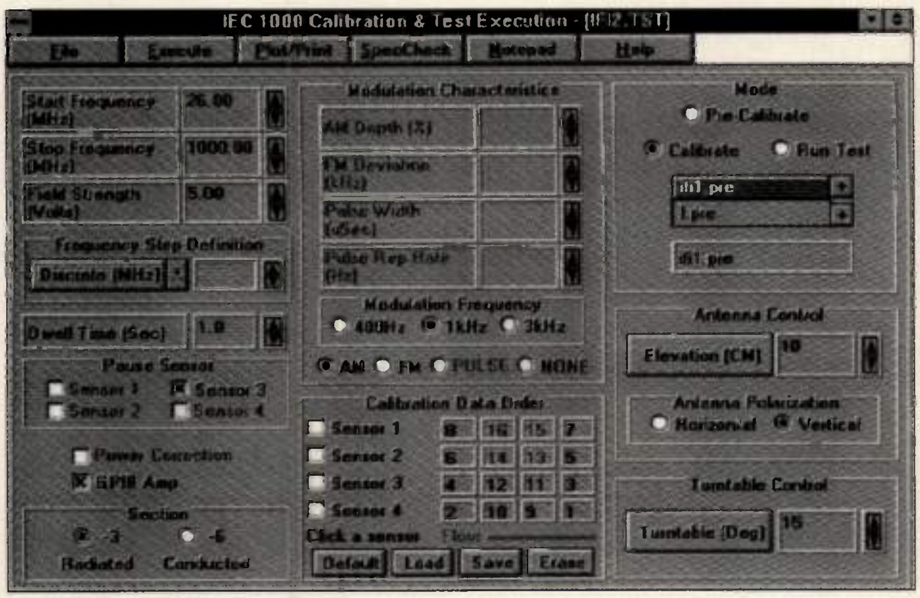
Literature

EMI Gasket Catalog

Spira offers a new catalog on spiral EMI gaskets and shielding products. Sections include: expanded product data sheets, shielding quality information, groove and surface-mounting guidelines, fastener spacing guidelines, corrosion control information, and custom gasket information. Spira's gaskets come in a wide range of diameters as small as 1/32 inch, provided in either tin/lead plated berylliuym copper or low-cost stainless steel.
Spria Mfg. Corp.
North Hollywood, CA
Info/Card #180

ESD Control Products

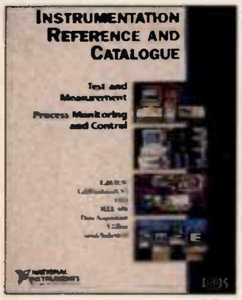
Charleswater has released their 1995 catalog of static control products and ESD training aids. Products include bags, cleaners, conductive paints, foam, foot grounders, ionization products, mats, laminates, floor finishes, ESD test intruments, workstation materials, wrist straps and many other ESD control items. Books, videos, ESD standards publications and field service kits are also offered in this new catalog.
Charleswater
Canton, MA
Info/Card #181



EMC Testing Software

System 55™ from IFI, Inc. provides automated EMC testing, offering the capability of determining whether a test room is calibrated for the IEC-801-3 specification. Calibration time can be reduced from days down to hours. The software also automates IEC-801-6, MIL-STD-461/462 and RTCA/DO-160 testing, and others. System 55 will analyze the data it obtains for the IEC-801-3 16-point E-field uniformity matrix and indicates the pass-fail points. It can gather data on antenna, amplifier, sensor and test room performance, while offering extensive control of the testing environment for test flexibility.
IFI, Inc.
Ronkonkoma, NY
Info/Card #154

ESD Literature & Product Showcase



FREE Instrumentation Reference and Catalog

NATIONAL INSTRUMENTS is providing a 1995 catalog detailing computer-based data acquisition, instrument control and data analysis products. Includes information on exciting new products and technologies such as Plug and PLay boards, Power Macintosh software, Test Executives, SPC and SQL add-ons, HP-UX instrument control, PCMCIA interfaces and VXI*plug&play*. There is also information on customer education classes. Includes tutorials and glossary.

NATIONAL INSTRUMENTS
6504 Bridge Point Parkway • Austin, Texas 78730
(512) 794-0100 • (800) 433-3488 (US and Canada)
Fax: (512) 794-8411

INFO/CARD 100

REDUCE EMI/RFI AND NOISE SPIKES

Micro/Q® 1000 ceramic decoupling capacitors can be retrofitted with no board redesign. They share the same IC mounting holes and fit underneath the DIP-IC. Micro/Q® 1000 saves space and decreases the current loop area, thereby reducing EMI/RFI and noise spikes.

Send for Product Literature

Circuit Components Inc.
2400 S. Roosevelt St.
Tempe. AZ 85282
602/967-0624 Fax: 602/967-9385

INFO/CARD 101

PolyPhaser Cable Grounding Kits

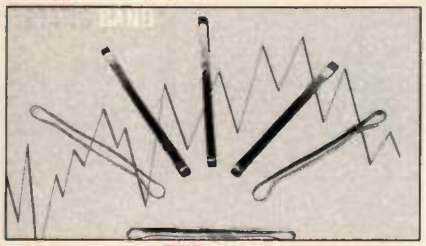
Uni-Kit 2 Cable Grounding Kits come in four variations including copper to copper, copper to tin, tin to tin, and tin to copper

Tests show that PolyPhaser's grounding kits have about half the resistance, inductance and voltage drop of others. Kits fit cables from 1/4" to 2" diameter and ellipticals. Weatherizing materials included.

POLYPHASER CORPORATION
2225 Park Place
P.O. Box 9000
Minden, NV 89423-9000
(702) 782-2511 • Fax: (702) 782-4476

INFO/CARD 102

STATICBAND® HIGH-TEMPERATURE ESD RUBBER BANDS



CONDUCTIVE HI-TEMPERATURE RUBBER BANDS

- IDEAL FOR HOLDING CHIP BOARDS DURING LONG BURN-INS. FOR HOLDING PARTS FOR CONFORMAL COATING OR WHERE HI-TEMPERATURES ARE USED. ALL "STATICBANDS"® ARE REUSABLE, WILL NOT STRETCH, GOOD MEMORY.
- ALL SIZES, CONDUCTIVE, 10/4 OHMS SQ.
- SILICONE, CARBON ADN SILVER TYPES.
- WILL WITHSTAND 500-1000 DEGREES "f" FOR 1 HOURS
- SEND FOR CATALOG AND SAMPLES...

Inventing products to combat ESD...

800-214-7900

ANTISTATIC INDUSTRIES®

ANTISTATIC INDUSTRIES, INC.
130 Gamewell Street, P.O. Box 460
Hackensack, NJ 07602-460 USA
(201) 489-4400 USA/FAX: (201) 489-7654

INFO/CARD 103

N E W

STATICSTIK®

ANTISTATIC INDUSTRIES INC. HACKENSACK, N.J. 07602

STATIC FREE TEFLON® PRODUCTS ESD DEVELOPED BY ANTISTATIC INDUSTRIES

- **Conductive teflon tapes from 1/4" to 36"**
- Can be with a liner or self wound
- 10/5 OHMS square- from .030 to .014
- **Conductive "STATICCOVERS" from .030 to .014**
- Protects work from prying eyes and dust
- 36" x 36" yards, easy to roll and store
- **Conductive teflon tubing from 1/2" to 2" I.D.**
- For volatile gasses and liquids
- High temperature, fire resistant
- ASK ABOUT OUR OTHER ANTI-STATIC TAPES

CALL 210-489-4400 OR FAX TO 201-489-7654 FOR PRICES FOR X-SIZES, CATALOGS, SAMPLES AND PRICES

Inventing products to combat ESD...

800-214-7900

ANTISTATIC INDUSTRIES®

ANTISTATIC INDUSTRIES, INC.
130 Gamewell Street, P.O. Box 460
Hackensack, NJ 07602-460 USA

INFO/CARD 104

STATICPAINT®

ANTISTATIC INDUSTRIES INC. HACKENSACK, N.J. 07602

NEW TUFF/RUFF HI-TENSILE STRENGTH LONGER WEARING QUALITIES WITH KEVLAR®

BRUSH-SPRAY

- MAKE ANY SURFACE ESD SAFE 10/s OHMS/SQ
- CONDUCTIVE PAINT IN ALL COLORS - WHITE TO BLACK
- WATER BASED/ NON-HAZARDOUS/ NON FLAMMABLE
- CONDUCTIVE ACRYLIC-URATHANE-EPOXY
- NEW SEALER AND CONDUCTIVE PAINT FOR FLOORS, CONCRETE, CEMENT, TILES, WOOD IN ALL COLORS
- NEW* CLEAR TRANSLUCENT CONDUCTIVE COATINGS
- ALL "STATICPAINTS" ARE WASHABLE, NO WAX NO STRIPPING...

TWO PART WATER-BASED CONDUCTIVE SYSTEMS

Inventing products to combat ESD...

800-214-7900

ANTISTATIC INDUSTRIES®

ANTISTATIC INDUSTRIES, INC.
130 Gamewell Street, P.O. Box 460
Hackensack, NJ 07602-460 USA
(201) 489-4400 USA/FAX: (201) 489-7654

INFO/CARD 105

STATIC DISSIPATERS *PREVENT* LIGHTNING STRIKES

LIGHTNING PREVENTION SYSTEMS manufactures static dissipaters that when mounted on a structure prevent lightning strikes by bleeding off the lightning attractive static charge that builds up during thunderstorms. For over 10 years now, Lightning Prevention Systems has had it's dissipaters installed on all types of structures such as communications towers, oil tanks, electrical substations, missiles, boats, buildings and all branches of the military to prevent and protect lightning damage.

LIGHTNING PREVENTION SYSTEMS
204B CROSS KEYS ROAD
BERLIN, NJ 08009
(609) 767-7209
Fax (609) 767-7547

INFO/CARD 106

Why Advertise in EMC Test & Design?

The best advertising buy to reach the primary of EMC/ESD products - EMC TEST & DESIGN. No other publication offers EMC's unique approach, improving the effectiveness of your advertising dollar.

Get into the best advertising buy in the EMC/ESD industry - EMC TEST & DESIGN. The only engineering publication in the market.

For more information call (800) 443-4696 or fax to: (404) 618-0342.

Two methods of getting your product through the red tape:

1. Hire him.

ICC

2. Call us.

We are your certification solution.

CERTIFICATED UL AGENCY Administrative

TÜV Rheinland Appointed Laboratory

EMC Laboratory Authorization No. EL-120

0001 ASSESSED LABORATORY

NVLAP

VCCI

International Compliance Corporation

Dallas/Ft. Worth
(817) 491-3696
Fax (817) 491-3699

Austin
(512) 719-3555
Fax (512) 719-4211

Attention. Fast results. Reliable experience... in one stop.

If you need...
● FCC Part 15, Part 68 ● IC for Canada ● AUSTEL Testing
● EU EMC ● Full range of EMC testing ● NVLAP accredited
● Product safety testing to all national and international standards

...we're the source. Schedule-sensitive. Responsive. Knowledgeable. With 27 offices and laboratories around the world. Call **1-800-WORLDLAB**.

Inchcape Testing Services

VTI

VACUUM TECHNOLOGIES, INCORPORATED
EMI Shielding

Elamet Licensee for USA
EMI/RFI Shielding Applied in Vacuum
Industries Served:
- Computer
- Industrial Controls
- Medical Devices
- Telecommunications

U.L. Recognition on Over 100 Substrates
Environmentally Safe Process
Capability to Heat Stake, Ultra-sonic Weld, Pad Print, & Value Added Sub-assembly

608-524-9822
Fax 608-524-9722

1215 Industrial Avenue
Reedsburg, WI 53959

EMC Mart

Place an ad

TODAY!

Call

Wes Hudson

(800) 443-4696

RF CURRENT PROBES FOR EVERY APPLICATION

The current probes you bought from Eaton and Stoddart are available from Tegam, Inc. These current probes feature:

OVER 40 YEARS proven performance in EMI/RFI testing.

OVER 50 MODELS available, including clamp on, fixed window, and surface current probes. Frequency ranges from 20 Hz to 1 GHz and window sizes from .75" to 5".

CUSTOM DESIGN current probes to fit your special requirements.

MILITARY COMPLIANCE: test to MIL-STD-461/A/B/C/D, 462, 462D and RTCA/DO-160.

TECHNICAL ASSISTANCE to help you understand the spec, select the right current probe, and design your test.

FREE! To get a copy of "The How and Why of Bulk Current Injection Testing" and a Current Probe Selection Guide, call:

1-800-666-1010 Ext. 117

Made With Pride In Geneva, Ohio

TEGAM INCORPORATED

Ten Tegam Way • Geneva, Ohio 44041
FAX 216-466-6110

INFO/CARD 69

A Review of the Methods for Obtaining the CE Mark

By Gary A. Breed
Editorial Director

In order to sell products in Europe, all products will soon be required to have the CE mark, indicating compliance with the requirements of all applicable European Directives. For EMC-related compliance, the EMC Directive and its amendments contain most requirements that must be met. Other Directives that contain EMC requirements include Telecommunications Terminal Equipment, Medical Devices, Motor Vehicles, and a few others. The EMC Directive becomes effective January 1, 1996.

In general, the EMC Directive has a practical purpose. It is intended to assure that products do not cause interference (radiated emissions), and that they can operate without disruption to to interference from other sources (immunity). The immunity requirements contained in the European EMC Directive are the first immunity requirements in the world that apply to all electronic products.

Three methods are available for gaining authority to use the CE mark: Self Certification, Technical Construction File and Type Examination. Each method has differing formal requirements and application to individual devices or families of products.

Self-Certification

As the name indicates, self-certification is performed by the manufacturer of the equipment. A Competent Body (an approved testing laboratory) is not necessarily required, but testing according to the applicable standards *is* required, even if it is done in the company's own laboratory. When testing is completed and the product is determined to be in compliance, a Declaration of Conformance is prepared and included with the product, either on the warranty card or in the manual. Product testing records must be maintained for ten years.

The advantage of Self-Certification is simplicity: a manufacturer that is confident that the product meets all requirements, and has performed sufficient testing to confirm compliance, can simply write the Declaration of Conformance, apply the CE mark and sell the product.

There are two principle disadvantages. The first is that each product and product variant must have its own test sequence and record. If a company makes a large number of similar products, the extra time and cost of separate tests may be excessive (see the next method). The other disadvantage is that, in the case of a complaint or challenge to a product's compliance, the company alone carries the burden of proof. This, of course, is also the factor that prevents companies from falsely claiming Self-Certification and using the CE mark without proper testing; the cost of cheating will be high!

Technical Construction File

This type of certification establishes that the products have been designed and constructed in a manner that assures compliance with EMC standards. Technical product details, usually including testing, are gathered in a design procedure file. This file is reviewed by a Competent Body which may or may not perform additional testing. When the Competent Body approves, the Declaration of Conformance can be prepared and the product sold with the CE mark.

The advantage of a Technical Construction File is that a family of similar products can be covered in one file, which can mean significant overall savings in cost and testing time to some companies. Also, the approval of a Competent Body brings a higher

Obtaining the CE Mark

level of confidence to consumers and enforcers of EMC requirements. It is likely that this method will be considered "stronger" than self-certification, and will be used by some companies to present an image of higher quality.

The disadvantage is cost and complexity. Documentation includes considerably more information than compliance testing results. In addition, the use participation of an outside party (the Competent Body) can significantly increase the time and cost required to complete the approval process.

Type Examination

This method certification is primarily reserved for very high importance products with the potential for widespread EMC effects. Radio and television transmitters are probably the main subjects for Type Examination. This method parallels current methods for approving these types of equipment. For many years, numerous countries have had separate performance requirements for communications transmitters. In some cases, these separate requirements are being maintained, but they are modified to use the EMC Directive as the defining standard for the EMC portion of those performance standards. Type examination is performed by a Notified Body, which may be a national regulatory agency or a testing laboratory specifically designated to act on the agency's behalf.

Summary

Obtaining the authorization to affix the CE mark and sell a product in Europe has three routes (two for most products). The early debate over potential protectionism through difficult certification procedures has ended with the clarification of the above procedures. Of most concern is the potential difficulty in achieving compliance with the EMC standards. The emissions standards are similar to those of the VDE and other individual countries, but the immunity standards include radiated and conducted RF, ESD, EFT and surge requirements that are completely new to most companies. It is the goal of the European Community to have more robust electrical and electronic products enter their markets, to avoid most problems due to interference and common powerline disturbances.

Future Trends

Countries around the world will be observing the operation of the European Union compliance process. Most developed countries have made some commitment to harmonization of regulations; not only for EMC, but for safety and other areas, as well. Especially important is immunity testing and compliance. In this area, Europe has taken the lead, forcing electronics manufacturers to make their products resistant to the detrimental effects of external fields and currents. ⏚

Advertising Index

INCO *VaporFab*™ Nickel Coated Fibers

The INCO *VaporFab* family of conductive nickel coated carbon fibers is produced in a proprietary fiber coating process at INCO's modern nickel refinery operations. The coating process yields several unique advantages. The nickel layer is very uniform, with extremely thin film coating. It provides for controllable conductivity, retained mechanical integrity, ease of handling and processing benefits.

Here are just a few applications for this new product from INCO. The *VaporFab* family of conductive nickel coated fibers provides exceptional shielding properties of electromagnetic and radio frequency interference when used in injection molding composites. It is well-suited for metal matrix composites, providing property improvement, fiber matrix wetting and processibility. And, *VaporFab* conductive nickel coated fiber provides lightning strike protection for composite structures.

For more information on this remarkable new product from INCO Specialty Powder Products, call or fax us today.

INCO SPP

681 Lawlins Road, Wyckoff, New Jersey 07481 USA, 201-848-1012 (Fax 201-848-1022)

Shin-Muromachi Building, 4-3, Nihonbashi-Muromachi 2-chome, Chuo-ku, Tokyo 103 Japan, 3-3245-0621 (Fax 3-3245-0628)

5th Fl., Windsor House, 50 Victoria St., London SW1H 0XB United Kingdom, 71-932-1505 (Fax 71-931-0175)

15/Fl Wilson House, 19-27 Wyndham Street Central, Hong Kong, 521-2333 (Fax 810-1965)

Royal Trust Tower, Toronto-Dominion Centre, Toronto, Ontario M5K 1N4, Canada, 416-361-7778 (Fax 416-361-7659)

Microstrip Coupled-Line Bandpass Filter Synthesis and Analysis Program

By Sean R. Mercer, Ph.D., Racal Canada,
Eric Mabada, University of Cape Town

Program BPF.BAS greatly simplifies the task of microstrip coupled-line bandpass filter design. Simply enter the desired performance characteristics of your filter and the program will synthesize the dimensions of the filter to meet the specified criteria. A simple analysis procedure provides tabular and graphical output and you can generate a file for HP-EEsof's Touchstone or Compacts Software's Super-Compact for further analysis. Filters synthesized using this program are, however, accurate enough to be used in many applications without any modification.

The process of filter synthesis using LC ladder or impedance inverter prototypes is well understood and there are many excellent texts describing the design or development of these filters [1,2,3,4]. The development of microstrip synthesis procedures for resonators such as coupled lines [5] has made it possible to create microstrip filters based on the prototype filters. The use of Chebychev prototype filters to create microstrip coupled line filters has been well documented [6]. However, this design procedure is a lengthy one, and an automated technique is preferable. Program BPF.BAS is coded in QBASIC and provides an automated solution to the design of microstrip coupled-line bandpass filters.

Both series and parallel resonators would be required to directly realize a bandpass filter from an LC ladder prototype filter. A microstrip resonator topology (coupled lines) can be arranged to exhibit either series or parallel resonance. Different resonator topologies are required for series and parallel resonators. However, if an impedance-inverter coupled lowpass prototype filter is used for bandpass filter synthesis, only one type of resonator is required. This greatly simplifies the filter topology by eliminating the need for shorted conductors and the associated complications with modeling and fabrication.

One of the factors limiting the achievable bandwidth with a coupled line filter is the amount of coupling possible between the lines forming the resonators. End-coupled or parallel-coupled lines are realizable in microstrip. The parallel-coupled line topology offers greater coupling than the end coupled line topology. Wider bandwidth designs are therefore possible with the parallel-coupled line topology.

The bandwidth performance of this coupled line bandpass filter topology is limited by realizable resonators. When the required bandwidth exceeds 15 percent it is often not possible to realize microstrip coupled-line resonators with the required odd and even mode impedance values. For this reason, this microstrip filter topology is usually limited to designs requiring less than 15 percent bandwidth. However,

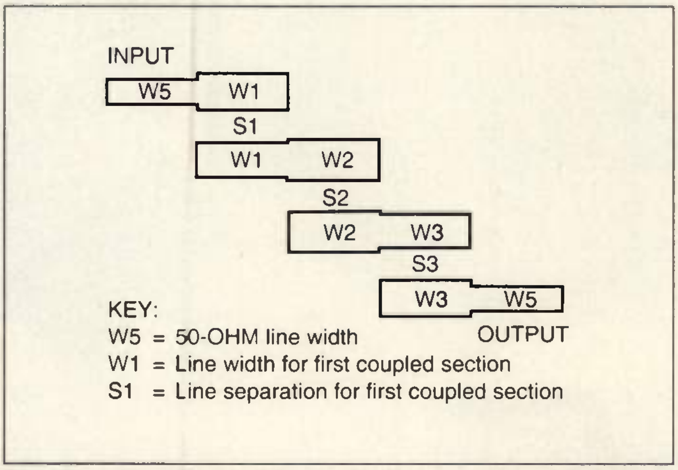


Figure 1. Bandpass filter with three coupled line sections.

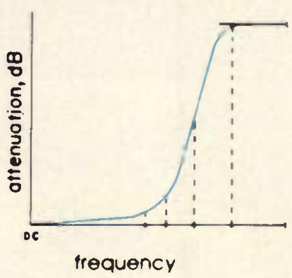
```
ENTER THE DESIRED FILTER PERFORMANCE CHARACTERISTICS
=====================================================
PASSBAND RETURN LOSS     in dB     ? 20
STOPBAND REJECTION       in dB     ? .40
SELECTIVITY                        ? 1.6

ENTER THE FILTER CENTRE FREQUENCY AND 3 dB BANDWIDTH
=====================================================
Filter centre frequency in GHz ?   8
Filter 3 dB bandwidth in GHz  ?    .8

ENTER THE SUBSTRATE PARAMETERS
==============================
Substrate thickness      h  [mm]   .635
Dielectric constant      Er        9.9
Conductor thickness      T  [mm]   .004
```

Figure 2. Sample input data for the program.

RF/IF Designer's Guide
RF IF Designer's Handbook

dc to 3GHz from $11.45

LOW PASS



low pass, Plug-in, dc to 155MHz

Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB
•★LP-1.9	DC-1.9	3.4-4.7	4.7-200
•★LP-2.5	DC-2.5	3.8-5.0	5.0-200
★LP-5	DC-5	8-10	10-200
★LP-10.7	DC-11	19-24	24-200
★LP-21.4	DC-22	32-41	41-200
★LP-30	DC-32	47-61	61-200
★LP-50	DC-48	70-90	90-200
★LP-70	DC-60	90-117	117-300
★LP-90	DC-81	121-157	157-400
★LP-100	DC-98	146-189	189-400
★LP-150	DC-140	210-300	300-600

dc to 1200MHz

Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB
★LP-200	DC-190	290-390	390-800
★LP-250	DC-225	320-400	400-1200
★LP-300	DC-270	410-550	550-1200
★LP-450	DC-400	580-750	750-1800
★LP-550	DC-520	750-920	920-2000
★LP-600	DC-680	840-1120	1120-2000
★LP-750	DC-700	1000-1300	1300-2000
★LP-800	DC-720	1080-1400	1400-2000
★LP-850	DC-780	1100-1400	1400-2000
★LP-1000	DC-900	1340-1750	1750-2000
★LP-1200	DC-1000	1620-2100	2100-2500

All models priced qty. 1-9 ($ea.), Conn. Type P = 11.45, B = 32.95, S = 34.95, N = 35.95
• Exceptions: ★LP-1.9 P = 13.95, B = 34.95, ★LP-2.5 P = 14.95 B = 35.95
On both models, add following to B price: $3.00 for N, $2.00 for S
75 ohm versions available

Surface-mount

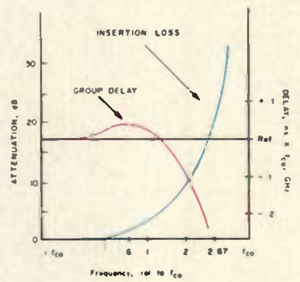
dc to 108MHz

SCLF-5	DC-5.0	8-10	10-200
SCLF-8	DC-8.0	12.5-16.5	16.5-200
SCLF-10.7	DC-11	19-24	24-200
SCLF-21.4	DC-22	32-41	41-200
SCLF-25	DC-25	36-47	47-200
SCLF-30	DC-30	47-61	61-200
SCLF-45	DC-45	70-90	90-200
SCLF-95	DC-95	146-189	189-400

dc to 1200MHz

SCLF-135	DC-135	210-300	300-600
SCLF-190	DC-190	290-390	390-800
SCLF-225	DC-225	340-440	440-1200
SCLF-380	DC-380	580-750	750-1800
SCLF-420	DC-420	750-920	920-2000
SCLF-550	DC-550	800-1050	1050-2000
SCLF-700	DC-700	1000-1300	1300-2000
SCLF-1000	DC-1000	1620-2100	2100-2500

Price: SCLF 21.4–SCLF 420 $11.45 ea. SCLF-8, 10.7, 550, 700, 1000 $12.95 ea. SCLF-5 $14.95 Qty. (1-9)

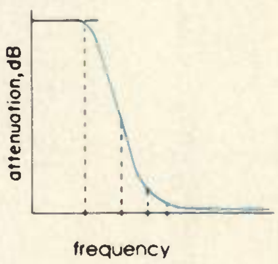


Flat Time Delay, dc to 1870MHz

Model No.	Passband MHz loss < 1.2dB	Stopband MHz loss >10dB	Stopband MHz loss >20dB	VSWR Freq. Range, DC thru 0.2fco X	VSWR Freq. Range, DC thru 0.6fco X	Group Delay Variations, ns Freq. Range, DC thru fco X	2fco X	2.67fco X
★BLP-39	DC-23	78-117	117	1.3:1	2.3:1	0.70	4.0	5.00
★BLP-117	DC-65	234-312	312	1.3:1	2.4:1	0.35	1.4	1.90
★BLP-156	DC-94	312-416	416	1.3:1	1.1:1	0.30	1.1	1.50
★BLP-200	DC-120	400-534	534	1.6:1	1.9:1	0.40	1.3	1.60
★BLP-300	DC-180	600-801	801	1.25:1	2.2:1	0.20	0.6	0.80
★BLP-467	DC-280	934-1246	1246	1.25:1	2.2:1	0.15	0.4	0.55
▲BLP-933	DC-560	1866-2490	2490	1.3:1	2.2:1	0.09	0.2	0.28
▲BLP-1870	DC-850	3740-5000	5000	1.45:1	2.9:1	0.05	0.1	0.15

Price, (1-9 qty), all models: plug-in $19.95, BNC $36.95, SMA $38 95, Type N $39.95
NOTE: ▲ -933 and -1870 only with N and SMA connectors.

HIGH PASS



high pass, Plug-in, 13 to 1200MHz

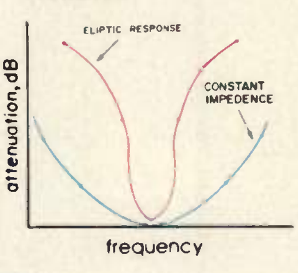
Model No.	Stopband MHz loss > 40dB	Stopband MHz loss > 20dB	Passband, MHz loss < 1dB	VSWR Passband Typ.
★HP-25	DC-13	13-19	27.5-200	1.7:1
★HP-50	DC-20	20-26	41-200	1.5:1
★HP-100	DC-40	40-55	90-400	1.5:1
★HP-150	DC-70	70-95	133-600	1.8:1
★HP-175	DC-70	70-105	160-800	1.5:1
★HP-200	DC-90	90-116	185-800	1.6:1
★HP-250	DC-100	100-150	225-1200	1.3:1
★HP-300	DC-145	145-190	†290-1200	1.7:1

210 to 2200MHz

Model No.	Stopband MHz loss >40dB	Stopband MHz loss > 20dB	Passband, MHz loss < 1dB	VSWR Passband Typ.
★HP-400	DC-210	210-290	395-[illegible]	1.7:1
★HP-500	DC-280	280-365	500-[illegible]	1.9:1
★HP-600	DC-350	350-440	[illegible]-1600	2.0:1
★HP-700	DC-400	400-520	700-1800	1.6:1
★HP-800	DC-445	445-570	780-2000	2.1:1
★HP-900	DC-520	520-660	910-2100	1.8:1
★HP-1000	DC-550	550-720	1000-2200	1.9:1

Price, (1-9 qty), all models: plug-in $14.95, BNC $36.95, SMA $38.95, Type N $39.95. For ★HP-25, Add $2 ea. †Loss 1.5 dB max.

BANDPASS



bandpass, Elliptic Response, 10.7 to 70MHz

Model No.	Center Freq. (MHz)	Passband I.L. 1.5 dB Max. (MHz)	3 dB Bandwidth Typ. (MHz)	Stopbands I.L. > 20dB at MHz	Stopbands I.L. > 35dB at MHz
★BP-10.7	10.7	9.5-11.5	8.9-12.7	7.5 & 15	0.6 & 50-1000
★BP-21.4	21.4	19.2-23.6	17.9-25.3	15.5 & 29	3.0 & 80-1000
★BP-30	30.0	27.0-33.0	25-35	22 & 40	3.2 & 99-1000
★BP-60	60.0	55.0-67.0	49.8-70.5	44 & 79	4.6 & 190-1000
★BP-70	70.0	63.0-77.0	58.0-82.0	51 & 94	6.0 & 193-1000

Price, (1-9 qty), all models: plug-in $18.95, BNC $40.95, SMA $42.95, Type N $43.95

Constant Impedance, 21.4 to 70MHz

Model No.	Center Freq. MHz	Passband MHz loss < 1dB	Stopband loss > 20dB at MHz	VSWR 1.3:1 Total Band MHz
★IF-21.4	21.4	18-25	1.3 & 150	DC-220
★IF-30	30.0	25-35	1.9 & 210	DC-330
★IF-40	42.0	35-49	2.6 & 300	DC-400
★IF-50	50.0	41-58	3.1 & 350	DC-440
★IF-60	60.0	50-70	3.8 & 400	DC-500
★IF-70	70.0	58-82	4.4 & 490	DC-550

Price, (1-9 qty), all models: plug-in $14.95, BNC $36.95, SMA $38.95, Type N $39.95

NOTE: **★Add Prefix P, B, N, or S for Pin, BNC, N, or SMA connector requirement.**

INFO/CARD 74

Mini-Circuits®
P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

CUSTOM PRODUCT NEEDS...*Let Our Experience Work For You.*

F 200 Rev Orig

SUBSTRATE parameters used were :
==============================

DIELECTRIC THICKNESS	=	0.635 mm
CONDUCTOR THICKNESS	=	0.0004 mm
PERMITTIVITY ER	=	9.90

REQUIRED FILTER DEGREE = 8

WIDTH of a 50 Ohm feed line is 0.614 mm.

PRESS ANY KEY TO VIEW FILTER DIMENSIONS

Figure 3a. Synthesized filter parameters - page 1.

CALCULATED COUPLED LINE DIMENSIONS in mm
==

WIDTH	SPACING	LINE LENGTH
0.567	0.090	3.542
0.771	0.553	3.436
0.779	0.77	3.421
0.781	0.830	3.419
0.781	0.842	3.418
0.781	0.830	3.419
0.779	0.777	3.421
0.771	0.553	3.436
0.567	0.090	3.542

PRESS ANY KEY TO VIEW FILTER DIMENSIONS

Figure 3b. Synthesized filter parameters - page 2.

there are techniques available to improve the bandwidth performance of this type of filter [8,9].

A diagram of a parallel coupled line microstrip bandpass filter with three coupled sections is shown in Figure 1. The conductor widths and spacings are clearly shown.

The effects of dispersion in microstrip and the frequency dependence of the microstrip effective permittivity ε_{eff}, are also calculated in this program [7] to improve the accuracy of the calculated filter conductor dimensions.

An overview of the method used in program BPF.BAS to synthesize microstrip parallel coupled line bandpass filters is given below:

1. Specify the filter design parameters.
2. Determine the required filter order.
3. Calculate the impedance inverter prototype filter values.
4. Calculate the required odd and even mode impedances for the coupled line resonator sections.
5. Synthesize the coupled line resonator sections by determining the strip width to substrate thickness (w/h) and strip separation to substrate thickness (s/h) ratios for each resonator. An iterative technique is used to determine the final line widths and spacings for the coupled line sections.
6. Output the computed filter dimensions.

Program Operation

The user is prompted to enter the desired filter characteristics, namely passband return loss, stopband rejection and selectivity. Filter selectivity is defined as the bandwidth at which the desired stopband attenuation is achieved divided by the filter 3 dB bandwidth. The desired filter center frequency and 3 dB bandwidth are also entered. The substrate dielectric thickness, dielectric constant and conductor thickness are the final inputs required before filter synthesis will begin.

Typical input data for the program is shown in Figure 2. The data shown in Figure 2 represents a filter with 10 percent bandwidth with a center frequency at 8 GHz. The substrate parameters are for 0.635 mm (25 mil) alumina with $\varepsilon_r = 9.9$.

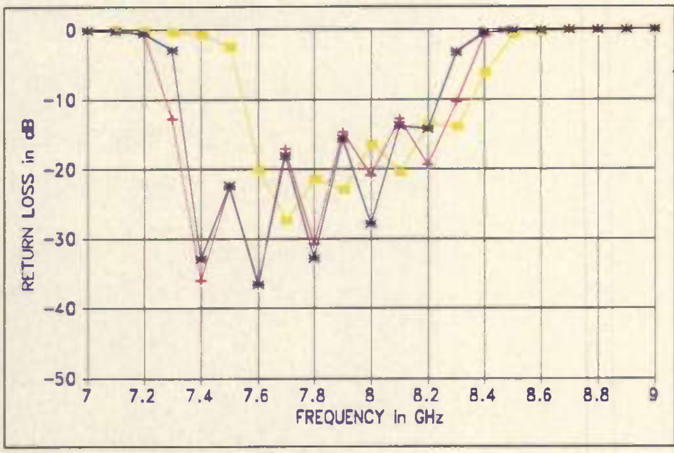


Figure 4a. Filter return loss.

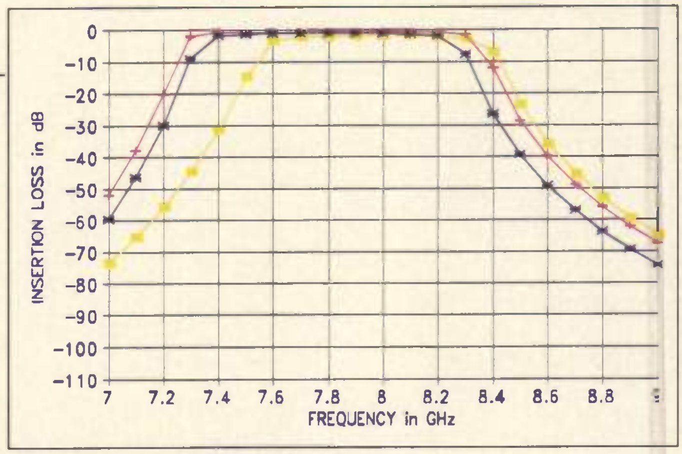


Figure 4b. Filter insertion loss.

The required number of resonators is then calculated and the impedance inverter prototype filter values are determined. The odd and even mode characteristic impedances for the parallel-coupled microstrip resonators are then computed. The line width to substrate height (w/h) and strip separation to substrate height (s/h) ratios are calculated for each resonator. An iterative technique is used to determine the final value for the s/h ratio for each resonator.

Program output consists of the number of resonators and the strip parameters of width, length and separation. The width of a 50 ohm line, used as input and output feed lines, is also computed for convenience.

A simple analysis of the filter performance over a user selected frequency range and step width is computed by multiplying the transfer matrices of the coupled line resonators together. The final "ABCD" transfer matrix for the filter is used to compute the insertion loss, return loss and group delay of the filter at each frequency point. The use of "ABCD" transfer matrix parameters is explained in detail in [1,4] and [10]. The analysis method used here is similar to a previously published routine [11].

The user can opt to analyze the filter performance over a number of different frequency ranges before viewing graphs of data over the last frequency range selected. The synthesized filter dimensions and all tabular listings of analysis data for all selected frequency points are written to a text file. This text file has a default name of "RESULTS.TXT" that can be changed by the user if desired.

The synthesized filter data are outputted on two screen pages and to the "RESULTS.TXT" file. The results calculated by the program for the input data given in Figure 2 are shown in Figure 3a and Figure 3b.

Comparison of Results with Proprietary Analysis Packages

Tabular and graphical output of return loss, insertion loss and group delay is provided over the user defined frequency range. This analysis is approximate and we suggest using a comprehensive analysis package such as Touchstone or Super-Compact to verify the filter performance if a center frequency accuracy of better than 1.5 percent is required. To this end, the program will generate either a Touchstone or a Super-Compact ".CKT" file for the user. These analysis packages consider the open-end effects of the open circuit resonators and the effects of step discontinuities in the filter structure.

Graphical outputs from program BPF.BAS, Touchstone and Super-Compact are compared in Figure 4a and Figure 4b. These results are for the filter data shown in Figure 2, Figure 3a and Figure 3b. The data indicates that the actual filter center frequency is slightly lower than that predicted by the simple analysis procedure in program BPF.BAS. This is largely due to the superior modeling of the open-ended line effect and step discontinuities included in the Touchstone and Super-Compact filter analysis.

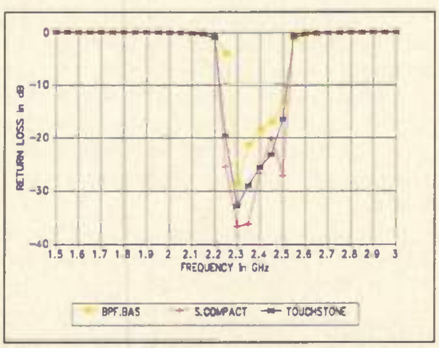


Figure 5a. Return loss for 2.4 GHz filter

Further results for filters of different bandwidths are shown in Figures 5a and 5b and Figures 6a and 6b. A 0.635 mm (25 mil) softboard substrate with ε_r = 10.5 was used for the design shown in Figure 5 and a 0.635 mm (25 mil) alumina substrate with ε_r = 9.9 was used for the design shown in Figure 6. It is clear that program BPF.BAS produces results that are within 2 percent accuracy of the proprietary analysis packages.

It is a simple matter to optimize the lengths of the open circuit resonators to shift the resonant frequency upwards by 1 - 2 percent. A filter with passband center frequency of 9 GHz was constructed using 0.635 mm (25 mil) Alumina with ε_r = 9.9. The filter was modeled using the same Touchstone model that is generated by program BPF.BAS. The actual filter center frequency was within 1.2 percent of that predicted by Touchstone.

It can be seen from the above information that, for many applications, program BPF.BAS is more than accurate enough to produce filters without the need for checking with one of the proprietary analysis packages.

Computer Requirements and Program Run Time

The program BPF.BAS will run

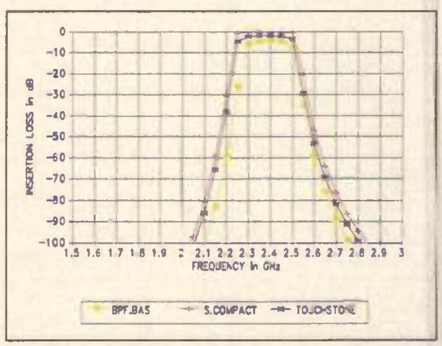


Figure 5b. Insertion loss for 2.4 GHz filter

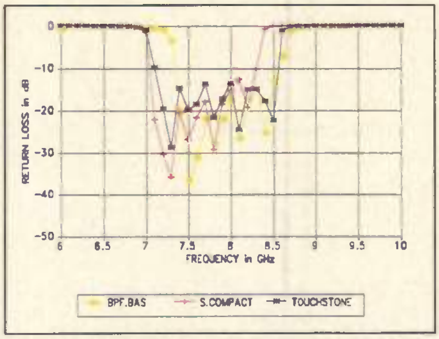


Figure 6a. Return loss for 8 GHz filter with 15% bandwidth

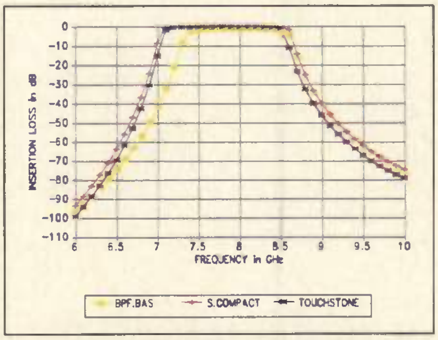


Figure 6b. Insertion loss for an 8 GHz filter with 15% bandwidth.

under DOS version 5 or later (QBASIC interpreter). VGA (or better) graphics are required. The computation time to synthesize the coupled line sections varies depending on the required filter order and bandwidth. On a 486DX2-66 PC the approximate computation time for the filter specified in Figure 1 (eight coupled line sections) is eighteen seconds.

Some Practical Hints

The first and last coupled line sections of a bandpass filter of this type are usually tightly coupled. This means that the coupling gaps between these conductors are relatively small. If you are working on softboard or PCB material, ensure that the chosen conductor thickness and fabrication process are suitable for achieving repeatable results with the required conductor and gap dimensions. Remember that thick conductors are prone to undercut in the etching process and filter response is sensitive to changes in the gaps between the printed lines.

The bandwidth of a parallel coupled line section filter is very sensitive to the separations of the first and last coupled line sections. The filter bandwidth can be reduced by slightly increasing the separation of these line sections.

The filter center frequency is strongly influenced by the length of the coupled line resonators. The analysis models used in a Touchstone or Super-Compact simulation are more accurate than the method used in this program. It is normal to see a slight difference in predicted filter center frequency when comparing those packages to this less accurate program. If the resonator lengths are optimized using either of the above proprietary packages it is possible to shift the filter passband to the desired center frequency.

A word of caution to the inexperienced designer. All of the analysis methods mentioned above predict very high values of stopband attenuation at frequencies far from the passband. In practice, however, it is very difficult to achieve isolation greater than 70 dB [12]. This high practical value of isolation usually requires excellent mechanical isolation and very careful attention to circuit layout.

Concluding Remarks

Program BPF.BAS provides quick and accurate synthesis of microstrip coupled line bandpass filters. The designs are accurate enough to use without modification in many applications but results can easily be compared to those from expensive proprietary packages.

Acknowledgement

The authors would like to thank M. Zeeman for assisting with the preparation of the diagrams for this article.

RF

References

1. Matthaei, G.L., Young, L. and Jones, E..M.T., *Microwave Filters, Impedance Matching Networks and Coupling Structures*, Artech House, 1980.
2. Zverev, A.I., *Handbook of Filter Synthesis*, John Wiley & Sons, 1967.
3. Malherbe, J.A.G., *Microwave Transmission Line Filters*, Artech House, 1979.
4. Helszajn, J., *Synthesis of Lumped Element, Distributed and Planar Filters*, McGraw - Hill Book Company, 1990.
5. Akhtarzads, S., Rowbotham, T.R, Johns, P.B, "The design of coupled microstrip lines", *IEEE Trans. on MTT-23*, No 6, June 1975, pp 486-492.
6. Edwards,T.C., *Foundations for Microstrip Circuit Design* Wiley, Chichester, 1981, pp 221 - 228.
7. Hoffman,R.K., *Handbook of Microwave Integrated Circuits* Artech House, 1987, pp 247 - 248.
8. Minnis, B.J., "Printed Circuit Coupled-Line Filters for Bandwidths up to and Greater than an Octave.", *IEEE Trans. on MTT-29*, no.3, March 1981, pp 215-222.
9. Kompa, G., Mehran, R., "Microstrip filter analysis using a microstrip waveguide model", *Radio and Electronic Engineer*, 50, No.1/2, January / February 1980, pp 54-58.
10. Bahl, I., Bhartia, P., *Microwave Solid State Circuit Design*, Wiley, 1988, Appendix 3.
11. Trinogga, L.A., Kaizhou, G., Hunter, I.C., *Practical Microstrip Circuit Design*, Ellis Horwood, 1991, pp 195 - 196.
12. Howe, H., *Stripline Circuit Design*, Artech House, 1974, pg 304

About the Authors

Sean Mercer is a Principal RF Engineer at Racal Canada, where he is currently involved in the design of HF transceivers covering 1.6 to 30 MHz. Previously he was a Development Engineer in the Microwave and Avionics Group, Technology Division, Plessey Tellumat South Africa Ltd. He received his BSc(Elec.Eng) from the University of Cape Town (UCT) in 1986, MSc(Eng) from UCT in 1987 and PhD(Eng) from UCT in 1990. He is a Member of the Institution of Electrical and Electronics Engineers (MIEEE) and an Associate Member of the Institution of Electrical Engineers (AMIEE). He can be contacted at Racal Canada, 1495 Franklin St., Vancouver, V5L 5B6. He can be contacted by phone at (604) 254-6411 x341, and by fax at (604) 254-2080.

Eric Mabada received his BSc(Elec.Eng) from the University of Cape Town in 1993. He is currently working towards his MSc(Eng) at UCT. He can be reached at the University of Cape Town, Department of Electrical Engineering, Private Bag, Rondebosch, 7700, South Africa.

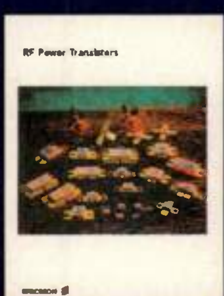
Now, A Worldwide Opportunity for Ericsson RF Components.

The world now has the opportunity to design-in Ericsson RF Components worldwide. The worldwide partnership between Ericsson RF Components and Richardson Electronics means you'll have access to RF design support and an extensive inventory of Ericsson products that you may never have had before. With Richardson, you'll receive personal RF design engineering support and a worldwide distribution network with nearly 50 years experience delivering products in the time the market demands.

For PCN, cellular and TV linear applications, Ericsson's RF power products are proven reliable, high-performance devices. Ericsson's ISO 9001-certified manufacturing process ensures its RF power products produce the highest gain and optimal linearity.

You may now refer to our Internet address (http://www.rell.com) for specifications on Ericsson's newest RF products. Contact Richardson Electronics today and let us bring you the world of Ericsson RF Components.

To Receive a copy of the Ericsson Data Book please fax, call or circle this inquiry number.



Richardson Electronics, Ltd. ERICSSON

(800) RF POWER in the U.S.

More than 50 locations worldwide to serve you - U.S. Toll Free (800) RF Power/ (800) 737-6937, Canada Toll Free: (800) 348-5580; Internet: http://www.rell.com, France: (1) 34.26.4000, Germany: Puchheim (089) 800 21 3-1, Hamburg (040) 555 88 4-0, Italy: Sesto Fiorentino (FI) (055) 420.10.30, Milano (02) 331.04.220, Rome (06) 417.33.751, Scandinavia: Sweden (0) 18 386900, Spain: Madrid (1) 528 37 00, Barcelona (3) 415 83 03, United Kingdom: Lincoln (01522) 542631, Slough (01753) 733010, Japan: (3) 3874-9933, Singapore: (65) 744-2128, Taiwan: 886-2-7269258, European Corporate Headquarters: Netherlands 020-6919148, Fax 020-6919378, U.S. Corporate Headquarters: LaFox, IL (708) 208-2200, Fax (708) 208-2550.

See us at RF EXPO EAST Booth# 316

INFO/CARD 90

Products Featured at RF Expo East

VXI Spectrum Analyzer

Morrow Technologies announces the new V9054 VXI Spectrum Analyzer, a "C" size, message-based instrument with coverage to 1.6 GHz; fully synthesized, with an amplitude range of –120 to +20 dBm.
Morrow Technologies
Booth 600
Info/Card #155

Ceramic Components for GPS

Patch antennas and bandpass filters for GPS frequencies are featured by Trans-Tech. Two and three-pole bandpass filters are available with bandwidths of 10 to 45 MHz at 1575 and 1227 MHz.
Trans-Tech
Booth 512
Info/Card #156

Power Transistors

New RF power transistors from Ericsson are featured by Richardson Electronics, their worldwide distributor. Model PTB20071 provides 21 watts with 9.5 dB gain at 1800-2000 MHz; PTB20081 offers 150 watts and 9.5 dB gain at 470-860 MHz, and PTB20017 provides 150 watts and 11 dB gain in the 860-900 MHz band.
Richardson Electronics, Ltd.
Booth 316
Info/Card #157

Digital Filters

Low cost over sampling filters, serial digital cable simulators, and fully filtered digital-to-analog converters are featured by Sterling Technology.
Sterling Technology
Booth 206
Info/Card #158

Custom Hermetic Packages

The BALO FLEX-A-PAC allows you to put together a custom hermetic microelectronic package. High thermal conductivity floor is expansion matched to Alumina or GaAs. Numerous feed-through connection options are offered.
Balo Hermetics Co.
Booth 507
Info/Card #159

SMT-Packaged Receivers

RFM's line of amplifier-sequenced hybrid (ASH) receivers come in SMT packages that are just 0.54 × 0.37 × 0.10 inch. The UHF receivers feature –102 dBm sensitivity, drawing only 1.1 mA from a 3 VDC supply. First frequencies offered are 303.825 and 433.92 MHz.
RF Monolithics, Inc.
Booth
Info/Card #160

MCX Connector Family

E.F. Johnson introduces the MCX family of connectors, 30 percent smaller than SMB connectors, for high-density packaging. Snap-on mating and crimpable contacts provide fast connector assembly.
E.F. Johnson Company
Booth 320
Info/Card #161

Schematic Editor for Simulators

Serenade Schematic 3.0 for Windows® integrates with Compact Software's PC-based simulators to provide high-frequency

THE WORLD'S LARGEST SELECTION

POWER SPLITTERS/ COMBINERS

2kHz-10GHz from $2.95

Choose from over 480 standard off-the-shelf models from 2-way to 48-way; 0°, 90° and 180°; 50 and 75 ohms; covering 2kHz to 10GHz. Mini-Circuits will also supply your special needs such as wider bandwidths, higher isolation, lower insertion loss, and phase matched ports...all at catalog prices with rapid turnaround time. Models include surface mount, plug-in, flat-pack and standard connectorized designs such as SMA, N, TNC, C, and F connectors as well as custom designs. Ultra-miniature surface mount units provide excellent solutions in cellular communications, cable systems and countless wireless applications. All units come with a 1year guarantee and "skinny" 4.5 sigma repeatability unit-to-unit and production run to production run.
Catalog models are guaranteed to ship within one week.

Mini-Circuits...we're redefining what VALUE is all about!

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

CUSTOM PRODUCT NEEDS...Let Our Experience Work For You.

F 202 Rev Orig

INFO/CARD 80

design support and analysis. A user-configurable toolbar and the ability to launch simulators directly from the editor are new features to ease the designer's task.
Compact Software
Booth 400
Info/Card #162

Wideband Digital Tuner

Sigtek announces the ST-105 wideband tuner, demodulator and bit sync, IBM AT compatible with Windows® user interface. Supports data rates of 2400 symbols/sec to 2.048 symbols/sec, with BPSK, QPSK, OQPSK and DPSK demodulation. Tuning resolution better than 0.5 Hz.
Sigtek, Inc.
Booth 602
Info/Card #163

Semiconductors for Wireless

M/A-COM announces the MD54-0001, the first in a series of passive GaAs mixers with the performance of a diode ring, but in a low-cost SOIC-8 plastic package. Also introduced is the MA4T6325 low voltage, high f_T silicon transistor for 3 V battery operation, featuring 1.5 dB NF at 1 GHz.
M/A-COM
Booth 401
Info/Card #164

Phase-Locked Multipliers

Techtrol Cyclonetics introduces the PLX800 series and PLX1400 phase locked multiplier products. The PLX1400 featured a noise floor of –130 dBc at 50 kHz offset at X-band frequencies.
Techtrol Cyclonetics, Inc.
Booth 417
Info/Card #165

Integrated Software Package

Eagleware has released GENESYS, an integrated set of programs to assist analog, RF and microwave circuit designers. A high-speed linear circuit simulator is included, along with synthesis tools and a schematic interface.
Eagleware
Booth 518
Info/Card #166

Microwave Power Amplifiers

Broadband power amplifiers covering 1-18 GHz using 200-watt TWTs are available in four models from Amplifier Research. Full monitoring, protection and IEEE interface capabilities are included.
Amplifier Research
Booth 500
Info/Card #167

INFO/CARD 86

SPANNING THE DECADES

HIGH POWER DIRECTIONAL COUPLERS

OUTSTANDING PERFORMANCE

100% HIGH POWER BURN-IN

HIGH AVERAGE POWER RATINGS

OVER 1500 MODELS AVAILABLE

FREQ. RANGE 0.01-2000 MHz

HIGH POWER COMPONENTS

SINCE 1965

PERFORMANCE SPECIFICATIONS

MODEL NO.	FREQUENCY MHz	COUPLING dB	DIRECTIVITY dB	POWER WATTS
C2630	0.01-1000	40	20	100
C1460	0.01-250	50	20	2Kw
C3271	80-1000	50	20	1.5Kw
C2717	1-30	70	35	100Kw
C2868	30-100	60	20	50Kw

WERLATONE BROADBAND DIRECTIONAL COUPLERS OFFER NO COMPROMISE

HIGH POWER MULTI-OCTAVE PERFORMANCE

Call us today for product information and your application needs.

WERLATONE
DECADES AHEAD

WERLATONE INC.
P.O. Box 47, Brewster, New York 10509
Telephone: (914) 279-6187
FAX: (914) 279-7404

RF marketplace

Classified display ads are available at $115 per column inch. Frequency rates available for multiple insertions. Please call for further information, 1-800-443-4969, ask for Shannon Shuman. Or fax your ad copy for a rate quote to (404) 618-0342.

CAREER OPPORTUNITIES

GO BEYOND LIMITS.

RIDE OUR AIRWAYS TO THE TOP.

L.A. Cellular, Southern California's premier cellular telephone service provider, is on a mission. We are once again making amazing technological breakthroughs. But we need the help of "top gun" telecommunication professionals to engineer these efforts. In addition to providing one of the most modern working environments, we offer a supportive team environment, encourage creative, "beyond the limit" thinking and uphold the industry's highest quality standards. Positions currently are available for:

MANAGER, RF ENGINEERING
You will be responsible for the network performance of a specific region of our cellular network, managing engineering personnel responsible for the RF design of our L.A. Cellular network, and ensuring quality and government compliance. The ideal candidate will possess a BSEE or related experience and 3 years of technical management. Job Code: RFM/RF

SENIOR RF ENGINEER
Responsibilities for this position include the RF design of the LA market wireless system and implementation of advanced technology designs in the LA network. A background in high speed data, a BSEE and 2-3 years of cellular design experience are required. Job Code: SRFE/RF

RF ENGINEER
You will be responsible for planning/implementing/continuously improving RF design to enhance network performance. This will involve both design work in an office environment and field activities. BSEE or related experience in cellular and/or communications industry is required. Spreadsheet, database and computer based propagation modeling software proficiency is preferred. Job Code: RFE/RF

L.A. Cellular is committed to providing competitive salaries and an outstanding benefits package to include 401(k). Please send your resume, including salary history/ requirements to: Human Resources, Job Code (INDICATE PROPER CODE HERE), 17785 Center Court Dr. N., Cerritos, CA 90703. For more information, call our Employment Line at (310) 403-8519. We are an Equal Opportunity Employer.

L.A. CELLULAR®
Twice the calling area.®

ENGINEER

MECHANICAL/ELECTRICAL

DynCorp, EENSP is currently seeking an experienced engineer to participate in an organization involved in the research, design, and development of state-of-the-art high power microwave and millimeter-wave vacuum devices. This position requires a strong technical background, preferably in the area of design and development of microwave tubes (TWT's). The ideal candidate should possess a background of 5+ years of experience and a BSME/BSEE or equivalent experience. Use of computer-aided software, with experience on Auto CAD desirable. Position is located at the Naval Research Laboratory in Washington, DC. Please send your resume with salary requirements to: Personnel Dept., DynCorp EENSP, Code-REM, P.O. Box 6012, Rockville, MD 20849. U.S. security clearance will be required. Principals only. EOE

Continental
FIELD SERVICE CORPORATION

National and International Assignments
RF Engineers/Cellular Installers
CATV Engineers and Strand Mappers
OSP Engineers
Right Of Way Agents
Project Managers, OSP
Contract Specialists
CAD/Draft Operations
Call: 800-431-2806
FAX: 914-592-7246
Send Resume to: 37 East Main St. Elmsford, NY 10523

RF DESIGN MARKETPLACE
(800) 443-4969

RF DESIGN ENGINEERS

World-Class Designer of advanced X'tal oscillators to develop new technologies/packaging in well equipped labs. Min 10 yrs rel exp. in high stability/low-noise OCXOs. Knowledge of GPS, Telecom, Space, SMT, Hybrids a plus. MSEE pref.

Project Engineer required to design quartz X'tal oscillators, TCXOs/VCXOs. Min 5 yrs rel exp. 1 MHz to 1 GHz range, including PLL's, ASICs; use CAD/CAE, simul, hands-on; SMT/Hybrids req. MSEE pref. Excellent benefits. Send resume w/sal requirements to:

VECTRON
The Crystal Oscillator Company

VECTRON LABORATORIES
M. Beccarelli
P.O. BOX 5160 • Norwalk, CT 06856
Fax: (203) 849-1423

EOE/M/F/V/D

MICRO SYSTEMS, INC.

MICRO SYSTEMS, INC. THE INDUSTRY LEADER IN AERIAL TARGET COMMAND & CONTROL SYSTEMS HAS IMMEDIATE OPENINGS TO SUPPORT EXISTING LONG TERM CONTRACTS.

PROJECT ENGINEER (DIGITAL SYSTEMS)
RF DESIGN ENGINEER

WE ARE AN AGGRESSIVE, GROWTH-ORIENTED COMPANY WITH A FULL RANGE OF BENEFIT PROGRAMS INCLUDING 401(K) AND PROFIT SHARING. TO BE A PART OF THIS EXCITING TEAM SEND A RESUME TO HUMAN RESOURCES, 55 HILL AVE. FORT WALTON BEACH, FL. 32548
PRE-EMPLOYMENT DRUG SCREEN REQUIRED
AA/M/F/V/H

Panasonic

Panasonic Technologies, Inc., has one opening for an RF Engineer in our Research and Development facility in Research Triangle Park, North Carolina.

Lead Satellite Communication Engineer

The lead Satellite Communications Engineer will perform RF analog circuit design and development for a low earth orbit satellite based ground terminal. The qualified applicant will possess 5+ years industrial design and development experience in medium power (5 to 10 watts) transceivers, synthesizers and particularly high efficiency amplifiers. Broad knowledge of RF circuitry and wireless communications is essential. Travel required approximately 10% of time.

We offer a highly competitive salary and benefits package. Send your resume, including salary requirements, to:
Panasonic Technologies, Inc., P.O. Box 14269, RTP, NC 27709

Sony's most effective lines of communication are no lines at all.

The ability to respond to a changing world has kept Sony at the forefront of the electronics field for over 30 years. In our newly established Wireless Telecommunication Company, located in San Diego, we have the following career opportunities:

RF DESIGN ENGINEERS
Qualified candidates must have the ability to design VHF to Ghz bands for RF circuits for cellular communications and/or radio products. Must possess a BSEE and 3+ years' experience. (Code: BS/RF)

ELECTRICAL ENGINEERS
We have several positions available for engineers with analog, digital and hardware expertise. Knowledge of radio frequency capability for cellular communications is preferred. Positions require a BSEE with a minimum 3 years' experience. (Code: BS/EE)

SOFTWARE ENGINEERS
The ideal candidates will have experience in designing SW for cellular communications products. The ability to effectively utilize communication protocols and the knowledge of HW/SW interface is also required. A BSCS/BSEE with a minimum 3 years' experience is also required. (Code: SC/SE)

Sony offers an excellent compensation and benefits package. For consideration, mail/fax your resume and salary requirements, specifying job code, to: **Sony Electronics Inc., Attn: Human Resources, Code ____,16450 W. Bernardo Dr., San Diego, CA 92127; FAX: (619) 673-3015.** EOE M/F/D/V.

SONY.

SENIOR RF ENGINEER

SpectraLink Corporation has been providing wireless voice communications to American businesses since 1992 and is the leader among wireless PBX vendors. Our in-building cellular phone systems are creating a dynamic and fast-growing new market. We are headquartered in Boulder, Colorado at the foot of the Rocky Mountains. Join us and become a key member of our engineering team and participate in the challenges and opportunities this market offers.

Responsibilities will include the design of a wide variety of RF transmit and receive circuitry in the 900 Mhz to 2GHz range. Individual will be involved in the conceptual as well as circuit design and should be experienced in digital modulation/demodulation techniques and phase locked loops as well as communications equipment design. Successful candidate will be a team player; willing to give strategic planning input; able to insure high volume production capabilities; and have the desire to take responsibility for the ultimate success of our products. Requirements include a BSEE with 4+ years in RF design. Experience in consumer wireless product and high-volume product design is a plus. Position offers and excellent salary with benefits and stock options. Please send or fax resumes to: **SpectraLink Corporation, 1650 38th Street, #202E, Boulder, CO 80301. Fax: 303-440-5331 Attn: Eng. Dept.** Equal Opportunity Employer.

SpectraLink

RF EXPLOSION

RF state of the Art Developer seeks degreed engineers to join expanding staff Positions available for the following: Fiber Optics, CATV, Cellular, Wireless, Analog/Digital, Test, MMIC, Mgmt. Additional oppts. available for Packaging, Mechanical Design, Power Supply, Acoustic, HW/SW, Systems Integration.

For consideration send your resume to:
Louis Schwartz Technical Employment Consultants
52 E Street Road • Suite C1 • Feasterville PA 19053

Ph: 215-396-1840 • Fax: 215-396-1501

RF DESIGN is **THE PLACE to REACH PRIME PROSPECTS** – more than 40,000 readers who are design and R&D engineers, engineering managers and corporate staff in the military, aerospace, communications and electronics industries.

RF design

For rates and closing dates, call Shannon Shuman at (404) 618-0217 or fax (404) 618-0342.

COMMUNICATIONS
RF DESIGN
Executive and Technical Openings Throughout the United States
Lanni Johnson, CPC

eXcel
OF ALBUQUERQUE, INC.

505-262-1871
FAX 505-268-4954
Excel of Albuquerque, Inc.
excelalb@ix.netcom.com
1700 Louisiana NE, Suite 210
Albuquerque, New Mexico 87110

Cut your mind loose.

STRATEGIC TECHNOLOGY DEVELOPMENT
SEATTLE, WA

McCaw Cellular Communications, Inc., a wholly owned subsidiary of AT&T Corporation and the premier provider of wireless communications in the U.S. is adding new positions in Strategic Technology Development.

McCaw is seeking highly motivated individuals who want to work on the leading edge of wireless communications technology. Join a dynamic technical group charged with pushing the boundaries of technology. You will work in a fast-paced team environment bridging telecommunications, cellular and computing technologies.

RF TEST ENGINEER
Bring to our team strong experience at testing and validating digital radio receivers and transmitting equipment. Frequency range: 800-3000 MHz region.

SYSTEM TEST ENGINEERS (RF/Telecommunications)
Bring to our team expertise with acquisition and recovery performance; interfering signal degradation sensitivity; antenna pattern performance; RFI and EMC testing; Co channel interference; Power control; command channel response; system alarms and error reporting.

H/W & S/W DESIGN ENGINEERS
Bring to our team expertise in ISDN Telephony; wireless interface; BRI with full knowledge of protocol layers 1-3.

NETWORK MANAGEMENT SYSTEMS
Bring to our team in-depth knowledge of tele/data communications and experience in implementing network management systems in large scale environments and experience in cellular/wireless RF planning.

Send, fax, or email resume, along with a cover letter describing your job(s) preferences and how your skills/experience makes you highly qualified, to: Strategic Technology Development, McCaw Cellular Communications, Inc., 14520 NE 87th St., Redmond, WA 98052. Fax: (206)702-2568. email: stg.jobs@mccaw.com EOE.

McCaw® Cellular Communications, Inc.

RF DESIGN is THE PLACE to REACH PRIME PROSPECTS –

more than 40,000 readers who are design and R&D engineers, engineering managers and corporate staff in the military, aerospace, communications and electronics industries.

For rates and closing dates, call Shannon Shuman at (404) 618-0217 or fax (404) 618-0342.

WIRELESS ENGINEERING OPPORTUNITIES with MOBILE SYSTEMS INTERNATIONAL

Mobile Systems International (MSI) currently has engineering positions open for RF and Network engineers. MSI is a world class company with a reputation for providing high quality advanced consulting support to telecommunications, PCS/PCN, ESMR, Cellular, and Paging operators, as well as other wireless system operators worldwide. MSI offers a wide range of services covering CDMA, GSM, IS-54 TDMA, AMPS, MIRS, Paging, and other wireless technologies. Typical services provided to our customers include:

- Radio, Signaling, and Network System Planning and Design
- Technology and Vendor Selection
- New Technology Integration
- Strategic and Management Consultancy
- System Dimensioning
- System Design Audits
- System Performance Monitoring
- Technical Training

MSI offers the opportunity not only to be involved with all of the newest wireless technologies but to also work with a group of highly qualified and experienced engineers. At MSI our engineering team takes pride in holding themselves to the highest engineering standards. Applicants should possess a BSEE or MSEE degree with a minimum of 1 year experience in the wireless engineering industry, and must be innovative as well as highly detail and results oriented. Excellent presentation and technical writing skills are also required. Other useful skills include knowledge of DOS and UNIX operating systems, microwave engineering, networking of wireless communications systems including GSM, IS-41 and SS7, development of RF propagation models, traffic engineering, and knowledge of antenna and receiver design principles. Travel may be required.

We at MSI are committed to further expanding our RF and Network engineering consultancy by the addition of experienced, well qualified wireless engineers. Engineers are needed in our Chicago, Dallas, Atlanta and Washington DC offices as well as other customer locations throughout North and South America and Asia. If you are a highly motivated engineer who meets the above mentioned qualifications MSI is the career move you are seeking. Please send your resume in strictest confidence to the address below. MSI is an equal opportunity employer.

MOBILE SYSTEMS INTERNATIONAL
Personnel Department
One Lincoln Centre, Ste 200 • Oakbrook Terrace, IL 60181
Fax: (708)261-3028

Redefine the Way the World Communicates With the Leader of Wireless Communications

Sprint Telecommunications Venture

Poised on the brink of the 21st Century, Sprint Telecommunications Venture is leading the communications industry into a completely new era. This powerful new venture will create an unprecedented communications alternative, packaging local telephone, long distance and wireless communications with cable services through a single contact for consumers and businesses. By winning the rights to the greatest number of wireless licenses in the recent FCC auction, Sprint Telecommunications Venture has positioned itself to become the number one provider of Personal Communications Services.

With this unparalleled growth potential will come outstanding opportunities for dynamic, exceptional individuals who join forces with the definitive provider of integrated voice, video, data and wireless services. Opportunities are available in major cities throughout the United States.

At Sprint Telecommunications Venture, we believe our employees are our most important resource. These individuals - inspired, innovative and empowered - will create the future of telecommunications. Please send your resume to: Sprint Telecommunications Venture, Dept. STV/RFD, P.O. Box 12915, Shawnee Mission, KS 66282-2915. We are proud to be an EEO/AA employer M/F/D/V. Also, we maintain a drug-free workplace and perform pre-employment substance abuse testing.

POSITIONS FOR:

- RF DESIGN MANAGER
  - RF DESIGN ENGINEER
  - RF OPTIMIZATION ENGINEER
- NETWORK DESIGN & OPERATIONS MANAGER
  - SWITCH ENGINEER
  - BACKHAUL ENGINEER
  - NETWORK OPERATIONS SUPERVISOR
- PROPERTY MANAGER (SITE ACQUISITION)
  - PROPERTY SPECIALIST
- IMPLEMENTATION MANAGER (CONSTRUCTION)
  - IMPLEMENTATION ENGINEER
- BUDGET MANAGER
  - BUDGET ANALYST

VECTRON

The Crystal Oscillator Company

Sales Applications Engineer

World-Class leading manufacturer of Crystal Oscillators seeks a proven growth orientated performer to work with reps and customers on design specifications; meet quotas; negotiate price/delivery. BSEE pref. Min 7 yrs. electronic sales experience preferred oscillator sales. Excellent benefits. EOE/M/F/V/D

VECTRON LABORATORIES, INC.

M Beccarelli
P.O. BOX 5160 • Norwalk, CT 06856

Fax: (203) 840-4444

RF DESIGN MARKETPLACE

(800) 443-4969

ENGINEERING OPPORTUNITIES

PCS/PCN/CELLULAR/CDPD
RF/HW/SW/FW/DSP
Terminals/Systems

FITZPATRICK & ASSOCIATES

P.O. Box 32546 • Phoenix, AZ 85064-2546
E-Mail: FITZPAT@ix.netcom.com

FAX: (602) 956-7644

IOWA MIDWEST

MIDWEST OPENINGS

RF COMMUNICATIONS EQUIPMENT DESIGN ENGINEERS

B.S./M.S., 2 to 8+ years experience, base-band to 3.0 GHz, in any of the following: Receivers, Transmitters, Power Amplifiers, Synthesizers, Spread Spectrum, RF ASIC/MMIC Design, Modems, Communications DSP. Desire strong analytical skills and experience in RF circuit simulation using RF CAE tools. Multiple openings with top commercial companies in attractive Midwest locations. Reply with assured confidentiality to:

DON GALLAGHER MSEE
Gallagher & Associates
1145 Linn Ridge RD. MT. Vernon, IA 52314
Phone: 319-895-8042 Fax: 319-895-6455

RF Engineering Recruiting for Midwest Clients Since 1987

Nationwide opportunities in the CELLULAR/WIRELESS industry.
Debra Sola-Furnari
TELE-TECH SEARCH
4773 Split Rail Place
W. Melbourne, FL 32904
(407) 951-4200 FAX (407) 951-0808

A telecommunications giant that "says all the right things to all the right people"

RF ENGINEERS

If you're the person we're looking for - brilliant, competitive, goal focused - you no doubt want assurances from any company you might consider joining that it knows where the future is going and has the bandwidth to run circles around the cybercrowd. We can assure you that we have something very special going for us.

Northern Telecom has a reputation for consistently coming up with 'the big idea' in a range of areas from digital switching through optical fiber transmission - and now wireless and broadband technology. Our world-class wireless portfolio establishes us as the premier supplier of cellular and PCS systems - as a matter of fact industry insiders agree that we are ahead of the technology curve in PCS.

After the upcoming FCC spectrum auctions, customers will be scrambling to build a new generation of PCS systems. Let's just say we're ideally positioned to support them - with families of products for each of the new PCS technologies - 1900 MHz, GSM, CDMA and PDMA to name a few.

Our incredible success and position of dominance in one of today's hottest technologies means we're here to talk opportunities in Texas, California and North Carolina.

As a member of our team, you'll develop expertise in the emerging 1900 MHz PCS as well as existing cellular technologies. You're not limited to one technology or aligned with one carrier who focuses activity on one market sector.

A BS in Electrical Engineering or Physics is required; an advanced degree is highly desirable. You must have three plus years of experience in telecommunications with a minimum of one year in the cellular field - plus a good understanding of radio technology and system design.

We offer excellent compensation and benefits - and superior career development opportunities.

To learn more about the opportunities we have available in Texas, California and North Carolina, simply fax your resume to 1-800-546-8092, Attn: Job # ENA171RFD.

Or, if you prefer, mail to **Northern Telecom/BNR, U.S. Resourcing Center, Attn: Job # ENA171RFD, P.O. Box 13010, Dept. 1175/NTP, Research Triangle Park, NC 27709.**

nt northern telecom

BNR

The research subsidiary of Northern Telecom

Northern Telecom and BNR are equal opportunity employers proud to support and maintain a smoke and drug-free environment.

Not All High-Tech People Qualify To Be On An Argus List.

Rent the circulation file of this publication for your direct mail needs. For our complete catalog, call Kristin at (404) 618-0479.

ARGUS DIRECT BUSINESS LISTS

Together We're Achieving What Other Companies Are Just Beginning To Imagine.

At Ericsson, we're dedicated to developing technology that's revolutionizing the way the world communicates. Our new $20 million, 240,000 square foot R&D Center, presently under construction in Research Triangle Park, North Carolina, is evidence of our commitment to design, manufacture and market the next generation of award-winning digital/analog cellular products. Keeping Ericsson, Inc. on the cutting edge of telecommunications technology requires the talents of individuals who are willing to meet the challenge of a dynamic industry. Presently, we have the following opportunities:

R.F. Design Engineers – B.S.E.E. and 5+ years experience in R.F. circuit design to the component level, system design, or receiver/transmitter design within the wireless industry coupled with a desire to work in the areas of transmitters, receivers or synthesizers. *Job Code 95RFSE9*

R.F. Senior Design Engineers – B.S.E.E. (M.S. desirable) and 7+ years experience in radio R.F. design, R.F. ASIC definition/design or power amplifiers coupled with a desire to work in the areas of transmitters, receivers, or synthesizers. *Job Code 95ASICSE8*

R.F. ASIC Design Engineers – B.S.E.E. and 3+ years of BiPolar or CMOS radio applications experience. *Job Code 94RTP72*

R.F. Development Engineers – B.S.E.E. and 2+ years R.F. design experience and familiarity with AMPS and DAMPS. *Job Code 95RMOA57*

Staff Engineers, Integration & Configuration – B.S.E.E. or B.S.E.T. and 3+ years experience in systems verification and test specification for telecommunications equipment coupled with an interest in cellular radio base station equipment and AKE digital switch test configuration. *Job Code 95RMOA128*

We offer an excellent salary and benefits package in addition to tremendous opportunities for career advancement. For immediate consideration, please send resume referencing Job Code to: **Ernie W. Leskovec, Ericsson Inc., One Triangle Drive, P.O. Box 13969, Mail Drop RF080195, Research Triangle Park, NC 27709, or fax us at 919-685-2610.**

Principals only – please no agency referrals.

ERICSSON

FOR THE HIGH-TECHKNOWLEDGEABLE SM

"An equal opportunity employer – affirmative action employer. M/F/HDCP"

RF DESIGN MARKETPLACE
(800) 443-4969

RECRUITMENT

PCS RF NETWORK ENGINEERS TO MID $70's
PCS ANTENNA ENGINEERS TO $80's
PARABOLIC RF & MECHANICAL ENGINEERS TO $70's
Please fax resume in confidence to
916-549-4168
RANDALL F. CHAMBERS & ASSOCIATES
"Wireless Recruiting Professionals"
*PO Box 723, Bella Vista, CA 96008 * Tel 916-549-5331*

COMMUNICATIONS ENGINEERS

Our clients are hiring RF engineers with the following skills:

Wireless Telecomm, Cellular, Mobile, Telephony, NPCS, spread spectrum, DSP, AMPS, SMR, GSM, CDPD, TDMA, CDMA, WLAN, WPBX, Transmitters, Receivers, modulators, demodulators, low noise amps, mixers, oscillators, filters, DDS, synthesizers, 900/1900 MHz.

- Never a fee to applicants.
- Positions available nationwide.
- Send email, fax, or call Randy Brei today!

Brei & Associates, Inc.
P.O. Box 445 Marion, IA 52302-0445
(319)377-9196 FAX (319)377-9219
RBREI@NETINS.NET
http://www.NETINS.NET/showcase/RDBREI/

MANAGEMENT RECRUITERS® OF BOULDER, INC.
The search and recruiting specialists

WINDY BRADFIELD
RF / MICROWAVE SPECIALIST

CONTINENTAL BLDG., SUITE 301
1401 WALNUT STREET, P.O. BOX 4657
BOULDER, COLORADO 80306
(303) 447-9900
FAX(303) 447-9536

SCTE Sustaining Member

Peter Froehlich & Co.
executive search

Engineering Positions Available:

Senior RF Design,
Test • Digital • Analog
Market Developement
Software Applications
Fiber Optic Electrical
Applications • Reliability
Manufacturing

Call or write. Fees paid.

P.O. Box 339 Weatherford, TX 76086
(800) 742-4947 • Fax: (817) 594-1337
E-Mail: 72774.3617@compuserve.com

RECRUITMENT

ENGINEERS

Make news – don't just read it

Recent articles in Electronic Engineering Times *and other publications have highlighted* **Philips Semiconductors'** *move to become a "multimedia powerhouse." Our RF products are cutting-edge, and we have the resources and dedication to keep the innovations right on schedule—which is to say, ahead of their time. From breakthroughs in cellular telephones to the latest networking advancements, we provide an environment where communication meets innovation. Help us continue our newsworthy accomplishments, and apply for one of the following opportunities at* **Philips Semiconductors**.

RF IC Design Engineers

You will be responsible for product definition, circuit design, and production release of integrated circuits for the RF communications market. These products will include amplifiers, mixers, oscillators, VCOs, prescalers, synthesizers, and other equipment operating up to 2GHz in bipolar or BiCMOS technologies. You need an MSEE or PhD in EE and 5+ years experience in RF IC design activities, good communication skills and the ability to work both independently and as a project lead. **(Dept. RFD)**

Mixed Mode Design Engineers

Your responsibilities will include IC product definition and specification, circuit design and simulation, characterization and product release in a cross-functional team environment for the communications market. You should have an MSEE or Ph.D in EE with a minimum of 5 years experience in analog and mixed signal CMOS design. Experience in bipolar/BiCMOS technologies is highly desirable, as is experience in communications and related applications. You must be able to work independently and function as a project leader. **(Dept. MMD)**

Test Engineers - Linear/Mixed Signal

You will develop complete test packages for linear and mixed signal integrated circuits. You must have a BSEE (MSEE preferred) and 3+ years experience in test development for linear or RF circuits in a production environment. Experience with LTX77 Synchromaster and Teradyne A3XX test equipment is highly desirable. **(Dept. LMS)**

Product Engineers - RF/Wireless

Take product engineering responsibility for the development of new RF IC product lines including synthesizers, mixers, low noise amplifiers and transmitters. You will also be responsible for yield enhancement of existing RF products. As you will interface with design, process, applications, and test engineers, you must have excellent communication skills. You must have a BS/MS EE and 3+ years related experience. Knowledge of BiCMOS technology is helpful. **(Dept. RFW)**

Cellular Radio System Engineer

Focus on wireless communication systems in North America as a key member of the Telecommunications Group in the new Product Concept and Application Laboratory. Working with our customers, you will translate radio system requirements into architectures and specifications for analog and digital radio subsystems. Requires an MSEE and 5 years related experience in radio frequency subsystems in the 900MHz to 2GHz range. Experience in radio system performance analysis, RF circuit and system simulation and test equipment is required, as well as excellent communication and presentation skills. **(Dept. CRS)**

Philips Semiconductors *offers competitive compensation and a comprehensive benefits package. Please send your resume to:* **Philips Semiconductors**, *Professional Staffing (with appropriate Dept. code), 811 East Arques Ave. MS 07, PO Box 3409, Sunnyvale, CA 94088-3409. FAX 408/991-2656. E-mail: staffing@scs.philips.com. We believe in maintaining a safe work environment for all employees and require pre-employment drug and alcohol testing. Principals only. No phone calls please. We are an Equal Opportunity Employer.*

Philips Semiconductors

PHILIPS

PRODUCTS & SERVICES

NOLAN LABORATORIES, INC.

Consulting, Design, Test and Manufacture
FOR
RF, Microwave, Antennas, Electromagnetics, EMI/RFI, Bioelectromagnetic Sensors
Design and Support for Manufacturability

James A. Nolan, MSEE, President
PO Box 567
Conifer, CO 80433-0567
(303) 838-0057

RF DESIGN Marketplace

(800) 443-4969

53,226 ELECTRONIC COMPONENTS

Whether you order 1 part or all 53,226...MOUSER stocks and...*ships same day!!*

CALL... (800) 992-9943 for your FREE CATALOG

958 North Main St.
Mansfield, TX 76063

MOUSER® ELECTRONICS
Sales & Stocking Locations Nationwide

LOCUS INCORPORATED

- Product Definition, Design, and Production
- RF Systems / Spread Spectrum
- Microprocessor Based Designs
- DSP / Digital Radio
- Harris and Hitachi Authorized Design Center

1842 Hoffman St. Madison, WI 53704
(608) 244-0500 FAX (608) 244-0528

1GHz RF SIGNAL GENERATOR

AM/FM, 100 KHz through 1 GHz
Quality crafted in the USA

Finally, a synthesized signal generator that's designed to help you generate more than just signals. The Ramsey RSG-10, is the signal generator you can afford, the signal generator that's designed to do what a signal generator is meant to do- provide a very stable, accurate, easy to control signal from 100 Khz to 1.0 Ghz.

For the price, you wouldn't expect any more. But, there is more to the RSG-10. An intelligent microprocessor controlled/programmable memory, for example, can store up to 20 of your most commonly used test set-ups. And unlike other units, just one touch of the memory exchange button is all it takes to quickly shift from one test set-up to another. You get more work done, easier and faster.

At $2495, the Ramsey RSG-10 is your profit generator.

RAMSEY

RAMSEY ELECTRONICS
793 CANNING PARKWAY, VICTOR, NY 14584
Fax: (716) 924-4555
TELEX: 466735 RAMSEY CI

ORDER DIRECT—CALL 1-800-446-2295

VISA MasterCard

RF DESIGN is **THE PLACE** to REACH PRIME PROSPECTS – more than 40,000 readers who are design and R&D engineers, engineering managers and corporate staff in the military, aerospace, communications and electronics industries.

For rates and closing dates, call Shannon Shuman at (404) 618-0217 or fax (404) 618-0342.

KTS ELECTRONICS
"Where your dreams turn into reality."

- STD. 5 AND 10 MHZ OCXO
- TCXO • VCXO • TC-VCXO
- VCO's • CLOCK OSCILLATORS
- CUSTOMIZED CRYSTAL FILTERS STD. 10.7 MHZ, 21.4 MHZ and 45 MHZ
- L/C FILTERS
- STANDARD IF FREQUENCYCRYSTALS
- SURFACE MOUNT AND LEADED PACKAGE

Call or Fax requirements.
16406 N. Cave Creek Rd. #5
Phoenix, AZ 85032-2919
Phone & Fax (602) 971-3301

RF DESIGN MARKETPLACE (800) 443-4969

RF LITERATURE/PRODUCT SHOWCASE

RF POWER AMPLIFIERS

200 W • 150-200 MHz • 55% Efficiency • 35dB Gain

1 MHz-2GHz 1W-1KW

- Small Size • High Efficiency • Durable
- Module and Rack Mount Systems
- Customization Available

LCF ENTERPRISES RF POWER AMPLIFIERS

651 Via Alondra, #712
Camarillo, CA 90312 USA
TEL: (805) 388-8454
FAX: (805) 389-5393

INFO/CARD 107

The filter design tool that does it all...for less.

- Lumped, Distributed and Hybrid Circuits
- Mechanical Dimensions for Distributed Circuits
- Pole Placed Transfer Functions
- Much More

$995 Complete
Domestic Shipping Included

FILTROID

GEESOF
P.O. Box 219
Sebago Lake, ME 04075
(207) 642-2728

INFO/CARD 108

R. F. DESIGN ESSENTIALS

LABORATORY - STANDARD

HIGH POWER BIAS - TEE NETWORKS FOR R. F. SEMICONDUCTOR AMPLIFIER DESIGNS.

TYPE	RANGE (GHz.)	S.W.R.	D.C. (A.)	LOSS (DB.)
9460-0.4	0.10-0.70	1.20	20.0	0.10
9460-0.8	0.40-1.25	1.20	20.0	0.10
9460-1	0.55-1.60	1.20	20.0	0.10
9460-2	1.00-3.00	1.20	20.0	0.30
9460-5	2.70-7.50	1.20	6.0	0.30

OTHER MODELS THRU 36 GHZ AT 6.0 A.

WIDE VARIETY OF CONNECTOR TYPES.

COAXIAL DOUBLE & TRIPLE SLEEVE TUNERS FOR WIRELESS, CELLULAR & OTHER APPLICATIONS. ALFORD DESIGN "EASYMATCH" TRIMMERS. VARIOUS MODELS COVER : H.F. -VHF - UHF -MICROWAVE. MATCHING V.S.W.R. > 14.0 : 1 UP TO 36 GHZ.

BROAD BAND ANTENNA ARRAYS
ALFORD DELTA DIPOLE - ALFORD SLOT TUBE - ALFORD LOOP ANTENNAS FOR TV & FM - E.C.M. - MIL. - ILS & VOR

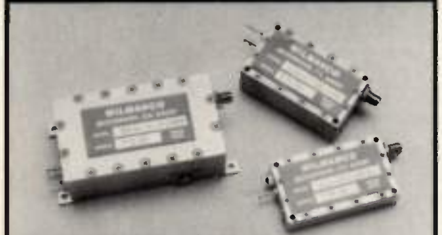
PRECISION COAX ADAPTERS

TELEPLEX, INC. - ALFORD DIV.
4801 INDUSTRIAL PKWY., INDIANAPOLIS, IN. 46226-4200
PH. 317-895-8800 FAX. 317-895-2900

INFO/CARD 109

RF LITERATURE/PRODUCT SHOWCASE

LOW COST HIGH PERFORMANCE FREQUENCY SOURCES



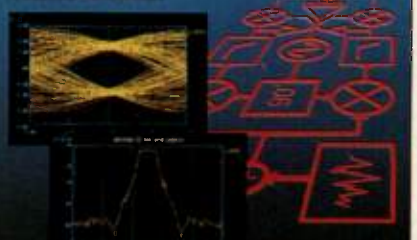
✓ MODEL VSA – $195.00 .01 GHz TO 1.0 GHz
✓ MODEL USA – $245.00 1.0 GHz TO 1.8 GHz
✓ MODEL SSA – $295.00 1.8 GHz TO 4.2 GHz

RF OUTPUT: +8dBm min., SMA Connector
FREQ. STABILITY: ±30ppm, -20°c to +60°c
B+: +12 to +16 VDC

Wilmanco 5350 Kazuko Court, Moorpark, CA 93021 (805) 523-2390 FAX (805) 523-0065

INFO/CARD 110

TESLA Communications Simulation



Still Only $695!

Why is TESLA winning all these awards? It's simple and easy to use, yet it does full RF non-linear, mixed analog & digital simulation. Why not see for yourself? Call now:

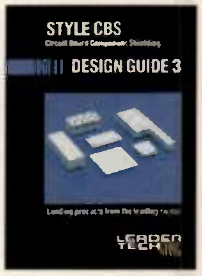
800-631-1113

TESOFT Inc. 404-751-9785 Fax404-664-5817
PO Box 305 Roswell GA 30077

INFO/CARD 111

CIRCUIT BOARD COMPONENT SHIELDING

Removable cover allows component accessibility

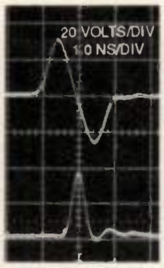


Leader Tech offers a standard board shielding components: available heights range from .13" to 2.00"; available sizes are from .50" × .50" to 6.00" × 24.00", on 1/4" increments.

The STYLE CBS removable cover design provides superior shock and vibration resistance while allowing component accessibility. All STYLE CBS series are available in thru-hole or surface-mount configurations, and, as always, there are no tooling or artwork charges. Contact Leader Tech at 14100 McCormick Dr., Tampa, FL 33626; (813) 855-6921, Fax (813) 855-3291.

INFO/CARD 112

MONOCYCLE GENERATORS AND IMPULSE GENERATORS



We have expanded our line of RF monocycle and impulse generators for SAW, ultrasonics and short pulse radar applications. The monocycle generators span the frequency and amplitude range of 20 MHz to 3 GHz and 10 Volts to 800 Volts while the impulse generators range from 10 Volts, 130 ps to 850 Volts, 5 ns. Call or fax for a copy of our new 113-page nanosecond pulse generator catalog (Cat. No. 9).

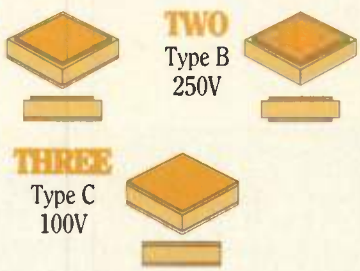
AVTECH ELECTROSYSTEMS
NANOSECOND WAVEFORM ELECTRONICS SINCE 1975

BOX 265, OGDENSBURG NY, 13669-0265
1-800-265-6681
(315) 472-5270
Fax: (613) 226-2802
e-mail: info@avtechpulse.com

INFO/CARD 113

Only TECDIA has THREE!

SINGLE LAYER CHIP CAPACITORS



FOR CAPACITORS WITH:

- Extremely smooth and uniform metalized surfaces
- Pt metalization to withstand 400°C die attach temperature up to 20 min max
- TiW adhesion layer to prevent diffusion and provide stability at very high temperatures

TECDIA
2672 Bayshore Parkway, Suite 702, Mountain View, CA 94043
Tel: (415) 967-2828 Fax: (415) 967-8428

INFO/CARD 114

Signal Processing & Communications Systems

ADVANCED SPREAD SPECTRUM & DIGITAL DEMODULATION PRODUCTS

- ST-101 Spread Spectrum Signal Generator
- ST-102 Spread Spectrum Demodulator
- ST-202 Spread Spectrum Digital Matched Filter
- ST-104 Spread Spectrum Remote Transmitter
- ST-105 Fast Acquisition BPSK/QPSK Demodulator
- ST-106 Programmable Error Corrector / Frame Synchronizer

SIGTEK
9841 Broken Land Pkwy., Ste 206, Columbia, MD 21046
Tel. (410) 290-3918 FAX (410) 290-8146

INFO/CARD 115

TCXO's IN "NO TIME"

Hy-Q's "D Series" TCXO

Frequency: 8 MHz. to 30 MHz.
Available Outputs: Clipped Sinewave; TTL; HCMOS
Supply Voltage: 5 vdc
Stability: ±0.5ppm 0° to 50°C
±2.0ppm -40°C to +85°C
*other stability options available

Various voltage control options available

Dimensions: Length 0.8"
Width 0.8"
Height 0.4"

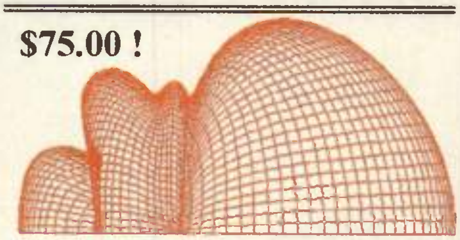
Typical Delivery: Stock to 6 weeks ARO

***Hy-Q International* (USA), Inc.**
1438 Cox Avenue • Erlanger, Kentucky 41018
Phone: 606-283-5000 • Fax: 606-283-0883

INFO/CARD 116

NEC-Win Basic for Windows™

$75.00 !



First Integrated Antenna Design & Analysis Program for Windows Under $100 Supporting NEC2

Features Include:

- Intuitive Graphical User Interface
- Powerful Azimuth and Elevation Plotting
- Three-Dimensional Radiation Patterns
- Automated VSWR, Beamwidth, F/B Ratio, Input Impedance and Current Calculations

Paragon Technology, Inc.
200 Innovation Blvd. Suite 240
State College, PA 16803
E-mail: NecWin@aol.com
(814) 234-3335 Fax (814) 234-0228

INFO/CARD 117

RF design

Realize the Potential!

Contact: Shannon Shuman
Tel: (800) 443-4969
Fax (404) 618-0342

RF design Buyers' Guide

The Buyers' Guide is a convenient guide to suppliers of products and services available for design and development engineers. Buyers' Guide listings are sold on an annual basis at the rates shown.

	Per Issue	Total/Year
Regular Listing	$22.00	$264.00
Additional Line	$19.00	$228.00
Bold Listing	$25.00	$300.00
Additional Line	$21.00	$252.00
1" Ad	$200.00	$2,400.00
Drop Out In White	$25.00	$300.00

All orders must be prepaid. You can forward your check or charge your ad to:

VISA

For information on closing dates and details on a special Introductory Offer, call **1-800-443-4969.** Ask for your yellow page representative.

DISCRETE COMPONENTS

CAPACITORS

Chip

Sprague Goodman , 134 Fulton Ave., Garden City Park, NY 11040-5395..............(516) 746-1385

Vacuum

COMET North America, 11 Belden Ave., Norwalk, CT 06850 ....(203) 852-1231

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

Surcom Associates, Inc., 2215 Faraday Ave., Suite A, Carlsbad, CA 92008.........(619) 438-4420

Variable

COMET North America, 11 Belden Ave., Norwalk, CT 06850 ....(203) 852-1231

CRYSTALS/RESONATORS

H.K. Crystals Co., Unit H, 22/F, Shield Ind. Ctr.,
34-36 Chai Wan Kok St., T.W. H.K ....Tel (852) 4120121 Fax (852) 4985908

Quartz

Bomar Cyrstal Co., 201 Blackford Ave., Middlesex, NJ 08846 ......(800) 526-3935

Valpey-Fisher Corp., 75 South St., Hopkinton, MA 01748 ......(508) 435-6831 Fax (508) 435-5289

DIODES

Loral Semiconductor Division, 75 Technology Dr., Lowell, MA 01851 ....(508) 256-4113 ext.3311

PIN

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

Varactor

Knox Semiconductor, Inc.
13 Quarry Rd., P.O. Box 609, Rockport, ME 04856...................(207) 236-6076 Fax(207) 236-9558

INDUCTORS

Ferrite Cores

Sprague Goodman, 134 Fulton Ave. Garden City Park, NY 11040-5395...............(516) 746-1385

Fixed

Sprague Goodman, 134 Fulton Ave. Garden City Park, NY 11040-5395...............(516) 746-1385

Variable

Coil Speciality Co.,
2730 Carolean Industrial Dr., PO Box 978, State College PA 16801..................(814) 234-7044

INTEGRATED CIRCUITS/MCM

Micro Hybrids, Inc., 2364 Route 112, Medford, NY 11763..(516) 732-3448

RESISTORS

High Power

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

TRANSISTORS

RF Power Bipolar

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

RF Power FET

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

MODULAR COMPONENTS

AMPLIFIERS

Broadband

Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724......(908) 542-113 Fax (908) 542-1118

Hybrid

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

RF Power

Silicon Valley Power Amplifiers, 529 Forman Dr. # B, Campbell, CA 95008..........(800) 986-9700

FILTERS

Crystal

Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147 ....(800) 348-5580

Saw

Phonon Corp., 7 Herman Dr., PO Box 549, Simsbury, CT 06070........................(203) 651-0211
SAW Components & Subsystems..Fax (203) 651-8618

MIXERS

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006 ....(201) 575-1300 Fax (201) 575-0531

MODULATORS

FSK

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006 ....(201) 575-1300 Fax (201) 575-0531

MODULAR COMPONENTS

I&Q

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006 ....(201) 575-1300 Fax (201) 575-0531

MODULAR COMPONENTS

OSCILLATORS

REEVES-HOFFMAN
DIVISION DYNAMICS CORPORATION OF AMERICA

For your Crystal Oscillator requirements, Clocks, TCXO's, VCXO's, OCXO's, Hybrid & Discrete.

400 W. North St., Carlisle, PA 17013, Tel: 717-243-5929, Fax: 717-243-0079

CRYSTAL OSCILLATORS
- ACMOS TTL to 200 MHz
- HCMOS TTL to 80 MHz
- ECL to 630 MHz
- VCXOs to 200 MHz
- SMD to 300 MHz

VALPEY-FISHER A SUBSIDIARY OF MATEC

FUNDAMENTAL Crystals to 350 MHz

800-982-5737 (ext. 244)

Valpey-Fisher Corporation • 75 South Street • Hopkinton, MA 01748 Fax: 508-497-6377

Crystal
Oak Frequency Control Group,
100 Watts St., PO Box B, Mt. Holly Springs, PA 17065....(717) 486-3411
Wenzel Associates, Inc., 1005 La Posada Dr., Austin, TX 78752....(512) 450-1400
Wilmanco, 5350 Kazuko Ct., Moorpark, CA 93021....(805) 523-2390
Microwave
Electronic Surveillance Co., Inc., 33328 Howe Ln., Creswell, OR 97426....(503) 895-5071

SYSTEM SUBASSEMBLIES

AMPLIFIERS

Broadband
Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724....(908) 542-1133 Fax (908) 542-1118
LNA
Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724....(908) 542-1133 Fax (908) 542-1118
Linear Power, RF

PACIFIC AMPLIFIER CORP. (805) 375-5773
- LO-MED-HI-POWER LINEAR AMPLIFICATION
- CELLULAR, TELEPHONY MULTI CHANNEL USE
- -30 dBc STANDARD; -60 dBc FEED FORWARD

RF Power
Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724....(908) 542-1133 Fax (908) 542-1118
High Dynamic Range
Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724....(908) 542-1133 Fax (908) 542-1118

PRINTED CIRCUIT BOARDS

CALL SOUTHWEST CIRCUITS NOW! (800) 279-5572
- PROTOTYPES AND SHORT RUNS FOR ALL MICROWAVE AND WIRELESS APPLICATIONS
- ALL POPULAR MICROWAVE LAMINATES: PTFE –TEFLON – DUROID – GX
- MULTI-LAYERS – QUICK TURN – EXOTICS

Southwest Circuits, 3760 E. 43rd Place, Tucson, AZ 85713
TEL (602) 745-8515 FAX (602) 747-8334 MODEM (602) 747-5108

RF TRANSMISSION COMPONENTS

ANTENNAS

Syndetix Inc., 2820 N. Telshor Blvd., Las Cruces, NM 88011....(505) 522-8762
Custom Antenna Design, High Power, Including Flight Certified....Fax (505) 521-1619

ATTENUATORS

Coaxial
SV Microwave, 3301 Electronics Way, West Palm Beach, FL..(407) 840-1800 Fax (407) 844-8551
Syndetix Inc., 2820 N. Telshor Blvd., Las Cruces, NM 88011....(505) 522-8762
Custom Antenna Design, High Power, Including Flight Certified....Fax (505) 521-1619

CABLE ASSEMBLIES

Kaman Instrumentation, 1500 Garden of the Gods, Colorado Springs, CO 80907....(719) 599-1821
Storm Products, Advanced Tech Group, 116 Shore Drive, Hinsdale, IL 60521....(708) 323-9121
Cable Interconnect Systems
C&M Corporation, 51 S. Walnut St., Wauregan, CT 06387....(203) 774-4812

DIRECTIONAL COUPLERS

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006....(201) 575-1300 Fax(201) 575-0531

FILTER ASSEMBLIES

REEVES-HOFFMAN
DIVISION DYNAMICS CORPORATION OF AMERICA

For your Crystal Filter requirements from 1 KHz to 150 MHz Fundamentals and up utilizing Overtone Crystals.

400 W. North St., Carlisle, PA 17013, Tel: 717-243-5929, Fax: 717-243-0079

INDUCTORS AND CHOKES

Kintronic Labs, 144 Pleasant Grove Rd., Bluff City, TN 37618..(615) 878-3141 Fax (615) 878-4224

ISOLATORS/CIRCULATORS

AEROTEK COMPANY LIMITED
Manufacturers of Circulators and Isolators
Coaxial and Drop-in types, 400 MHz–18 GHz
"TOP QUALITY, REASONABLE PRICE"
1756 Sukhumvit 52, Sukhumvit Rd., Bangkok, Thailand.
AEROTEK Tel: (662) 311-4448, 332-5035 Fax: (662) 332-5034

MICROWAVE CONNECTORS

Applied Engineering Products, P.O. Box 510 New Haven, CT 06513....(203)776-2813
Southwest Microwave, Inc., 2922 S. Roosevelt St., Tempe, AZ 85282....(800) 587-5995

MULTICOUPLERS

Trontech, Inc., 381 Industrial Way East, Eatontown, NJ 07724....(908) 542-1133 Fax (908) 542-1118

PHASE SHIFTERS

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006....(201) 575-1300 Fax (201) 575-0531

PRECISION

TELEPLEX, INC. - ALFORD DIVISION
4801 INDUSTRIAL PKWY. - INDIANAPOLIS, INDIANA - 46226-4200 (317) 895 8800

• PRECISION COAX & W/G SLOTTED LINES	30MHZ. TO 40 GHZ.
• LOW V.S.W.R. INTERSERIES COAX ADAPTERS	6 1/8" TO 2.40mm.
• HIGH POWER - LOW LOSS BIAS TEES	20 AMPS THRU 3.0 GHZ.
• CONSTANT IMPEDANCE LINE STRETCHERS	LOW LOSS TO 18 GHZ.
• ADJUSTABLE COAX TUNERS	MATCH S.W.R. > 14:1, VHF TO 36 GHZ.
• ANDREW ALFORD ANTENNA PRODUCTS	VHF-UHF-ITFS-VOR-MIL.

ALFORD

POWER DIVIDERS/COMBINERS

Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006....(201) 575-1300 Fax (201) 575-0531

RF CONNECTORS

ITT Cannon RF Products, 585 E.Main ST., New Britain, CT 06051....(800) 532-3750
Merrimac Industries, Inc.,
41 Fairfield Pl., W. Caldwell, NJ 07006....(201) 575-1300 Fax(201) 575-0531
Molex, Inc., 2222 Wellington Ct., Lisle, IL 60532....800-MOLEX78
Richardson Electronics, Ltd., 40W267 Keslinger Rd., LaFox, IL 60147....(800) 348-5580
SV Microwave, 3301 Electronics Way, West Palm Beach, FL..(407) 840-1800 Fax (407) 844-8551

SURGE & TRANSIENT PROTECTORS

FCC
Lightning Suppressors · D.C. - 26 GHz
Coaxial · Powerline · Digital
FISCHER CUSTOM COMMUNICATIONS, INC. • (310) 891-0635

Polyphaser Corp., P.O. Box 9000, Minden, NV 89423....(800) 325-7170, (702) 782-2511

SWITCHES

Electromechanical
Dow-Key Microwave Corp., 1667 Walter St., Ventura, CA 93003....(805) 650-0260
Matrix Systems corp., 5177 N. Douglas Fir Rd., Calabasas, CA 91302....(818) 222-2301
MBF Microwave, Inc., Rt. 2, Box 252A, Hardy, AR 72542....(501) 856-2685

SYNTHESIZERS

Novatech Instruments,
1530 Eastlake Ave. E., #303, Seattle, WA 98102....(206) 322-1562 Fax (206) 328-6904

TELEMETRY

EMHISER RESEARCH, INC.
Verdi, Nevada USA
TEL (702) 345-2705
FAX (702) 345-2484
Will customize to your requirements:
Transmitters & Receivers
Telemetry • Video • Digital • Command • Beacon
Command Encoders & Decoders
Since 1978

RF TRANSMISSION COMPONENTS

VACUUM CAPACITORS
COMET North America, 11 Belden Ave., Norwalk, CT 06850 ....(203) 852-1231

VACUUM TUBES

DIGITAL SIGNAL PROCESSING

SYSTEMS DEVELOPMENT, REAL TIME
Adaptive Technology, Inc., 309 Curtis St., Syracuse, NY 13208...(800) 724-6968 Fax (315) 472-3279

MATERIALS AND HARDWARE

COMPONENTS/HYBRID PACKAGES
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013....(717) 243-5929

CRYSTAL BLANKS
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013....(717) 243-5929

PC BOARDS
Laminates, Polyester Copper Clad
Glasteel Industrial Laminates, P.O. Box 910, Collierville, TN 38027....(901) 853-5070

TEST EQUIPMENT
Instrument Repair Labs, Inc., 2100 W. 6th Ave., Broomfield, CO 80020 ....(800) 345-6140

PRA, Inc., 8320 E. Gelding Dr., #103 Scottsdale, AZ 85260 ....(602) 991-4180
Test & Measurement Systems ....Fax (602) 991-4362

Racal Instruments, 4 Goodyear St., Irvine, CA 92718 ....(800) 722-3262

SPECTRUM ANALYZERS
DC TO LIGHT, P.O. Box 7140, Bozeman, MT 59771 .... (406) 586-5399 Fax (406) 586-6556

SERVICES

ANTENNA MEASUREMENT SYSTEMS
Jef Consultants, Inc., 8501 Beck Rd., Bldg. 2227, Belleville, MI 48111-1254 ....(313) 482-5505

ANTENNA DESIGN & MEASUREMENT
Kintronic Labs, 144 Pleasant Grove Rd., Bluff City, TN 37618..(615) 878-3141 Fax (615) 878-4224

CONSULTANTS
Management Recruiters of Boulder ....Fax (303) 447-9536 Tel (303) 447-9900
Windy Bradfield CSAM, Bob Sund ....
Goldman Research, 12705 Monfort, Dallas, TX 75230 ....(214) 788-1122
RF Design & Modeling – Spice, EEsof, Wireless ....WNJU80A@PRODIGY.COM

EMC/EMI TESTING
Liberty BEL EMC SVCS., P.O. Box 5431, MS20, Compton, CA 90224 ....(310) 537-4235
Above MS20 represents RF Design
TUV Rheinland of North America, Inc.,
12 Commerce Road, Newtown, CT 06470 ....(203) 426-0888 Fax (203) 270-8883

EQUIPMENT CALIBRATION
Instrument Repair Labs, Inc., 2100 W. 6th Ave., Broomfield, CO 80020 ....(800) 345-6140

INSTRUMENT RENTAL/LEASING
Naptech, 12312 Hwy 175, Cobb, CA 95423....(800) 336-7723 Fax (707) 928-1963

OEM PRODUCTS
Locus, Inc., 1842 Hoffman St., Madison WI 53704 ....(608) 244-0500

TELEMETRY SYSTEMS & ENGINEERING
Telemetry Technologies, Inc., 3307 West St., Rosenberg, TX 77471 ....(713) 344-9000

SOFTWARE & SYSTEMS, CAD/CAE

SOFTWARE
Design Automation, Inc., 4 Tyler Rd., Lexington, MA 02173....(617) 862-8998 Fax (617) 862-3769
Circuit Simulation
COMET North America, 89 Taylor Ave., Norwalk, CT 06854....(203) 852-1231
ingSoft Ltd. – the providers of the RF Designer® Solution....(416) 730-9611
312 Dunview Ave., North York, ON M2N-4H9, Canada; bbs: 226-9820 .... Fax: 733-3884

SYSTEM SIMULATION
Tesoft, Inc., 205 Crossing Creek Ct., Roswell, GA 30076 ....(800) 631-1113
Makers of TESLA Com Simulator ....Fax (404) 664-5817 Intl (404) 751-9785

ELECTRONIC COMPONENTS AND EQUIPMENT

EMI SUPPRESSION COMPONENTS
Cables and Connectors
Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506....(814) 835-4000
EMI/RFI Filters
POTTER PRODUCTION CORPORATION, 3004 Hwy. 51 N., Wesson, MS 39191 ....(601) 643-2215
Santek, 9765 Marconi Dr., #205, San Diego, CA 92173 ....(619) 661-8119
Ferrite Beads, Rods, Forms
Fair-Rite Products Corp., P.O. Box J, Wallkil, NY 12589....(800) 836-0427
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401....(615) 867-4100 Fax (615) 867-4102
Ferrite Suppression Components
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401....(615) 867-4100 Fax (615) 867-4102
Filtered Connectors
Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506....(814) 835-4000
Filters, Power Line
Qualtek Electronics Corp., 7675 Jentler Dr., Mentor, OH. 44060 ....(216) 951-3300
RtroN Corp., P.O. Box 743 Skokie, IL 60076....(708) 679-7180
Transformers/ Filters
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401....(615) 867-4100 Fax (615) 867-4102

ESD AND SURGE CONTROL COMPONENTS
Lightning Arrestors
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505....(310) 891-0635
Polyphaser Corp., P.O. Box 9000, Minden, NV 89423....(800) 325-7170 (703) 782-2511

CABLE AND CONNECTORS
Connectors And Adapters
ADC Telecommunications, 4900 W. 78th St., Minneapolis, MN 55435....(800) 366-3891 X3000
Optical Fibers And Connectors
ADC Telecommunications, 4900 W. 78th St., Minneapolis, MN 55435....(800) 366-3891 X3000

EMC TEST EQUIPMENT - EMISSIONS
Absorbers
Advanced Electromagnetics, Inc., P.O. Box 711719, Santee, CA. 92072- 1719....(619) 449-9492
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853....(800) 403-3930
Rantec, P.O. Box 1546, Austin, TX 78767....(512) 835-4684
Anechoic Chambers
Advanced Electromagnetics, Inc., P.O. Box 711719, Santee, CA. 92072- 1719....(619) 449-9492
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853....(800) 403-3930
Rantec, P.O. Box 1546, Austin, TX 78767....(512) 835-4684
Antennas
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705....(310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767....(512) 835-4684
Antennas Above 30 MHz
A.H. Systems Inc., 9710 Cozy Croft Ave, Chatsworth, CA 91311..(818) 998-0223 Fax (818) 998-6892
EMCO, P.O. Box 1546, Austin, TX. 78767....(512) 835-4684
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853....(800) 403-3930
Antennas Masts
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705....(310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767....(512) 835-4684
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853....(800) 403-3930
Current Probes
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505....(310) 891-0635
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853....(800) 403-3930
Ion Physics Corp., 11 Industrial Way, Atkinson NH 03811 ....(603) 893-6687

ELECTRONIC COMPONENTS AND EQUIPMENT

Ferrite Absorber Tiles
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853 .... (800) 403-3930
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

GTEM Cells
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

EMC TEST EQUIPMENT - EMISSIONS

Line Impedance Stabilization Networks
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853 .... (800) 403-3930
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

Near Field Probes
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853 .... (800) 403-3930

Preamplifiers
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853 .... (800) 403-3930

Preselectors
IBEX Group, Inc., 23 Markham Dr., Long Valley, NJ 07853 .... (800) 403-3930

Shielding Effectiveness Testers
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

EMC TEST EQUIPMENT - SUSCEPTIBILITY

Antennas
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

E-Field Probes
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

GTEM Cells
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Power Amplifiers
Applied Systems Engineering, Inc., 8623 Hwy. 377 S., Fort Worth, TX 76126 .... (819) 249-4180
Varian Microwave Equip. Prods., 3200 Patrick Henry Dr, Santa Clara, CA 95054 .... (408) 496-6273

Sheilded Fiber Optic Links
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888

Surge Generators
Velonex Corp., 560 Robert Avenue, Santa Clara, CA 95050 .... (408) 727-7370
Pulse, Surge, Transient, ESD, Hybrid Generators

ESD TEST EQUIPMENT

ESD Event Detectors
Monroe Electronics, Inc., 100 Housel Avenue, Lyndonville, NY 14098 .... (800) 821-6001
TREK INC., 3932 Salt Works Rd., P.O. Box 728, Medina, NY. 14103 .... (800) FOR-TREK

Surface & Volume Resistivity Meters
Monroe Electronics, Inc., 100 Housel Avenue, Lyndonville, NY 14098 .... (800) 821-6001
TREK INC., 3932 Salt Works Rd., P.O. Box 728, Medina, NY. 14103 .... (800)FOR-TREK

EMC TEST EQUIPMENT - ADDITIONAL

Field Strength Meters
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888

MATERIALS, HARDWARE AND PACKAGING

SHIELDING MATERIALS

Antenna Towers
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Architectural Shielding
Specialty Technical Components, Inc., P.O. Box 2106, Southeastern, Pa 19399 .... (610) 647-9000

Broadband EMI
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401 .... (615) 867-4100 Fax (615) 867-4102

Conductive Adhesives
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-5900

Conductive Fiber/Fabric
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-5900

Ferrite Absorber Tiles
Fair-Rite Products Corp., P.O. Box J, Wallkil, NY 12589 .... (800) 836-0427

Gasketing Materials
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-5900

Laminates
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-5900

Magnetic Shielding
Ad-Vance Magnetics, Inc., 625 Monroe St., Rochester, IN 46975 .... (219) 223-3158

Positioning Controllers
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Sheilding Foils and Tapes
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-5900

Tripods
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Turntables
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

SHIELDING EMI/RFI SERVICES
Vacuum Platers, Inc., 115 S. Union Street, Mauston, WI 53948 .... (608) 847-5644

SHIELDED ENCLOSURES - EQUIPMENT

Component/Module Cases
Marmin-Hil Plastics, Inc., 101 Roselle St., Linden, NJ 07036 .... **(908) 925-2940 (800) 886-2940**

SHIELD ROOMS AND CHAMBERS

Shielded Rooms EMI/RFI/Magnetic
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

ESD PACKAGING

Antistatic Polyurethane/Polyethylene
Pad-Tastics, Inc., P.O. Box 50479, Cicero, IL 60650 .... (708) 780-8402 FAX (708) 780-1636

Conductive Polyurethane
Pad-Tastics, Inc., P.O. Box 50479, Cicero, IL 60650 .... (708) 780-8402 FAX (708) 780-1636

Custom Packaging
Pad-Tastics, Inc., P.O. Box 50479, Cicero, IL 60650 .... (708) 780-8402 FAX (708) 780-1636

ESD ENVIRONMENTAL CONTROL

Antistatic or Conductive Flooring
Freudenberg Building Systems, Inc./Nora Rubber Flooring
94 Glenn St., Lawrence, MA 01843 .... (508) 689-053

TEST LABORATORIES AND CONSULTANTS

TEST LABORATORIES

- Indoor Range / Open Area Test Site
- Global EMC Testing & Certifications
- Susceptibility / Immunity Testing
- Product Safety • Calibration Services
- EMC Design Consulting • EMC Site Surveys

ELLIOTT ASSOCIATED LABORATORIES INC
International EMC and Safety Engineering
Mountain View, CA
Tel: (415) 967-4166 Fax: (415) 967-7315

Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506 .... (814) 835-400
TUV Product Service, Inc., 1775 Old Hwy. 8, New Brighton, MN 55112 .... (800) 472-799

Open Area Test Sites
Compatible Electronics - 8 open field test sites in So. Calif .... (714) 579-050

EMI/EMC TESTING
LambdaMetrics, P.O. Box 1029, Cedar Park, TX 78630-1029 .... (512) 219-821
FCC listed lab, one EMC Engineer, 30 years RF design experience, Prompt Personal Service

CONSULTANTS
Kimmel Gerke Assoc. Ltd., 1544 N. Pascal, St. Paul, MN 55108 .... (612) 330-372
EMC Design/Troubleshooting-Medical, Industrial, ITE, Vehicles & More-50+ years exp.
Regulatory Consultants Network, P.O. Box 344, Liberty Hill, TX 78642 .... (800) 326-633
EMC Design, EMC/EMI/EMS/ESD & Electrical Product Safety


RF EXPO
THE WIRELESS SHOW THAT
EAST
GOES THE DISTANCE
1995
August 21-23, 1995
Baltimore Convention Center
Baltimore, Maryland
Sponsored by
RF design
HIGHLIGHTS INCLUDE:
Full-Day Special Courses
30+ Educational Sessions
Expansive Exhibit Area With the Leading Suppliers Exhibiting the Latest in Industry Technology
Unlimited Networking Opportunities
Exhibitor/Attendee Receptions
RF Expo East '95 features both intensive tutorials and technical paper presentations exploring the challenges of the RF industry today -and tomorrow
For Information on Attending, Contact:
Argus Trade Shows
RF Expo East '95
6151 Powers Ferry Road, NW
Atlanta, GA 30339
800-828-0420
FAX: 404-618-0441
404-618-0393

EM Analysis

The MacNeal-Schwendler Corporation has announced the release of MicroWave-Lab, a 3-D electromagnetic analysis system for high frequency applications such as resonators, as well as microstrip and waveguide components. MicroWaveLab, using edge elements and absorbing boundaries, calculates important network parameters such as scattering matrices, port impedances and propagation constants. The program is available now on both the popular Unix-based workstations and multi-processing supercomputers.
MacNeal-Schwendler Corp.
INFO/CARD #190

Integrated Circuit Analysis

HP EEsof has released a new version of the HP integrated circuit characterization and analysis program (IC-CAP) modeling suite, which achieves a higher level of automation than ever before. The software provides three new device models and enhanced device modeling capability. IC-CAP version 4.4 supports the following models: EEFET3 GaAs FET model, EEHEMT GaAs HEMT model, and EEBJT2 BJT model. In addition, enhancements have been made to the BSIM 3 model extraction procedures. The new version also includes new instrument drivers. IC-CAP 4.4 is priced at $31,000, the new models are purchased separately and are priced at $4,080 each.
HP-EEsof
INFO/CARD #189

Component Synthesis

MODELMAKER is a component synthesis tool kit for SpiceAge*4W. It includes tools for creating op amp, transformer, attenuator and bipolar transistor simulation models. Using information straight from a supplier's catalog, models are synthesized. While less complex than SPICE models, they are adequate for most applications and calculate many times faster. MODELMAKER is available at $224 and links with version 3.00 (and later) and Professional Level 3 (and higher) SpiceAge*4W.
Tatum Labs, Inc.
INFO/CARD #188

Spreadsheet Analog Simulation

Avista Design Systems introduces Spectre/XL, which embeds circuit simulation inside Microsoft Excel. Spectre/XL's combination of immediate access to all circuit values, and instant "what if" analysis gives analog designers a uniquely flexible tool for evaluating, developing and optimizing circuit designs. The Spectre/XL system supports SPICE3 device models and returns DC (operating point), AC (small signal), or non-linear frequency (spectral) responses. Spectre/XL is priced at $695 and requires Microsoft Excel 5.0 for Windows.
Avista Design Systems
INFO/CARD #187

Schematic Capture

Compact Software has released a new version of Serenade Schematic for the PC. Serenade Schematic 3.0 for Windows includes special high frequency component and layout-oriented symbols that drive Compact's circuit simulation and layout tools. New features include: user-configurable toolbar, integration with Microwave Scope, Harmonica and Super-Compact 6.5, integration with Super-Spice, a new property editor, and user-defined settings.
Compact Software
INFO/CARD #186

Spurious Analysis

Orion Software International's Spurious Analysis Professional Version 1.0 for Windows is a spurious frequency and PLL analysis CAE program. The program analyzes single, dual and triple conversion designs for all internally generated spurious frequencies. The PLL section of the program takes the tunable local oscillator values calculated from the analysis done in the spurious frequency section and uses these to determine the value of the N and A counters used in the dual modulus PLL IC. The program is priced at $229.95 plus $5.00 S&H.
Orion Software International
INFO/CARD #185

NEC2 on Windows

Paragon Technology has released the NEC-WIN Basic antenna modeling package. The software combines the power of the NEC2 core with an intuitive graphical user interface that runs under Windows. With NEC-WIN Basic users can quickly model complex antennas and obtain 2-D or 3-D radiation patterns. NEC-WIN Basic is shipped with a 125-page bound manual, online help and technical support, and has a list price of $75.
Paragon Technology, Inc.
INFO/CARD #184

CAD File Converter

Bay Technology announces CADNEX, a DOS-based CAD file format converter that provides transfer from one CAD file format to another. Import and export GDS-II, DXF, CIF and Gerber files. The converter links mechanical CAD systems to the manufacturing process. In addition to the CAD file converter, a robust graphics editor allows view, edit and plot of imported files. CADNEX is available at an introductory price of $1,500.
Bay Technology
INFO/CARD #183

RF literature

Analog Design Book

Butterworth-Heinemann announces the publication of *The Art and Science of Analog Circuit Design*, edited by Jim Williams of Linear Technology Corp. Jim Williams and sixteen other engineers (plus one physicist) have written twenty chapters grouped into four major parts: Learning How, Making It Work, Selling It, and Guidance and Commentary. The 392-page hardback sells for around $49.95.
Butterworth-Heinemann
INFO/CARD #206

XMTR Capacitor Catalog

High Energy Corporation's 16-page catalog offers a detailed description of an extensive variety of custom designed and manufactured ceramic RF transmitting capacitors. These capacitors are designed for use in applications requiring high currents, high KVA ratings and working voltages up to 40 kV. Capacitances range from 1 to 10,000 pF.
High Energy Corp.
INFO/CARD #205

Circulators and Isolators

DITOM Microwave has released a brochure covering their line of circulators and isolators designed exclusively for wireless commercial communications applications. Many of DITOM Microwave's products are low 3rd order intermodulation designs, providing optimum operation over a wide range of power for cellular base station equipment.
DITOM Microwave
INFO/CARD #193

Chip Capacitor Brochure

Metelics' capacitor brochure provides information on the company's MIS (metal-insulating layer-silicon) chip capacitors. These capacitors, intended for use in hybrid RF and microwave circuits, feature a dual insulating layer, low loss, large pad area for ribbon or multiple bonds, and a very low temperature coefficient.
Metelics Corp.
INFO/CARD #200

Catalog Supplement

Elantec introduces its 1995 New Product Supplement, which lists all new analog and mixed signal ICs released or planned for the year. It includes a complete review of new amplifiers, ASIC video devices, power MOSFET drivers and communications ICs.
Elantec, Inc.
INFO/CARD #192

Switches, Relays and Matrices

K&L/TRANSCO Switch Products announce a catalog encompassing all of its newly enhanced capabilities. The 160-page catalog contains three basic sections, K&L standard RF and microwave switches, K&L/TRANSCO standard RF, microwave and waveguide switches, and K&L RF and microwave distribution systems.
K&L Microwave, Inc.
INFO/CARD #198

Short Form Catalog

RF Products has published a 20-page short form catalog covering its full line of RF and microwave power transistors, 50 ohm unit amplifiers, 50 ohm transistor pallets and high power stripline resistors and terminations.
RF Products, Inc.
INFO/CARD #202

Service Information

The latest version of *Bench Briefs* from Hewlett-Packard includes information about a spare parts kit for the HP 8711A network analyzer, timebase ground-loops, and the implications of a clogged fan-filter on metrology instruments. Also included is an instrument service-note index.
Hewlett-Packard Co.
INFO/CARD #201

Antenna Brochure

Antennaco has released a brochure providing an overview of their complete line of antennas for the wireless communication industry. Included in their antenna line-up are medium-duty and heavy-duty Yagis, omnidirectional and hemispherical antennas, dipoles, PCS/PCN links and antennas for the broadcast industry.
Antennaco, Inc.
INFO/CARD #199

RF Book Catalog

Crestone Engineering has published catalog 0795, featuring over 90 books, software products and instructional videos. All catalog selections have been chosen specifically for engineers working in communications systems, circuit design and EMC. Books include classic reference texts as well as the latest releases from 17 different publishers. International service is provided; major credit cards accepted.
Crestone Engineering
INFO/CARD #197

RF Bandpass Filter Catalog

POLE/ZERO has released a catalog of tunable (solid state) RF bandpass filters. The catalog presents their modular digitally tuned RF filters and preselectors. The 22-page catalog contains information on POLE/ZERO's expanded MINI-POLE™, MAXI-POLE™ and POWER-POLE™ hopping filters.
POLE/ZERO Corp.
INFO/CARD #196

Cellular Products

Microwave Power Devices (MPD) has released a 14-page brochure describing the company's mission and their amplifiers for cellular/PCS applications. Their amplifier lines include Class A, Class AB, Class C and feed-forward amplifiers.
Microwave Power Devices, Inc.
INFO/CARD #195

RFIC Power Amplifiers

ITT GTC's 40-page RFIC Power Amplifier catalog contains data on seven different power amplifiers for various cellular and ISM band applications, along with package drawings and an application note titled, "Gate Bias Power Control Using MAX853 Negative Voltage Generator."
ITT GTC
INFO/CARD #194

Signal Source Catalog

Wavetek announces the release of a new shortform catalog for their Signal Source Technology product line. The catalog provides an overview of Wavetek's benchtop, programmable (GPIB/RS-232) and VXI waveform generation instrumentation. A series of product matrices enable users to easily identify the most suitable models for their applications.
Wavetek Corp.
INFO/CARD #191

RF guide to editorial coverage

RF advertising index

RF design

I wish to receive/continue receiving RF DESIGN

❐ Yes ❐ No

Signature ______________________ Date ______________

Name ______________________ Title ______________

Company ______________________

Address ______________________

City/State/Zip ______________________ Country ______________

Telephone ______________ Fax ______________ E-mail ______________

FREE INFO

MAIL OR FAX COMPLETED CARD TO (413) 637-4343

Issue Date **August 1995**

Expiration Date **November 1995**

1. Please indicate the primary end product manufactured (or service performed) at your plant:

06 ❐ Radar Systems
07 ❐ Weapons Control, Ordinance, Fusing Systems
08 ❐ Ground Support Equipment, Aircraft/Missile
09 ❐ Navigation Telemetry Systems
10 ❐ Global Positioning Systems
11 ❐ Electronic Warfare Systems
12 ❐ Communications Systems, Equipment
13 ❐ Cellular Systems Equipment
14 ❐ Consumer Electronics
15 ❐ CATV Broadcast Systems
16 ❐ Data Transmission, Computer Systems
17 ❐ Laser/Electro-Optical Systems Equipment
18 ❐ Security/Identification
19 ❐ Test and Measurement Equipment
20 ❐ Active Components (including Antennas), Devices, Subsystems
21 ❐ Passive Components
22 ❐ Materials, Hardware
23 ❐ Industrial/Commercial Control, Processing Equipment
24 ❐ Industrial/Academic Laboratories, Consultants
26 ❐ Government/Military: Research, Design, Engineering & Test
27 ❐ Medical Equipment
28 ❐ Automotives/Transportation
29 ❐ Education
❐ Other (please specify) ______________

2. Check your principal job function.

38 ❐ Design and Development Engineering
39 ❐ Design and Development Engineering Management
40 ❐ Engineering Services (Evaluation, QC, Reliability, Standards, Test)
41 ❐ Engineering Services Management (Evaluation, QC, Reliability, Standards, Test)
42 ❐ General and/or Corporate Management
43 ❐ Basic Research Management
44 ❐ Basic Research Engineering
45 ❐ Manufacturing and Production Management/Supervision
46 ❐ Manufacturing and Production Engineering
47 ❐ Purchasing and Procurement
48 ❐ College/University Faculty
❐ Other (please specify) ______________

3. Your main area of interest is: (Check all that apply)

50 ❐ DC - 200 MHz
51 ❐ 200 MHz - 500 MHz
52 ❐ 500 MHz - 1 GHz
53 ❐ 1 GHz - 8 GHz
54 ❐ 8 GHz - 18 GHz
55 ❐ 18 GHz - 26.5 GHz
56 ❐ 26.5 GHz - 40 GHz
57 ❐ 40 GHz +

4. Do your designs involve EMI protection or EMC compliance?

58 ❐ Yes 59 ❐ No

5. Please estimate the annual value of purchases which you influence:

60 ❐ Less than $10,000
61 ❐ $10,000 and $49,999
62 ❐ $50,000 and $99,999
63 ❐ $100,000 and $299,999
64 ❐ $300,000 to $499,999
65 ❐ $500,000 or more

Information on the products and services advertised in this issue can be obtained by circling the INFO/CARD number (which appears below the advertisement or product release) below.

1	24	47	70	93	116	139	162	185	208	231
2	25	48	71	94	117	140	163	186	209	232
3	26	49	72	95	118	141	164	187	210	233
4	27	50	73	96	119	142	165	188	211	234
5	28	51	74	97	120	143	166	189	212	235
6	29	52	75	98	121	144	167	190	213	236
7	30	53	76	99	122	145	168	191	214	237
8	31	54	77	100	123	146	169	192	215	238
9	32	55	78	101	124	147	170	193	216	239
10	33	56	79	102	125	148	171	194	217	240
11	34	57	80	103	126	149	172	195	218	241
12	35	58	81	104	127	150	173	196	219	242
13	36	59	82	105	128	151	174	197	220	243
14	37	60	83	106	129	152	175	198	221	244
15	38	61	84	107	130	153	176	199	222	245
16	39	62	85	108	131	154	177	200	223	246
17	40	63	86	109	132	155	178	201	224	247
18	41	64	87	110	133	156	179	202	225	248
19	42	65	88	111	134	157	180	203	226	249
20	43	66	89	112	135	158	181	204	227	250
21	44	67	90	113	136	159	182	205	228	251
22	45	68	91	114	137	160	183	206	229	252
23	46	69	92	115	138	161	184	207	230	253

For your own subscription to RF DESIGN, circle number 253. You will be billed.

RF design

YES! Send RF DESIGN magazine.

Subscription Offer!

USA		Outside USA surface	air
2 years	❐ $72.00	❐ $112.00	❐ $192.00
1 year	❐ $42.00	❐ $62.00	❐ $102.00

all prices include a non-refundable $4.00 processing charge

❐ Check Enclosed ❐ Bill Me

Charge my: ❐ VISA/MC ❐ AMEX

Card# ______________ Exp. ________

Signature ______________

Date ______________

Name (print) ______________

Title ______________

Company ______________

Address ______________

City/State/Zip ______________

Country ______________

Phone ______________

Fax ______________

ALLOW 6-8 WEEKS TO RECEIVE FIRST ISSUE

Fax to: 703-647-7543

1. Please indicate the primary end product manufactured (or service performed) at your plant:

06 ❐ Radar Systems
07 ❐ Weapons Control, Ordinance, Fusing Systems
08 ❐ Ground Support Equipment, Aircraft/Missile
09 ❐ Navigation Telemetry Systems
10 ❐ Global Positioning Systems
11 ❐ Electronic Warfare Systems
12 ❐ Communications Systems, Equipment
13 ❐ Cellular Systems Equipment
14 ❐ Consumer Electronics
15 ❐ CATV Broadcast Systems
16 ❐ Data Transmission, Computer Systems
17 ❐ Laser/Electro-Optical Systems Equipment
18 ❐ Security/Identification
19 ❐ Test and Measurement Equipment
20 ❐ Active Components (including Antennas), Devices, Subsystems
21 ❐ Passive Components
22 ❐ Materials, Hardware
23 ❐ Industrial/Commercial Control, Processing Equipment
24 ❐ Industrial/Academic Laboratories, Consultants
26 ❐ Government/Military: Research, Design, Engineering & Test
27 ❐ Medical Equipment
28 ❐ Automotives/Transportation
29 ❐ Education
❐ Other (please specify) ______________

2. Check your principal job function.

38 ❐ Design and Development Engineering
39 ❐ Design and Development Engineering Management
40 ❐ Engineering Services (Evaluation, QC, Reliability, Standards, Test)
41 ❐ Engineering Services Management (Evaluation, QC, Reliability, Standards, Test)
42 ❐ General and/or Corporate Management
43 ❐ Basic Research Management
44 ❐ Basic Research Engineering
45 ❐ Manufacturing and Production Management/Supervision
46 ❐ Manufacturing and Production Engineering
47 ❐ Purchasing and Procurement
48 ❐ College/University Faculty
❐ Other (please specify) ______________

3. Do your designs involve EMI protection or EMC compliance?

49 ❐ Yes 50 ❐ No

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO 11077 ATLANTA GA

POSTAGE WILL BE PAID BY ADDRESSEE

ARGUS BUSINESS
RF DESIGN
PO BOX 5286
PITTSFIELD MA 01203-9608

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO 1099 SKOKIE IL

POSTAGE WILL BE PAID BY ADDRESSEE

ARGUS BUSINESS
RF DESIGN
PO BOX 1147
SKOKIE IL 60076-9736

RF design

I wish to receive/continue receiving RF Design

❐ Yes ❐ No

Signature ______________________ Date ______________

Name ______________________ Title ______________

Company ______________________

Address ______________________

City/State/Zip ______________________ Country ______________

Telephone ______________ Fax ______________ E-mail ______________

FREE INFO

MAIL OR FAX COMPLETED CARD TO (413) 637-4343

Issue Date **August 1995**

Expiration Date **November 1995**

1. Please indicate the primary end product manufactured (or service performed) at your plant:

06 ❐ Radar Systems
07 ❐ Weapons Control, Ordinance, Fusing Systems
08 ❐ Ground Support Equipment, Aircraft/Missile
09 ❐ Navigation Telemetry Systems
10 ❐ Global Positioning Systems
11 ❐ Electronic Warfare Systems
12 ❐ Communications Systems, Equipment
13 ❐ Cellular Systems Equipment
14 ❐ Consumer Electronics
15 ❐ CATV Broadcast Systems
16 ❐ Data Transmission, Computer Systems
17 ❐ Laser/Electro-Optical Systems Equipment
18 ❐ Security/Identification
19 ❐ Test and Measurement Equipment
20 ❐ Active Components (including Antennas), Devices, Subsystems
21 ❐ Passive Components
22 ❐ Materials, Hardware
23 ❐ Industrial/Commercial Control, Processing Equipment
24 ❐ Industrial/Academic Laboratories, Consultants
26 ❐ Government/Military: Research, Design, Engineering & Test
27 ❐ Medical Equipment
28 ❐ Automotives/Transportation
29 ❐ Education
❐ Other (please specify) ______________

2. Check your principal job function.

38 ❐ Design and Development Engineering
39 ❐ Design and Development Engineering Management
40 ❐ Engineering Services (Evaluation, QC, Reliability, Standards, Test)
41 ❐ Engineering Services Management (Evaluation, QC, Reliability, Standards, Test)
42 ❐ General and/or Corporate Management
43 ❐ Basic Research Management
44 ❐ Basic Research Engineering
45 ❐ Manufacturing and Production Management/Supervision
46 ❐ Manufacturing and Production Engineering
47 ❐ Purchasing and Procurement
48 ❐ College/University Faculty
❐ Other (please specify) ______________

3. Your main area of interest is: (Check all that apply)

50 ❐ DC - 200 MHz
51 ❐ 200 MHz - 500 MHz
52 ❐ 500 MHz - 1 GHz
53 ❐ 1 GHz - 8 GHz
54 ❐ 8 GHz - 18 GHz
55 ❐ 18 GHz - 26.5 GHz
56 ❐ 26.5 GHz - 40 GHz
57 ❐ 40 GHz +

4. Do your designs involve EMI protection or EMC compliance?

58 ❐ Yes 59 ❐ No

5. Please estimate the annual value of purchases which you influence:

60 ❐ Less than $10,000
61 ❐ $10,000 and $49,999
62 ❐ $50,000 and $99,999
63 ❐ $100,000 and $299,999
64 ❐ $300,000 to $499,999
65 ❐ $500,000 or more

Information on the products and services advertised in this issue can be obtained by circling the INFO/CARD number (which appears below the advertisement or product release) below.

1	24	47	70	93	116	139	162	185	208	231
2	25	48	71	94	117	140	163	186	209	232
3	26	49	72	95	118	141	164	187	210	233
4	27	50	73	96	119	142	165	188	211	234
5	28	51	74	97	120	143	166	189	212	235
6	29	52	75	98	121	144	167	190	213	236
7	30	53	76	99	122	145	168	191	214	237
8	31	54	77	100	123	146	169	192	215	238
9	32	55	78	101	124	147	170	193	216	239
10	33	56	79	102	125	148	171	194	217	240
11	34	57	80	103	126	149	172	195	218	241
12	35	58	81	104	127	150	173	196	219	242
13	36	59	82	105	128	151	174	197	220	243
14	37	60	83	106	129	152	175	198	221	244
15	38	61	84	107	130	153	176	199	222	245
16	39	62	85	108	131	154	177	200	223	246
17	40	63	86	109	132	155	178	201	224	247
18	41	64	87	110	133	156	179	202	225	248
19	42	65	88	111	134	157	180	203	226	249
20	43	66	89	112	135	158	181	204	227	250
21	44	67	90	113	136	159	182	205	228	251
22	45	68	91	114	137	160	183	206	229	252
23	46	69	92	115	138	161	184	207	230	253

For your own subscription to RF Design, circle number 253. You will be billed.

RF design

I wish to receive/continue receiving RF Design

❐ Yes ❐ No

Signature ______________________ Date ______________

Name ______________________ Title ______________

Company ______________________

Address ______________________

City/State/Zip ______________________ Country ______________

Telephone ______________ Fax ______________ E-mail ______________

FREE INFO

MAIL OR FAX COMPLETED CARD TO (413) 637-4343

Issue Date **August 1995**

Expiration Date **November 1995**

1. Please indicate the primary end product manufactured (or service performed) at your plant:

06 ❐ Radar Systems
07 ❐ Weapons Control, Ordinance, Fusing Systems
08 ❐ Ground Support Equipment, Aircraft/Missile
09 ❐ Navigation Telemetry Systems
10 ❐ Global Positioning Systems
11 ❐ Electronic Warfare Systems
12 ❐ Communications Systems, Equipment
13 ❐ Cellular Systems Equipment
14 ❐ Consumer Electronics
15 ❐ CATV Broadcast Systems
16 ❐ Data Transmission, Computer Systems
17 ❐ Laser/Electro-Optical Systems Equipment
18 ❐ Security/Identification
19 ❐ Test and Measurement Equipment
20 ❐ Active Components (including Antennas), Devices, Subsystems
21 ❐ Passive Components
22 ❐ Materials, Hardware
23 ❐ Industrial/Commercial Control, Processing Equipment
24 ❐ Industrial/Academic Laboratories, Consultants
26 ❐ Government/Military: Research, Design, Engineering & Test
27 ❐ Medical Equipment
28 ❐ Automotives/Transportation
29 ❐ Education
❐ Other (please specify) ______________

2. Check your principal job function.

38 ❐ Design and Development Engineering
39 ❐ Design and Development Engineering Management
40 ❐ Engineering Services (Evaluation, QC, Reliability, Standards, Test)
41 ❐ Engineering Services Management (Evaluation, QC, Reliability, Standards, Test)
42 ❐ General and/or Corporate Management
43 ❐ Basic Research Management
44 ❐ Basic Research Engineering
45 ❐ Manufacturing and Production Management/Supervision
46 ❐ Manufacturing and Production Engineering
47 ❐ Purchasing and Procurement
48 ❐ College/University Faculty
❐ Other (please specify) ______________

3. Your main area of interest is: (Check all that apply)

50 ❐ DC - 200 MHz
51 ❐ 200 MHz - 500 MHz
52 ❐ 500 MHz - 1 GHz
53 ❐ 1 GHz - 8 GHz
54 ❐ 8 GHz - 18 GHz
55 ❐ 18 GHz - 26.5 GHz
56 ❐ 26.5 GHz - 40 GHz
57 ❐ 40 GHz +

4. Do your designs involve EMI protection or EMC compliance?

58 ❐ Yes 59 ❐ No

5. Please estimate the annual value of purchases which you influence:

60 ❐ Less than $10,000
61 ❐ $10,000 and $49,999
62 ❐ $50,000 and $99,999
63 ❐ $100,000 and $299,999
64 ❐ $300,000 to $499,999
65 ❐ $500,000 or more

Information on the products and services advertised in this issue can be obtained by circling the INFO/CARD number (which appears below the advertisement or product release) below.

1	24	47	70	93	116	139	162	185	208	231
2	25	48	71	94	117	140	163	186	209	232
3	26	49	72	95	118	141	164	187	210	233
4	27	50	73	96	119	142	165	188	211	234
5	28	51	74	97	120	143	166	189	212	235
6	29	52	75	98	121	144	167	190	213	236
7	30	53	76	99	122	145	168	191	214	237
8	31	54	77	100	123	146	169	192	215	238
9	32	55	78	101	124	147	170	193	216	239
10	33	56	79	102	125	148	171	194	217	240
11	34	57	80	103	126	149	172	195	218	241
12	35	58	81	104	127	150	173	196	219	242
13	36	59	82	105	128	151	174	197	220	243
14	37	60	83	106	129	152	175	198	221	244
15	38	61	84	107	130	153	176	199	222	245
16	39	62	85	108	131	154	177	200	223	246
17	40	63	86	109	132	155	178	201	224	247
18	41	64	87	110	133	156	179	202	225	248
19	42	65	88	111	134	157	180	203	226	249
20	43	66	89	112	135	158	181	204	227	250
21	44	67	90	113	136	159	182	205	228	251
22	45	68	91	114	137	160	183	206	229	252
23	46	69	92	115	138	161	184	207	230	253

For your own subscription to RF Design, circle number 253. You will be billed.

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO 11077 ATLANTA GA

POSTAGE WILL BE PAID BY ADDRESSEE

ARGUS BUSINESS
RF DESIGN
PO BOX 5286
PITTSFIELD MA 01203-9608

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO 11077 ATLANTA GA

POSTAGE WILL BE PAID BY ADDRESSEE

ARGUS BUSINESS
RF DESIGN
PO BOX 5286
PITTSFIELD MA 01203-9608