An INTERTEC® Publication

RF design™

engineering principles and practices

April 1996

High Level Integration Comes to DDS Devices

Technical Features —

Baseband Signal Processing

SS Sliding Correlator

Show Issue!
IWCE/RF Design Seminars

When you're looking for the leader of the pack in CDMA testing, there's only one name to call: Noise Com.

The WIS Series (Wireless Impairment System) — A complete, automated solution for testing CDMA base and mobile stations.

To completely characterize the performance of CDMA base and mobile stations, a hodge-podge of general-purpose test equipment just won't do. You need an integrated solution designed to satisfy all of the demands of test standards such as IS-97 and IS-98 for cellular, and ANSI J-STD-019 and ANSI J-STD-018 for PCS applications. That's precisely the job Noise Com's WIS Series is designed to do.

The WIS Series is the only test station to combine so many automated CDMA measurement capabilities in a single, rack-mount system. They can provide emulation of wireless channel impairments such as additive white Gaussian noise (AWGN), multipath fading, as well as interference.

Multipath fading, AWGN and interference...

To emulate multipath fading, the WIS Series can model wireless communication channels between base stations and mobile transceivers using Rayleigh, Rician, Log-Normal, Suzuki, and Nakagami fading statistics. The WIS Series is also the only CDMA test solution with an AWGN generator that can precisely set Eb/No, C/N, and C/I ratios. The WIS series can be configured with either base or mobile station interference sets or both, providing a complete impairment solution.

Combine the WIS Series with either a base station or mobile transmitter, or a base or mobile station simulator, and you have the most accurate, comprehensive CDMA measurement solution available.

The configuration of the WIS Series is flexible, too, so you can pick and choose the capabilities you want right now, with the option to modify or upgrade them later. So, whether your measurement needs are in product development and design verification, production testing, or quality control, the WIS Series is the system you can rely on today...and tomorrow.

Call us about our entire line of wireless test solutions.

When you want to deal with the leader of the pack in CDMA, there's only one name to remember: Noise Com. For more details, call us today at (201) 261-8797, fax us at (201) 261-8339, e-mail: noisecom@haven.ios.com, or write us at E. 49 Midland Ave., Paramus, NJ 07652. Noise Com. We're your global partner for wireless, telecommunications, and noise testing solutions.

The Wireless Telecom Group is a publicly traded company and is listed on the American Stock Exchange. Symbol: WTT

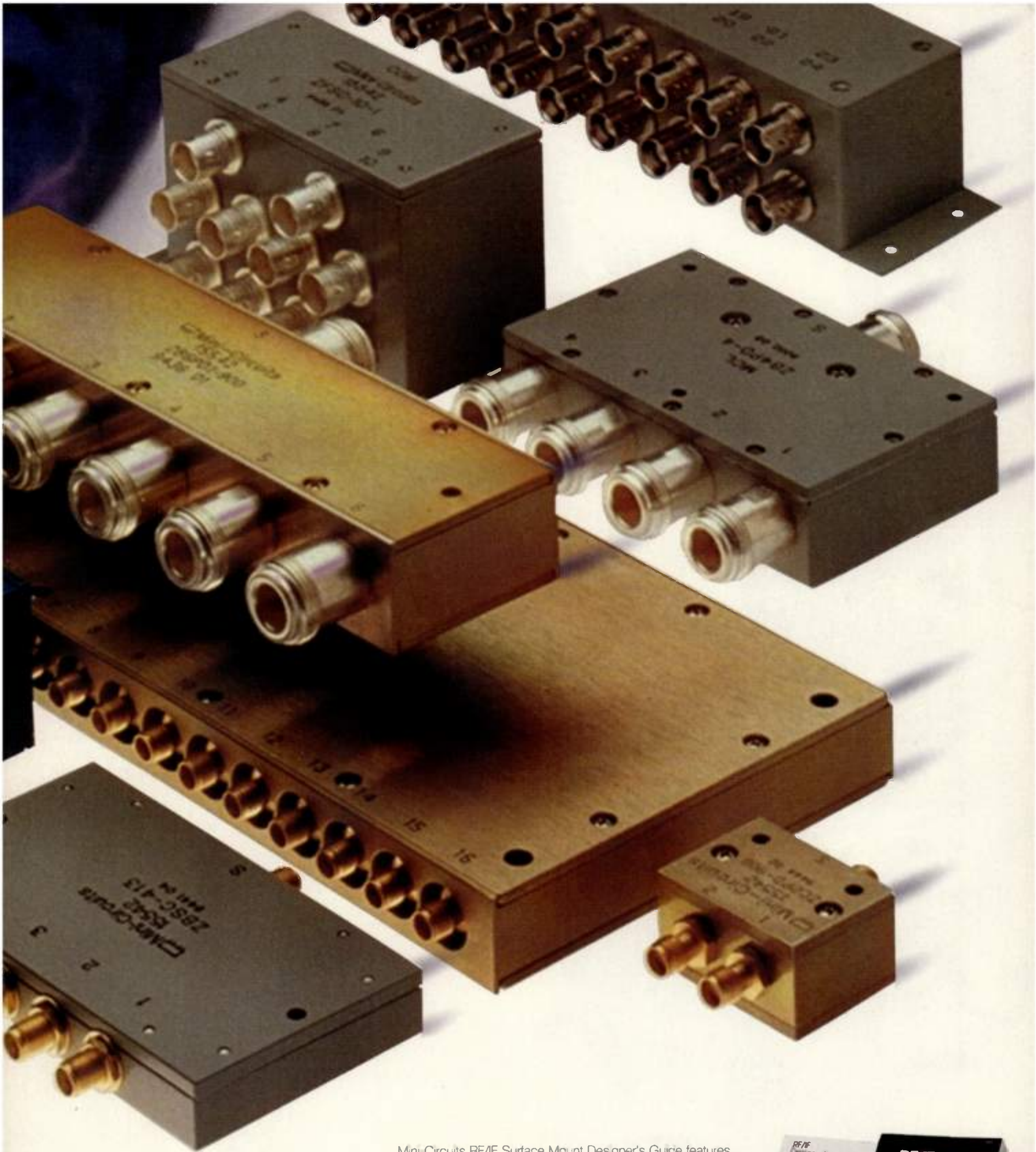
AMERICAN STOCK EXCHANGE

The Smarter Place To Be

NOISE/COM

A WIRELESS TELECOM GROUP COMPANY

INFO/CARD 1



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

RF design

contents

April 1996

cover story — p. 56

EMC
TEST & DESIGN

EMC coverage starts on page 81 —

News, Products, and A P.C. board design feature article...

RF editorial

I will be leaving *RF Design*, but it's not "Good-bye"

By Gary A. Breed
Editor

After more than ten years at *RF Design*, I am moving on to those proverbial "bigger and better things." (No, this isn't an April Fool's joke) My new job will be President of Noble Publishing, which some of you may recognize as a technical book publishing company. Instead of seeking out the most appropriate technical articles for you to read, I will be finding authors and developing the most appropriate textbooks and reference books to put in your library.

RF Design will be in good hands. No, we haven't yet found the next Editor, but he or she is certainly out there among the many excellent RF engineers who have a broader-than-usual outlook on business and technology. In the mean time, I will help the present staff in any way necessary to maintain *RF Design*'s quality.

This magazine has prospered while I've been here, growing steadily even through the dark years of military cutbacks. I suppose I should take some of the credit for that success, but only a part. The concept of providing useful, timely engineering information in *RF Design* was established long before I became Editor. With only a few dissenters, you have repeatedly told me that I've done a good job fulfilling that mission. Your appreciation of my efforts is humbly acknowledged. Thanks for your support.

As the title above suggests, you won't be rid of me! Noble Publishing's books emphasize RF design techniques and other communications-related topics. I will be at many of the same engineering conferences and trade shows where you've seen me before, talking with you about all things related to RF. I will probably continue to contribute articles to *RF Design*, maybe even some editorial comments like you've found in this column every month. I will still be easy to find!

See You at IWCE and the RF Design Seminar Series

Don't forget to make the trip to Las Vegas April 23-26! I will be there, hosting the *RF Design*-sponsored events. The RF Design Seminar Series offers valuable short courses that are still open for registration (if you hurry). In addition, the giant International Wireless Communications Expo (IWCE) will have hundreds of radio equipment suppliers and more than 70 exhibit booths with the RF suppliers you need to see. They will be presenting the latest components, equipment and software for you to evaluate.

IWCE presentations cover all aspects of the radio communications business — regulations, operations, standards, business concerns, and of course, a Thursday afternoon session of RF-related technical papers. This is the place to catch up on the issues surrounding mobile communications!

IWCE provides a unique environment, combining end-user products (hand-held, mobile and base station radios and accessories), with system-level hardware (antennas, control systems, transmission lines and towers), and now including components, software and instruments for the design of those finished products. The synergy of users, system operators and design engineers all in one one place should create lots of new ideas, and a new appreciation for each level of technology.

Kalmus: A Tradition of High Performance, Value-Packed RF Amplifiers

"When Kalmus began designing and manufacturing RF amplifiers in 1971, the vision was to produce the best high performance product possible for the best possible price."

"As we address the needs of the engineering community in the 21st century, we never lose sight of this tradition. At the same time, however, we are taking our operations to an unprecedented level of engineering and manufacturing excellence."

"For example, our engineering and design capability enables us to respond rapidly to customer requirements. And with improved order handling and production capability, we are continually reducing delivery times."

"With the resources of Thermo Voltek behind us, Kalmus is committed to producing technically advanced RF amplifiers upon which customers can depend, and to expanding its leadership position."

Colin I. W. Baxter, President
Kalmus

Straight Talk About RF Power Amplifiers.

Kalmus offers over 120 ruggedly built RF amplifiers for use in EMC testing, medical, communications and general laboratory applications. A comprehensive line of RF amplifier modules and custom amplifier options are also available.

RF AMPLIFIERS

- Stock and Custom Amplifiers and Modules
- Meets RF Immunity Standards, including IEC 1000-4-3 and 1000-4-6

EMC Test Amplifiers
- RF power levels from 1 to 3000 Watts
- Covering the frequency spectrum from 10KHz to 1GHz

Communications Amplifiers
- RF power levels to 1000 Watts
- Covering communications bands to 1GHz

Pulsed Amplifiers
- RF power levels to 12 KW
- Fast rise and fall times, high efficiency

Dual Band Amplifiers
- RF power levels to 100 Watts
- Offers operator convenience and cost savings without technical/capability compromise

Distributed Tube Amplifiers
- RF power levels to 2000 Watts
- Cover 14 octaves from 10KHz to 220MHz with rise and fall times of better than 3 nanoseconds

O.E.M. Amplifier Modules
- RF power levels from 1 to 250 Watts
- Many stock and custom modules can be tailored for specific O.E.M. applications

For detailed information about the full line of Kalmus RF amplifiers, please contact: **1-800-344-3341**

KALMUS

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

Distributor:
KeyTek • One Lowell Research Center • Lowell • MA 01852-4345 USA
(800) 753-9835 • Tel: (508) 275-0800 • Fax: (508) 275-0850

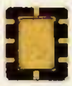
http://www.thermovoltek.com

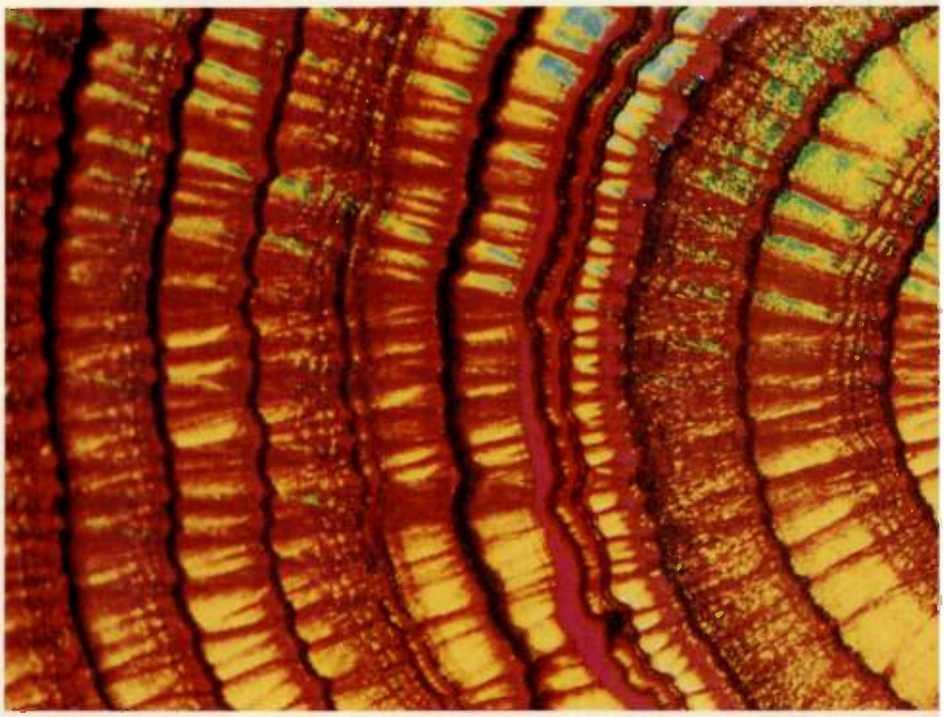
Thermo Voltek

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

WHEN IT COMES TO RF SAW FILTER TECHNOLOGY, THE CHOICE IS CLEAR.

ANTENNA DUPLEXER
9.5 mm x 7.5 mm





900 MHz
TWO-WAY
PAGERS

PCS APPLICATIONS
3 mm x 3 mm

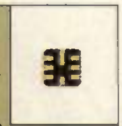
You want your wireless designs to outperform the competition, so you need a wide range of superior RF SAW Filter technologies. That's why Fujitsu delivers the most comprehensive selection of unparalleled, low loss, subminiature SAW Filters in the industry—internally matched to 50 Ω for system design simplicity.

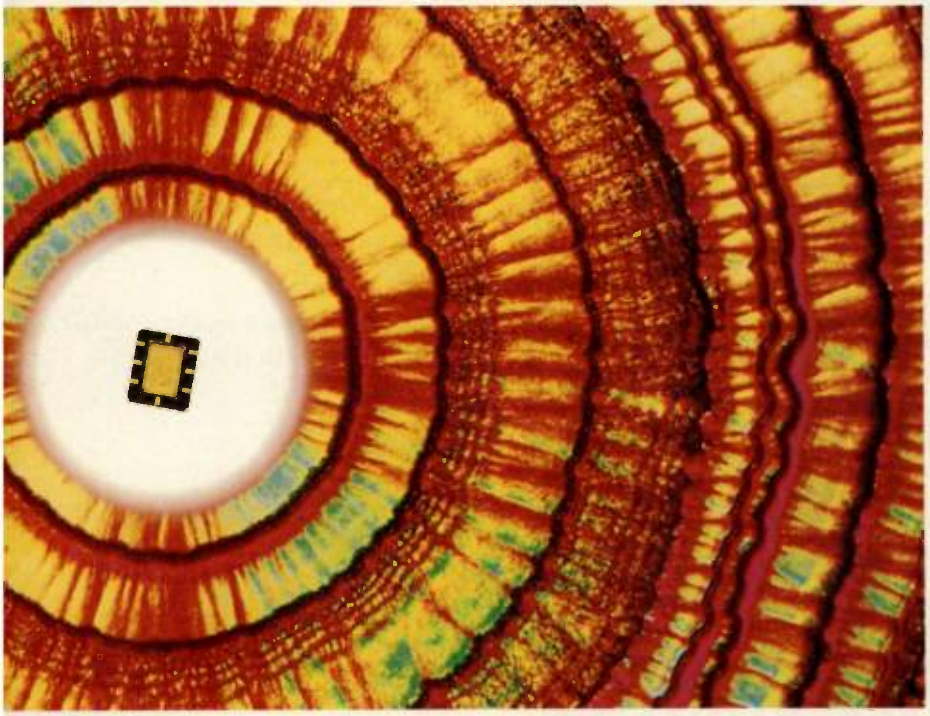
Fujitsu's extensive research and development supports the integration requirements of increasingly smaller, lighter, and higher performance wireless systems—enabling you to create viable products for leading wireless applications. Our Lithium Tantalate Bandpass SAW Filters provide broad support for wireless applications from 200 MHz to 2.5 GHz and offer compatibility with major cellular standards including GSM, AMPS, NMT, ETACS, NTACS, PDC and NTT. While meeting stringent performance requirements in a small footprint.

FUJITSU MICROELECTRONICS, INC., 3545 North First Street, San Jose, CA 95134.

WIRELESS LANS & WANS

5 mm X 5 mm HIGH POWER ANTENNA SAW FILTERS





200 MHz TO 600 MHz IN DEVELOPMENT

BUILDING THE SMALLEST SOLUTION

Our latest product developments include a revolutionary Antenna Duplexer, the smallest in the industry, for AMPS, TDMA and CDMA cellular systems. Also our high-performance SAW Filters for PCS and DCS1800 systems and wireless LANs feature 3.0 x 3.0 mm packages for space critical applications. In addition, we offer standard SAW Filter products for two-way paging and messaging applications.

We're working hard to meet all of your future price/performance needs with exceptional SAW Filter solutions. So if you're looking for the best way to achieve high performance while reducing size and weight, choose Fujitsu. We'll deliver the products you need to reach the smallest system solution. Call Fujitsu Microelectronics today at 1-800-866-8608, or visit our web site at http://www.fujitsumicro.com.

FUJITSU

COMPUTERS, COMMUNICATIONS, MICROELECTRONICS

Chips are shown at actual size.

INFO/CARD 8

RF design
Established 1978

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

Editor
Gary A. Breed

Assistant Editor
Stacey O'Rourke

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*
Raymond Sicotte, *American Microwave Corp.*
Robert J. Zavrel, Jr., *IBM*

Senior Managing Editor
Tom Cook

Intertec Publishing Corporation offices
9800 Metcalf
Overland Park, KS 66212-2215
Tel: (913) 341-1300

President and CEO
Raymond E. Maloney

Senior Vice President
Cameron Bishop

Publisher
Mercy Contreras

Vice President — Circulation
Nick Cavnar

Circulation Director
Michele Bartlett

Marketing Manager
Midwest and West — AR, IA, IL, IN, KY, MI, MN, MO, ND, SD, NE, WI, AL, LA, MS, TN, AK, CO, ID, KS, MT, NM, NV, OK, OR, TX, UT, WA, WY, CA, AZ, HI, Ontario and Western Canada
Janell Count (303) 220-0600

Marketing Manager
East — CT, DE, MA, ME, NH, NJ, NY, PA, RI, VT, OH, VA, WV, DC, MD, FL, GA, NC, SC, Quebec and Eastern Canada
Mike Henry (703) 257-1202

Classified Advertising Manager
Shannon Shuman

Reprints Manager
Ed Laborwit

List Rental Manager
Etta Davis

Creative Director
Brian Buxton

Production Manager
Barbara Newmarker

BPA INTERNATIONAL

INTERTEC PUBLISHING
Argus Inc., A Division of Intertec Publishing Corporation

Subscription inquiries: (847) 647-0756

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

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°

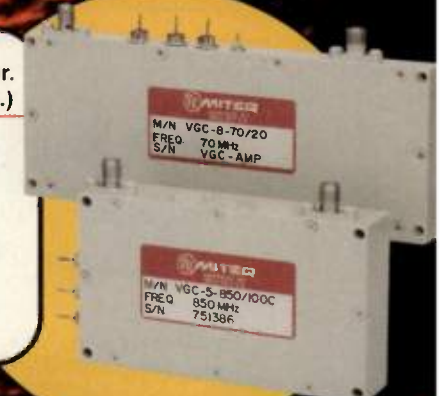
Call today for your RHG cross-reference guide

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

Editor Wanted for RF design

?

ARE YOU INTERESTED IN EVERYTHING ABOUT RF?

HERE'S THE BEST JOB AN RF ENGINEER COULD WANT!

RF Design needs a new Editor to continue our strong tradition, and guide our magazine into the 21st Century.

Qualifications include a love of RF circuits and systems; a BSEE or equivalent and 3-5 years experience; excellent language skills; and broad-based knowledge of RF technologies, products and companies in the industry. Duties include all aspects of publishing — obtaining articles, directing production of each issue, managing a staff of two additional editors, and representing *RF Design* to the industry. Salary is competitive with most RF engineering positions, and Intertec Publishing offers excellent benefits. This is an exciting position in a strong forward-looking company!

To apply, send your resume with a cover letter outlining your interest and qualifications to:

RF Design Editor Search
Intertec Publishing
5660 Greenwood Plaza Blvd., Suite 350
Englewood, CO 80111
fax: (303) 793-0454

RF calendar

April

16-17 **Minnesota EMC Event**
Bloomington, MN
Information: Judie Anderson, 3001 Habor Lane, Suite 150, Plymouth, MN 55447. Tel: (612) 559-0332; Fax: (612) 553-9326.

23-26 **International Wireless Communications Expo (including the RF Design Seminar Series)**
Las Vegas, NV
Information: Intertec Presentations, 6151 Powers Ferry Road, N.W., Atlanta, GA 30339. Tel.: (800) 828-0420 or (770) 618-0499. Fax: (770) 618-0441.

28-1 **IEEE Vehicular Technology Conference-VTC '96**
Atlanta, GA
Information: Wendy Rochelle, IEEE/VTC'96 Registrar, P.O. Box: 1331, Piscataway, NJ 08855-1331. Tel: (908) 562-3870; Fax: (908) 981-1769. E-mail: VTC96@IEEE.com

June

5-7 **Frequency Control Symposium**
Honolulu, HI
Information: Michael Mirarchi, Synergistic Management, 3100 Route 138, Wall Township, NJ 07719. Tel: (908) 280-2024. Fax: (908) 681-9314.

16-21 **MTT-S International Microwave Symposium**
San Francisco, CA
Information: Derry Hornbuckle, Hewlett-Packard; Tel: (707) 577-3658; Fax: (707) 577-2036, or Jerry Fiedziusko, Space Systems/Loral Corp. Tel: (415) 852-6868. Fax: (415) 852-5068.

24-25 **Time and Frequency Seminars: Introduction-Level 1**
Boulder, CO

26-28 **Time and Frequency Seminars: Fundamentals-Level 2**
Boulder, CO
Information: Wendy Ortega Henderson, National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80303-3328. Tel: (303) 497-3593; Fax: (303)497-6461. E-mail: ortegaw@boulder.nist.gov

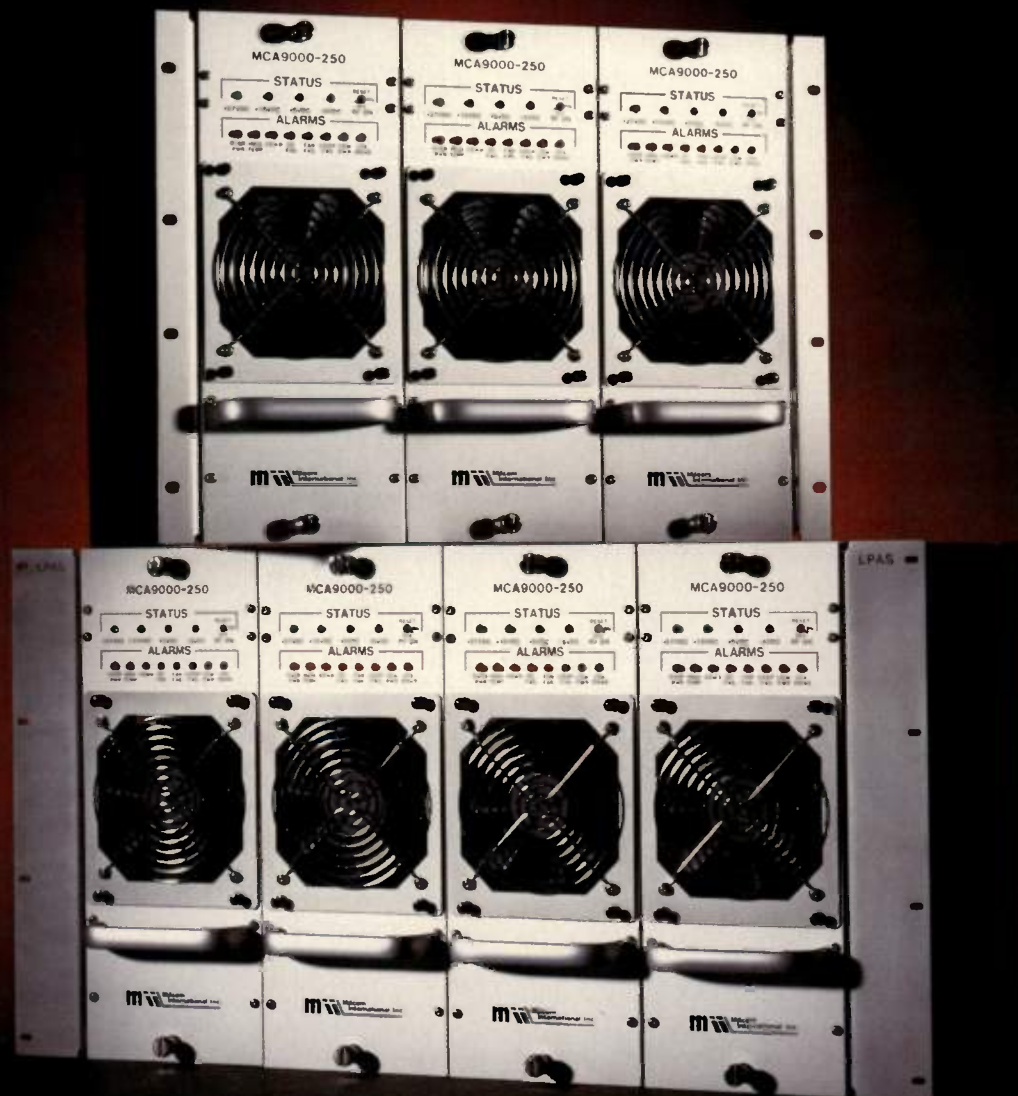
July

21-26 **1996 IEEE AP-S International Symposium and URSI Radio Science Meeting**
Baltimore, MD
Information: Mr. Jon Moellers, Steering Committee Chair, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331. Tel: (410) 993-6774; Fax: (410) 993-7432.

August

21-23 **Wireless Communications Workshop**
Boulder, CO
Information: Dr. Roger Marks, National Institute of Standards and Technology, 325 Broadway, MC 813.06, Boulder, Co 80303. Tel: (303) 497-3037; Fax: (303) 497-7828; E-mail: marks@nist.gov

You're looking at the only high power, multichannel, feedforward amplifier that's being delivered. In volume.



System standards include:
AMPS, CDMA/TDMA, TACS, SETACS, ETACS, FHMA and PCS (coming soon).

Oh sure, others can promise you an amplifier for your applications, but Milcom delivers. In fact, we've already shipped over 4,000 modules to the Pacific Rim and North America during the past year. So, put our extensive MCA Linear Technology experience to work for you. For full product specifications, or to place an order call us at (714) 757-0530.

Features include: *Hot standby-hot swap-system redundancy/reliability.*
Average power of 25-50 Watts per module, expandable to 200.
IMD specifications from -45 dBc to -70 dBc.
Frequency 800MHz to 960MHz.
Rack mountable, standard or custom, 19 and 26 inch versions.

Milcom International Inc.
Your partner in wireless technology.
17500 Gillette Avenue, Irvine, California 92714
Fax (714) 757-0941

INFO/CARD 16

RF courses

Antennas: Principles, Design and Measurements
May 14-17, 1996, St. Cloud (Orlando), FL
Information: Kelly Brown, Northeast Consortium for Engineering Education, 1101 Massachusetts Ave., St. Cloud, FL 34769. Tel: (407) 892-6146. Fax: (407) 892-0406.

DSP Without Tears
April 17-18, 1996, Fort Lauderdale, FL
May 1-3, 1996, Boston, MA
Information: Z Domain Technologies, Inc., 325 Pine Isle Court, Alpharetta, GA 30202. Tel: (770) 587-4812; Fax: (770) 518-8368.

RF and Wireless Engineering
April 23-25, 1996, Las Vegas, NV
Practical High Frequency Filter Design
April 23, 1996, Las Vegas, NV
Oscillator Design Principles
April 24, 1996, 1996, Las Vegas, NV
Digital Modulation and Spread Spectrum for Wireless Communications
April 23, 1996,
RF Power Transistors and Amplifiers
April 24, 1996, Las Vegas, NV
Information: RF Design Seminar Series, Argus Trade Shows, 6151 Powers Ferry Rd., N.W. Atlanta, GA 30339. Tel: (800) 828-0420.

Maximize Performance of Transmission Lines
April 9-11, Orland Park, IL
May 7-9, 1996, Orland Park, IL
June 4-6, 1996, Orland Park, IL
Information: Andrew Corporation, Dept. 355, P.O. Box: 9000, San Fernando, CA 91341-9978. Tel: (800) 255-1479 ext. 117.

Modern Receiver Design
April 15-19, 1996, London, U.K.
Wireless Infrastructure Network Engineering for Cellular, PCS, LEO and WPBX
April 15-19, 1996, Washington, DC
Microwave Tubes, High-Power Transmitters, and Microwave Systems: Basic Principles
April 29-May 3,1996, Washington, DC
Grounding, Bonding, Shielding and Transient Protection
April 29-May 3, 1996, San Diego, CA
Satellite Communications Engineering Principles
May 7-10, 1996, Washington, DC
Digital Image Processing
May 13-14, 1996, Washington, DC
Mobile Satellite Communications Systems
May 13-15, 1996, Washington, DC
Modern Digital Modulation Techniques
May 13-17, 1996, Washington, DC
Modern Digital Video Processing
May 15-17, 1996, Washington, DC
Global Positioning System: Principles and Practice
May 20-23, 1996, Washington, DC
Electromagnetic Interference and Control in Modern Communications Systems
May 20-24, 1996, Washington, DC
Mobile Communications Engineering
May 22-24, 1996, Washington, DC

Hazardous RF Electromagnetic Radiation: Evaluation, Control, Effects, and Standards
June 12-14, 1996, 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.

Grounding & Shielding Electronic Systems, and Circuit Board Layout
June, 1996 (dates TBA), Chicago, IL
August 14-16, 1996, San Jose, CA
Information: Continuing Education, University of Missouri-Rolla, 103 ME Annex, Rolla, MO 65409-1560. Tel: (314) 341-4132; Fax: (314) 341-4992.

Digital Video Technology
April 10-12, 1996, Los Angeles, CA
Wireless Voice and Data Communications
April 16-19, 1996, Los Angeles, CA
Advanced Communications Systems Using Digital Signal Processing
April 22-24, 1996, Los Angeles, CA
Wired and Wireless Telecommunications Networking
May 20-24, 1996, Los Angeles, CA
Information: UCLA Extension, 10995 Le Conte Ave., Suite 542, Los Angeles, CA 90024. Tel: (310) 825-1047; Fax: (310) 206-2815. E-mail: mhenness@unex.ucla.edu

---

RF IC Design of Wireless Communication Systems
April 23-26, 1996, San Francisco, CA
Information: Mead, Microelectronics, Inc., 7100 NW Grandview Dr., Corvallis, OR 97330. Tel: (541) 758-0828; Fax: (541) 752-1405.

Training Program for Cellular, PCS Staff
Independent Learning Program
Information: Virginia Polytechnic Institute and State University, Mobile and Portable Radio Research Group, 840 University City Blvd., Pointe West Commons, Suite 1, Blacksburg, VA 24061-0350. Tel: (540) 231-2970; Fax: (540) 231-2968.

Principles of Electronic Counter-Countermeaures
April 9-11, 1996, Atlanta, GA
Phased-Array Radar System Design
April 29-May 2, 1996, Atlanta, GA
Information: Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel: (404) 894-2547.

RF and Wireless Made Simple
April 29-30, 1996, Los Altos, CA
July 8-9, 1996,. Los Altos, CA
Applied RF Techniques I
April 29- May 3, 1996, Los Altos, CA
July 15-19, 1996, Los Altos, CA
Wireless RF System Design
May 6-10, 1996, Los Altos, CA
Applied RF Techniques II
May 6-10, 1996, Los Altos, CA
Information: Besser Associates, 4600 El Camino Real, Suite 210, Los Altos, CA 94022. Tel:(415) 949-3300; Fax: (415) 949-4400.

Forecast Predicts Small Increase in R & D Expenditures for 1996

R & D expenditures in 1996 are expected to increase to about $174 billion according to a Battelle - R & D Magazine forecast. This is a 1.7 percent increase over the $171 billion that the National Science Foundation estimates was spent in 1995. Although R & D investment stalled in the early 1990s, this period of stagnation is concluding and R & D spending will increase in the near future. The gradual recovery in R & D expenditures follows a pattern that Battelle predicted five years ago. Noting the growth of R & D expenditures in the 1980s, it was apparent that such growth would not be sustained. Battelle predicted a slowdown in growth in the early 1990s, followed by an increase in R & D spending by mid-decade. Major predictions for 1996 include:

- Federal R & D Spending will decrease, about a half-percent in 1995.
- Industry will increase R & D Spending, about 3 percent over last year.
- The remainder of R & D expenditures — $8.8 billion — will be supported by universities and non-profit organizations.
- A key to industrial investment is that long-anticipated real growth, outdistancing inflation, will occur in 1996.
- Private industry will increasingly look for opportunities to outsource internal R & D functions.
- An increasing share of U.S. Industry's R & D will be performed off shore, primarily in facilities owned by the same industry.
- The federal government's efforts at budget-cutting, coupled with philosophical changes toward national science policy, will affect R & D support and the federal laboratories.

Video Module Interface Proposed

A video interface specification, initiated by SGS-THOMSON Microelectronics and offered as an open standard, is winning support from the PC

Business Briefs

Densitron Moves to Larger Facility — Densitron Corporation America has moved to a larger facility in Santa Fe Springs, California. The new facility will accommodate Densitron's Engineering, Sales, Marketing, Finance, and manufacturing staff for its North American operations. Effective March 1,1996, Densitron's address is: 10430-2 Pioneer Blvd., Santa Fe Springs, CA 90670. Tel: (310) 941-5000; Fax: (310) 941-5757.

Rogers Corporation Acquires Product Lines From ARLON, Inc. — Rogers Corporation has acquired the relatively small business of high dielectric constant PTFE based non-reinforced circuit laminate products from ARLON, Inc., including the products known as DICLAD®810 and EPSILAM®10 circuit board materials.

JEFA Acquires COMSAT RSI — JEFA International, Inc. acquired by COMSAT RSI, Inc. on October 1,1995, to become "COMSAT RSI JEFA Wireless Systems." This acquisition includes a wider range of equipment, services, and resources to design and implement large, complex communications systems. JEFA Wireless has also moved up the road to: 2100 Couch Drive, McKinney, TX 75069; Tel: (214) 547-4455; Fax: (214) 542-4557.

Group Technologies Corporation Announces Sale of Metrum Unit — F. W. Bell, Inc. has purchased substantially all the assets of Metrum, Inc., of Littleton, Colorado, a wholly-owned subsidiary of Group Technologies Corporation of Tampa Florida. Metrum designs, manufactures and markets high performance, digital and analog recording technologies for data acquisition applications.

Interad, Ltd. has moved — Their new address is: 8020 Queenair Drive, Gaithersburg, MD 20879. Tel: (301) 948-1626; Fax: (301)977-7559.

Fujitsu Towa Electron Opens U.S. Office — Fujitsu Towa Electron Limited, a Japanese manufacturer of electronic components and assemblies, announced its expansion into the U.S. with the opening of Fujitsu Towa Electron U.S.A., Inc. in San Jose, California. The new office will manage product sales, marketing and technical support for North America. Fujitsu Towa Electron U.S.A., is located at 1641 N. First St., Sutie 155, San Jose, CA 9512. Tel: (408) 437-8900; Fax: (408) 437-0700.

Comtech Consolidates SPS Division into PST Division — Comtech Microwave Products Corp., a wholly-owned subsidiary of Comtech Telecommunications Corp., announced that effective immediately, its scientific Power Systems Division (SPS) will be consolidated into Comtech's Power Systems Technology Division (PST). All current SPS products and technology will be fully supported by PST.

Cadence Picks Systems Science to Provide Waveform Display Technology — Systems Science, Inc., a developer of design verification, test and visualization tools, and Cadence Design Systems, Inc., a major provider of EDA software and services, today announced that they have entered into an agreement to bundle Systems Science's SimWave® waveform display with Cadence's digital and analog simulators.

Cubic Communications Acquires Direction-Finding Product Line — Cubic Communications, Inc., has acquired the direction-finding product line assets of Ocean Applied Research (OAR) Corp.

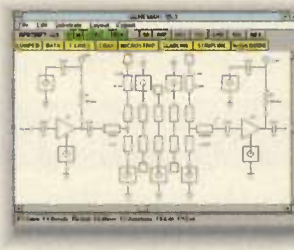
Harris Semiconductor Announces Major Expansion to High Speed Converter Portfolio — Harris Semiconductor has added 14 new high speed converters acquired through a buy-resell agreement with Sony; more Sony converters will be added over the next six months, in addition to new Harris developed converters.

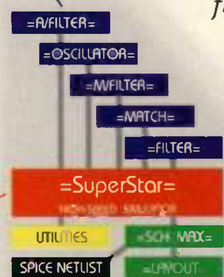
Weinschel relocates — Weinschel Corporation has relocated. Their new address is 5305 Spectrum Dr., Frederick, MD 217-7362. Tel: (800) 638-2048; (301) 831-4701; Fax: (301) 831-4570.

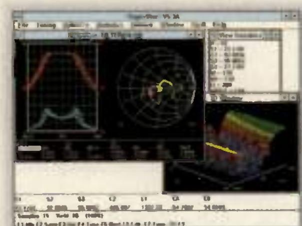
DESIGN FROM START-TO-ART

1 GENESYS synthesis modules make it easy to create initial designs for L-C filters, matching networks, active filters, oscillators, printed and machined filters, amplifiers and group delay equalizers. The many design alternatives and quick evaluation of each help you save time and achieve higher performance.

2 Schematics make it easy to enter your own designs, modify synthesis created designs and merge subcircuits. Schematics and simulation are integrated for back annotation. The GENESYS schematic module also writes Touchstone and Spice files.







3 =SuperStar= Professional redefines the circuit simulator standard. Step up to real-time tuning, statistical analysis, unrestricted global noise analysis, adaptive optimization, accurate models, unparalleled execution speed and the industry's easiest to use interface. Non-linear and time domain analysis is supported through the Spice interface.

NEW!

4 The new layout module creates artwork on your plotter or printer and in DXF (AutoCad) and optimized Gerber file formats. Discontinuity and transmission line dimensioning, coplanar ground pours, multilayers, arbitrary polygons and user footprint libraries make RF and microwave layout easier than ever before.

EAGLEWARE
11th Anniversary

Our first program shipped in 1985. Today, with thousands of users worldwide, Eagleware is a recognized leader in RF and microwave design software for IBM and compatible PCs. Here are a few reasons why we feel GENESYS provides unequaled value:

* Start-to-art solution including synthesis
* One easy to learn interface for all programs
* Industry's fastest execution means less waiting
* Accuracy verified with in-house lab
* Reads industry standard S-parameter files
* Free technical support with no annual fees
* Low cost
* 30 day money back satisfaction guarantee

Eagleware products run on standard IBM and compatible PCs under DOS, Windows 3.1, Windows NT and Windows 95. Windows versions are 32-bit for even faster execution.

GENESYS
VERSION 5.4

=SuperStar= Professional simulator	$999
Simulator with schematic entry and layout	$1990
Complete GENESYS package with synthesis	$5990
Layout upgrade for current customers	$699

(Upgrade discounts available for a limited time)

日本のお問い合わせ先
テクダイヤ株式会社
170 東京都豊島区東池袋3-1-1
TEL 03-3988-1731 FAX 03-3988-1706

SAME PRICES INTERNATIONALLY
DIRECT SALES & USER SUPPORT
BY FAX, PHONE OR LETTER

EAGLEWARE
Eagleware Corporation ★ 1750 Mountain Glen ★ Stone Mtn, GA 30087 ★ USA
http://www.eagleware.com ★ eagleware@eagleware.com
TEL (770) 939-0156 ★ FAX (770) 939-0157

Multimedia industry, including leading manufacturers such as STB Systems, Cirrus Logic, Trident, Sierra Semiconductor, Oak Technology, SiS, Alliance Semiconductor and ULSI systems. Known as the Video Module Interface (VMI), the proposal addresses the connection of video modules such as MPEG, video phone and video decoder, to GUI chip. Developed in conjunction with other manufacturers, including Cirrus Logic and Sierra Semiconductor, the key benefits of VMI are its flexibility and low-cost.

Report on Telecommunications Industry

With the passage of the Telecommunications Act of 1996, the spoils of wireless and wireline connectivity have been put on the table. At stake is the $45 billion in revenues generated annually from local telecommunications service in the US, a market Allied Business Intelligence, Inc. (ABI) forecasts to grow to $56.2 billion by 2001. This not including the CATV market, accounting for $33.4 billion in subscriber revenues and expected to reach $44.5 billion by 2001. Forecasting, historical data and a detailed breakdown of the component markets stemming from local loop telecommunications and CATV service are set forth in "The New Local Loop: Wireless & Wireline Telecommunications — 1996 to 2001 Strategic Analysis." The report was prepared over 10 months, from June, 1995, through March, 1996, by ABI's Senior Research Consultant, Francis X. Duffy. The qualitative section of the report offers details and insight about the local loop industry, regulation, established technologies, emerging technologies, and opportunities. The quantitative section takes a careful look at the US market by subscribership revenues and equipment sales. ABI is a high-tech strategic research firm based in Oyster Bay, New York. The technological developments now unfolding could change the shape of the wireless industry forever. For more details or to speak with the analyst regarding this study or a specific area of this study, please contact Tim Archdeacon at 516-624-3113.

"At the Asterisk, the Time Will be..."

NIST recently upgraded the equipment that provides its Automated Computer Time Service, or ACTS, for setting clocks in computers. Computers (and other equipment) can be programmed to call (303) 494-4774 for the time of day. The service has 12 incoming lines (in rotary), and PC based servers can accept calls at speeds up to 9,600 baud. These changes should provide smoother service to a broader variety of user modems. Software to use ACTS is available for $45 by ordering Standard Reference Material 8101b from the NIST SRM Program, Tel: (301) 975-6776; Fax: (301) 948-3730; E-mail: srminfo@enh.nist.gov. World Wide Web surfers can see a printout of the exact time at http://time.nist. gov:13/, but this will not reset your computers clock. And what about that "asterisk" in the title?


We designed and manufactured an antenna to find a polar bear in a snowstorm. And a rattlesnake in a sand dune. We can develop the right antenna for your application, too.
The challenge: design and manufacture an antenna that will withstand sixty below cold and one hundred degree heat. Mount on a snowmobile. Hang from an airplane. Bounce off a mountain. And still provide reliable telemetry.
Our solution: a virtually indestructible antenna that is compact and flexible, yet provides optimum range and sensitivity.
We're Centurion International. For nearly two decades, we've designed and manufactured top performance antennas to demanding requirements for use around the world. It's what we do every day.
First, we take the principles of RF and apply our innovative design insight. Then we mobilize our vertically integrated manufacturing process to produce antennas for a wide range of wireless applications—from land mobile radios and cellular phones to portable modems and computers, wireless bar-coding, PCS, GSM and GPS.
Put our proven design expertise and advanced in-house manufacturing capabilities to work for you. Send us your Pro-E or Unigraphics solid modeling drawings by modem, disk or tape (even sketches or samples) and we'll develop the right antenna solution for you.
Call 800-228-4563 for information.
Centurion International Inc.
P.O. Box 82846
Lincoln, Nebraska 68501
(800) 228-4563
(402) 467-4491
FAX (800) 848-3825
(402) 467-4528
TUF DUCK
CENTURION
INFO/CARD 20

The NIST computer systems use and asterisk as the on-time marker, analogous to the tone transmitted on shortwave radio and on the telephone at (303) 499-7111.

Jobs May Be Getting Scarcer For PhDs

Landing the job of their choice may be getting harder for science and engineering doctoral students, a recent national study suggests. Prospects are reported as particularly bad for those seeking a university research position. As few as one out of every three retiring university professors are replaced as of 1992. The number of job applicants outweighs the number of jobs available. Dr. Mary Frank Fox, a Georgia Institute of Technology Sociologist, and Georgia State University Economist Dr. Paula Stephan of the Policy Research Center, looked at five fields of study: chemistry, computer science, electrical engineering, microbiology and physics. In a survey of 3,800 student, 2,400 students responded about their perceptions of their career fields. According to Fox, today's science and engineering doctoral students are facing three major economic changes that may hamper their career prospects, including government deficits and their effects on federal funding for research and research training; the end of the Cold War and its effect on funding for scientific research tied to defense; and the lifting of the mandatory age for retirement and its effect on the replacement of scientific personnel.

Contracts

Baltimore Selects Motorola — The City of Baltimore Board of Estimates has awarded Motorola a $38 million contract to manufacture and install a new 800 MHz radio communications system for the city's public safety and public service agencies. The new Motorola ASTRO™ digital system initially will service City of Baltimore Fire Department. The system replaces a number of individual radio systems whose capabilities couldn't meet growing department communications needs.

Cancom Completes $20 Million Network — Canadian Satellite Communications (Cancom) put into service an MPEG-based digital video compression system from Scientific-Atlanta to make enhancements to its programming lineup without increasing costs for satellite transponder space. The US $20 million network includes 25 uplinks and approximately 14,000 Scientific-Atlanta digital satellite receivers.

Motorola Division Chooses ADRA — The Advanced Messaging Systems Division (AMSD) of Motorola, Inc., in Fort Worth, Texas, has selected Matrix, Adra System's unique PDM system, to manage and control information related to the product design process. Matrix will enable employees in AMSD to manage information and control the processes that govern the lifecycles of that information.

The Giga-tronics 8540B is the World's Best Power Meter for Communications Testing.

But Don't Take Our Word for It.

"Power meters generally fare well when characterizing simple continuous wave (CW) or pulsed RF/microwave signals. But modern communications signals, with digital information on phase–, frequency–, and amplitude–modulated carriers, pose problems for most power meters. The exception is the 8540B from Giga-tronics. The latest version of this high-speed measurement tool performs true average power measurements even on multitone signals with digital modulation."

Microwaves & RF
June 1995

Call 800-726-GIGA (4442)
or fax 510-328-4700 for more information for a demonstration.

Giga-tronics

Giga-tronics Incorporated ▪ 4650 Norris Canyon Road ▪ San Ramon, California 94583 ▪ Telephone: 800-726-4442 or 510-328-4650 ▪ Telefax: 510-328-4700

INFO/CARD 22

DSP Grows in Importance for New Communications Technologies

By Gary A. Breed
Editor

On the north side of the Dallas, Texas metropolitan area, in Richardson, the Texas Instruments campus has five construction cranes and hundreds of hard hats, turning former parking lots into wafer fabs. The main reason for this huge investment is to supply digital signal processing (DSP) ICs for the millions of new wireless, cable, and satellite communications products that will come to market in the next few years.

Like Texas Instruments, other DSP companies like AT&T Microelectronics, Motorola Semiconductor, Harris and Analog Devices are making similar investments in the future. They, and dozens of other companies with interface and data handling ICs in their product lines, are anticipating dramatic growth in DSP.

Because most new communications technologies are data-based, rather than analog-based, DSP is a natural fit for "back-end" signal filtering, error correction, echo-cancelling, and other signal processing functions. With data transmission requiring smaller signal-to-noise ratios than analog methods (but with wider bandwidth requirements), 10-bit or 12-bit digital words are sufficient, and easily handled in 16-bit DSP devices. For the dynamic range associated with analog transmission, 20 bits or more would be required.

Analog is Still Part of the Process

Analog techniques are, of course, essential for the amplification and detection of the RF transmissions that carry the data. In the transmitter, an RF carrier signal is modulated by the data, up-converted to the operating frequency, amplified, switched and filtered before being sent to the antenna. In the receiver, the signal is also filtered, switched, down-converted, filtered again, and demodulated to present the recovered data to the DSP part of the system.

Like other DSP IC makers, AT&T Microelectronics is seeking new, large markets in wireless communications. Their DSP1627 has 50 MIPS computing power when operating from a 3 volt supply; 70 MIPS at 5 volts.

Harris and Stanford Telecom have pioneered the development integrated digital down- and up-conversion devices, which can eliminate one part of the analog RF circuitry. However, the speed/frequency range of these devices is not yet high enough to replace the intermediate frequency (IF) circuitry in most communications equipment operating at 800 MHz or higher. The accuracy of digital processing can improve performance in those applications where digital conversion and demodulation are appropriate.

MPEG 2 video compression is a major technology in new communications applications. The VLSI Technology VES2020 transport demultiplexer is part of the data management system used in digital video set-top boxes.

DSP is here to stay, in conjunction with analog techniques. It is safe to suggest the the real "revolution" in communications technology today is the integration of many different techniques in a single product — or on a single chip. Radios aren't just radios any more. They are microprocessor-controlled, power-managed, analog and digitally processed devices. The separation of RF and digital into different disciplines is disappearing.

Digital signal processing is powerful, precise, and cheap when compared to equivalent analog processing. DSP's place in the next generation of radio-based products is assured. RF

Pioneers met the Challenge of the Western range on its own uncompromising terms, and developed a special breed of survivors

VARIL

We Have A Part In Your Future

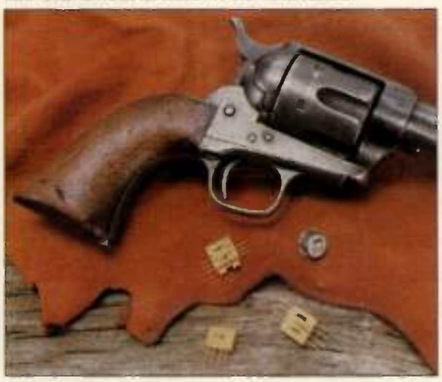
43 Years of Excellence in Manufacturing of RF & Microwave Components

Vari-L microwave devices are pictured with an ancient southwestern U.S. Anasazi pot filled with miniature corn and husks. Vari-L offers a complete line of mixers, transformers, switches and power dividers for a variety of military, industrial and commercial applications. For more information, request our NEW 1995 selection guide.

INFO/CARD 144

A turn-of-the-century wireless textbook pictured with current, state-of-the-art Vari-L surface mount VCOs and PLL modules for wireless applications. The VCO-190 & VCO-191 Series of VCOs are available in frequencies from 45 to 4000 MHz. Both series exhibit exceptional phase noise performance and low power consumption in miniature SMT packages. The PLL-300 and PLL-400 Series of Phase Locked Synthesizers are offered in frequency bands in the 45 to 3000 MHz range. The PLL Synthesizers also exhibit exceptional phase noise and low power consumption in miniature SMT packages. For more information, request our surface mount VCO/PLL brochures.

INFO/CARD 145



Authenticated from Custer battlefield, a U.S. Calvary 45 calibre single action Peacemaker is pictured with hybrid VCOs for high performance aerospace, military and industrial platforms. Vari-L manufactures hybrid VCOs from 25 to 5000 MHz. For more information, request our NEW 1995 hybrid VCO catalog.

INFO/CARD 146

Vari-L Double Balanced Mixers are photographed with a branding iron from the U.S. West. Vari-L mixers offer excellent performance in insertion loss, isolation, VSWR and intermodulation intercept point in a wide variety of packages for military, industrial and commercial applications. For more information, request our NEW 1995 selection guide.

INFO/CARD 147

1840's barbed wire and a rare buffalo skinning tool, pictured with a Vari-L PS-2-4000F power divider/combiner. The wideband, two-way, in-phase divider/combiner offers guaranteed performance over the wide frequency range of 20-4000 MHz. For more information, request a data sheet for the PS-2-4000F or for other power divider/combiners models, request the NEW 1995 selection guide.

INFO/CARD 148

Vari-L people are a special breed also, thriving on challenges and innovation in the development of Wireless products. We have a part in your future.

VARI-L is a precision manufacturer of RF components for a wide range of Aerospace, Military, Industrial and Commercial applications. Products offered include:

- Voltage Controlled Oscillators
- PLL Synthesizer Modules
- Double Balanced Mixers
- Wideband Transformers
- Power Dividers/Combiners
- Phase Detectors
- Phase Shifters
- Special Integrated Assemblies

Contact the Vari-L Sales Department for your special microwave and RF component assembly needs.

VARI-L Company, Inc. • 11101 East 51st Avenue • Denver, Colorado 80239 • Phone: 303/371-1560 • FAX: 303/371-0845

INFO/CARD 23

OUR STANDARD MONOLITHIC CRYSTAL FILTERS

All 2 pole and 4 pole monolithics ship from stock on hand.

10.7 MHz

NO. POLES	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM.(Rp//Cp) OHM/PF
2	TE5000	3	3.75	20	18.0	-	-	2	1.0	50	1800//+4
4	TE5010	3	3.75	30	14.0	-	-	3	2.0	60	1500//+3
6	TE5020	6	3.75	60	12.5	-	-	4	2.0	70	1500//+3
8	TE5030	6	3.75	60	10.0	90	12.5	5	2.0	80	1500//+3
2	TE5040	3	6.50	20	30.0	-	-	1	1.0	50	2700//0
4	TE5050	3	6.50	30	15.0	-	-	2	2.0	75	3100//0
6	TE5060	6	6.50	60	19.5	-	-	3	2.0	90	3100//0
8	TE5070	6	6.50	60	13.0	80	17.5	4	2.0	100	3100//0
2	TE5080	3	7.50	20	35.0	-	-	1	1.0	50	3000//0
4	TE5090	3	7.50	30	17.5	-	-	2	2.0	75	3300//0
6	TE5100	6	7.50	60	22.5	-	-	3	2.0	90	3300//0
8	TE5110	6	7.50	60	15.0	80	20.0	3	2.0	100	3300//0
2	TE5120	3	15.0	20	70.0	-	-	1	1.0	35	5000//-1
4	TE5130	3	15.0	30	35.0	-	-	2	2.0	60	5000//-1
6	TE5140	6	15.0	60	45.0	-	-	2	2.0	90	5000//-1
8	TE5150	6	15.0	60	30.0	80	40.0	3	2.0	100	5000//-1

21.4 MHz

NO. POLES	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM.(Rp//Cp) OHM/PF
2	TE5180	3	3.75	15	12.5	-	-	2	1.0	50	850//+6
4	TE5190	3	3.75	30	12.5	-	-	3	2.0	70	850//+5
6	TE5200	6	3.75	60	12.5	-	-	4	2.0	90	850//+5
8	TE5210	6	3.75	60	10.0	80	12.5	5	2.0	100	850//+5
2	TE5220	3	6.50	15	20.0	-	-	2	1.0	50	1300//+2
4	TE5230	3	6.50	30	22.5	-	-	3	2.0	70	1400//0
6	TE5240	6	6.50	60	22.5	-	-	4	2.0	90	1400//0
8	TE5250	6	6.50	60	17.5	80	22.5	4	2.0	100	1400//0
2	TE5260	3	7.50	15	25.0	-	-	2	1.0	50	1500//0
4	TE5270	3	7.50	30	25.0	-	-	3	2.0	70	1600//0
6	TE5280	6	7.50	60	25.0	-	-	4	2.0	90	1600//0
8	TE5290	6	7.50	60	20.0	80	25.0	4	2.0	100	1600//0
2	TE5300	3	15.0	15	50.0	-	-	2	1.0	45	3000//0
4	TE5310	3	15.0	30	45.0	-	-	3	2.0	60	3000//-1
6	TE5320	6	15.0	60	45.0	-	-	3	2.0	90	3000//-1
8	TE5330	6	15.0	60	33.0	80	45.0	4	2.0	100	3000//-1

45.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM.(Rp//Cp) OHM/PF
2	TE9420	3-OT	3	3.75	18	16.0	3	1	40	2000//-1.0
4	TE9310	3-OT	3	3.75	30	12.5	3	1	70	2000//-1.0
2	TE7420	3-OT	3	7.50	18	28.0	2	1	40	3000//-1.0
4	TE7430	3-OT	3	7.50	40	30.0	3	1	70	3000//-1.0
2	TE7440	3-OT	3	15.0	15	47.0	2	1	40	8000//-1.5
4	TE7450	3-OT	3	15.0	30	50.0	3	1	70	8000//-1.5
2	TE7730	FUND	3	15.0	15	50.0	2	1	40	1100//+1.5
4	TE7740	FUND	3	15.0	40	60.0	3	1	70	800//+1.0

70.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND KHz	LOSS dB	RIPPLE dB-MAX	TERM.(Rp//Cp) OHM//PF
2	TE10400	3-OT	3	7.5	18	30	35	-910	2	1	2000//-1
4	TE10410	3-OT	3	7.5	35	25	80	-910	3	1	2000//-1
2	TE10420	3-OT	3	10	15	30	35	-910	2	1	2500//-1
4	TE10430	3-OT	3	10	35	40	80	-910	3	1	2500//-1

90.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND KHz	LOSS dB	RIPPLE dB-MAX	TERM.(Rp//Cp) OHM//PF
2	TE10440	3-OT	3	7.5	18	30	35	-910	2	1	2000//-1
4	TE10450	3-OT	3	7.5	35	25	80	-910	3	1	2000//-1
2	TE10460	3-OT	3	10	15	30	35	-910	2	1	2500//-1
4	TE10470	3-OT	3	10	35	40	80	-910	3	1	2500//-1
4	TE10480	3-OT	3	15	30	50	80	-910	3	1	4000//-1

VISA AND MASTERCARD ACCEPTED

MONOLITHIC CRYSTAL FILTER PROTOTYPING KITS ARE STILL AVAILABLE

CONSULT TEMEX FOR ALL YOUR FREQUENCY CONTROL PRODUCTS

IN THE UNITED STATES CONTACT: **TEMEX ELECTRONICS, INC.**

3030 W. DEER VALLEY RD. PHOENIX, AZ USA 85027

(602) 780-1995 FAX (602) 780-2431

Sideband Suppression Considerations for Complex Baseband Processing of FDM Waveforms

By Rick Roberts
Harris Corporation

Frequency Division Multiplexing (FDM), in its various forms [1], continues to be popular for data communications. With the advent of the digital processor, a common technique for generation and processing of FDM is the zero Hertz IF; that is, quadraphase complex baseband waveform processing. This paper shows that the quadraphase characteristics can be degraded during frequency translation to/from a real frequency by I/Q imbalance resulting in cross channel interference between pairs of carriers. The amount of interference is quantified as sideband suppression. It is suggested that the frequency translation be done via DSP to achieve superior sideband suppression.

With the advent of digital signal processing, a common technique for generation and processing of FDM is a zero hertz IF baseband waveform in conjunction with the complex IFFT/FFT. It is desired that this baseband waveform be complex quadraphase, however, the quadraphase characteristics can be degraded during frequency translations due to I/Q modulator/demodulator amplitude/phase imbalance. As shall be shown, this I/Q imbalance can result in cross channel interference between pairs of FDM carriers. If the interference is extreme, one may be forced to use cross channel interference cancellation techniques to correct the problem. In this paper, the mechanism that gives rise to less than perfect sideband suppression will be discussed and an expression for the resulting level of interference will be derived. A method for doing the frequency translation via DSP is shown, which results in excellent sideband suppression with insignificant levels of cross channel interference.

Sideband Suppression

The concept of sideband suppression is illustrated by considering the down conversion of a real [2] bandpass signal to a zero Hertz centered complex bandpass signal using the I/Q demodulator shown in Figure 1. The terms A and q in the I arm respectively represent LO amplitude and phase imbalance.

The goal is to generate a single sideband LO signal, via an I/Q demodulator, so as to implement the Fourier frequency translation property as illustrated in Figure 2. However, any phase or amplitude imbalance between the I and Q arms of the demodulator introduces an undesirable sideband component to the LO (i.e. leaky LO) that causes spectral aliasing from the negative frequency spectral envelope as shown in Figure 3. The level of the aliasing interference is proportional to the level of the undesirable leaky LO sideband component, hence the term "sideband suppression".

This concept of spectral aliasing due to poor sideband suppression also applies to the upconversion process,

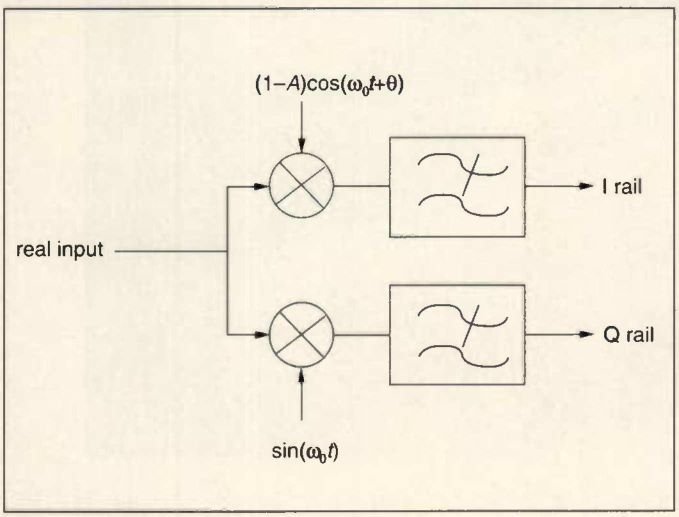


Figure 1. I/Q demodulator operation.

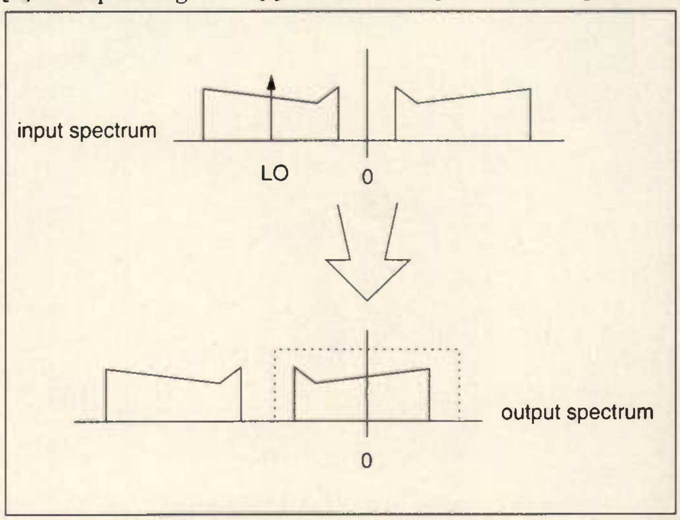


Figure 2. Ideal quadraphase downconverter.

EMI SOLUTIONS BY TUSONIX

Meeting All Your Requirements... Quality, Delivery, Service & Price.

At TUSONIX, solutions are easy to come by. With more than 35,000 quality EMI filters and ceramic capacitors, and an extensive line of disc, plate and variable capacitors, we're confident you'll find the answer to your EMI/RFI needs.

Plus NEW! products like the 4700 Series SMT EMI Filters and the 7600 Series Filtered Terminal Block make finding a solution that much easier. More than 750 employees make up our TUSONIX family. Each is committed to providing quality products, excellent service, on-time delivery, all at an attractive price.

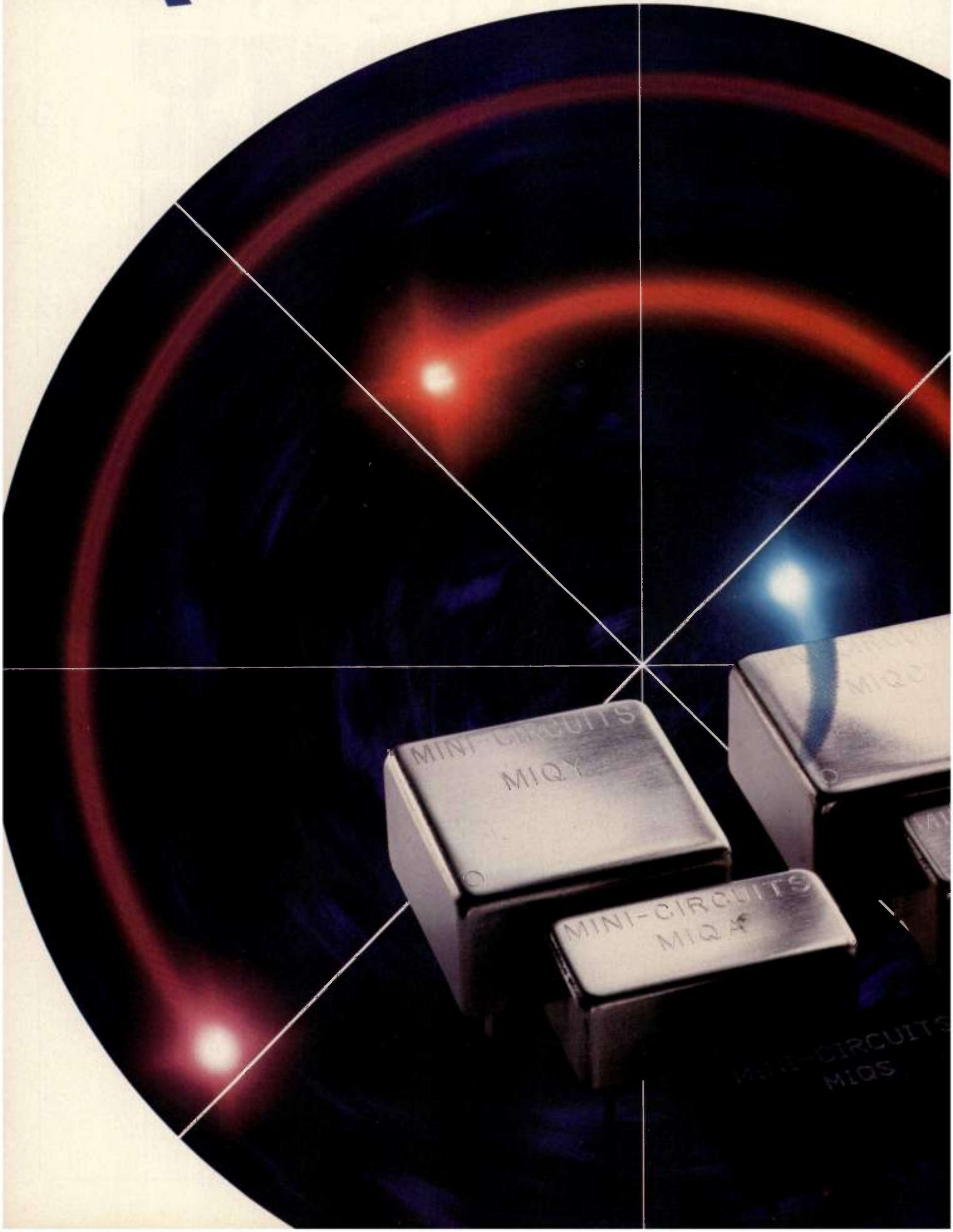
SMT π Filters

Filtered Terminal Blocks

See Us Online! http://tusonix.com

7741 N. Business Park Drive / Tucson, Arizona 85743 / 520-744-0400 FAX: 520-744-6155 / email: tusonix@rtd.com
Authorized Stocking Distributors: Penstock 1-800-736-7862 • RS Electronics 1-313-525-1155 • TTI 1-800-225-5884

I&Q MODULATORS

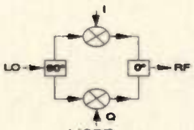


DEMODULATORS

1.15MHz to 1880MHz from $19.95

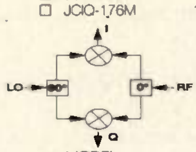
I&Q Modulators and Demodulators . . . another smart offering from MiniCircuits that's pushing industry standards to new heights (and prices to new lows)! Infuse your cellular, radar and communication system project with the powerful new I&Q Modulator and Demodulator, surface mount and plug-in units. Units so reliable, the specified statistical data on performance holds up with rock-solid repeatability unit-to-unit. For high speed assembly operations, I&Q Modulators and Demodulators are available in tape and reel format, so you can bank on consistent assembly performance for production efficiency time after time . . . and with prices starting at just $19.95, these powerful and compact units truly are the next generation of value on the market today. So, call your Mini-Circuits distribution center at a number listed below for guaranteed one week shipment or, turn to our applications department with your special specs for custom units at catalog prices.

We're redefining what VALUE is all about!



I/Q MODULATORS

MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	σ	CARRIER REJ. (-dBc) Typ.	SIDEBAND REJ. (-dBc) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	5xI/Q	PRICE $ Qty. (1-9)
MIQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQC-38M	34	38	5.6	0.10	48	37	54	65	49.95
MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
☐ MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
☐ MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95
Surface Mount Models									
☐ JCIQ-88M	52	88	5.6	0.1	40	35	45	65	49.95
☐ JCIQ-176M	104	176	5.6	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	σ	AMP. UNBAL. (dB) Typ.	PHASE UNBAL. (Deg.) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	5xI/Q	PRICE $ Qty. (1-9)
MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
MIQA-70D	66	73	6.2	0.10	0.15	0.7	56	58	49.95
MIQC-38D	34	38	5.5	0.10	0.10	0.5	60	65	49.95
MIQC-60WD	20	60	5.3	0.10	0.15	1.0	55	67	79.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
☐ MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
☐ MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
☐ MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95
Surface Mount Models									
☐ JCIQ-176D	104	176	5.5	0.1	0.15	2	52	65	54.95
☐ JCIQ-895D	868	895	8.6	0.1	0.2	1	45	65	99.95
☐ JCIQ-1785D	1710	1785	8	0.2	0.2	2	50	65	99.95
☐ JCIQ-1880D	1805	1880	8	0.2	0.2	2	50	65	99.95

☐ NON-HERMETICALLY SEALED

MIQA case .4 x .8 x .4 in. MIQY case .8 x .8 x .4 in.
MIQC case .8 x .8 x .4 in. JCIQ case .9 x .8 x .25 in.

All Models Available in New J-LEAD Surface Mount Package. Consult Factory for Details.

J-LEAD

Mini-Circuits®

US 26 INT'L 27
CIRCLE READER SERVICE CARD

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 *INTERNET* http://www. minicircuits. com

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

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

F 156 Rev C

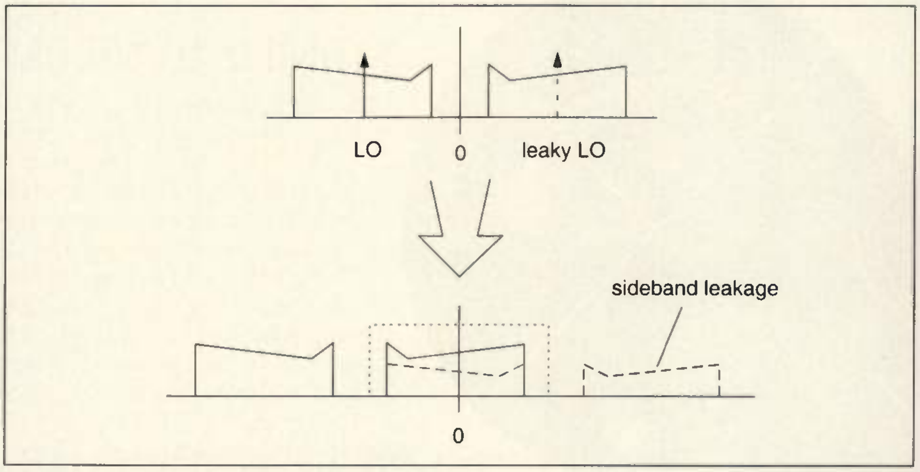


Figure 3. Downconverter sideband leakage.

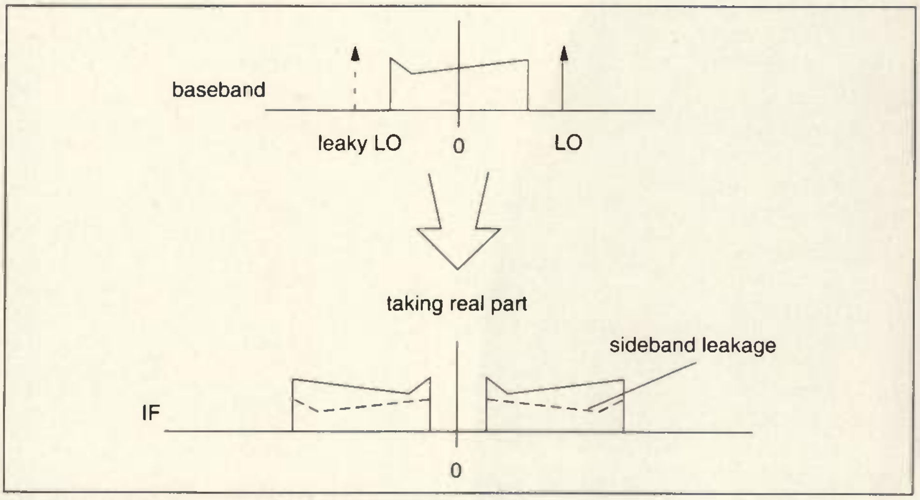


Figure 4. Upconverter Sideband Leakage

associated with a I/Q modulator, as shown in Figure 4.

The exact expression for sideband suppression in terms of the I/Q phase and amplitude imbalance is derived in the appendix; but for those cases where it is reasonably near quadrature, the level of sideband suppression is given as:

$$\gamma_{dB} \approx -6 + 10\log\left[A^2 + \theta^2\right]$$

where A is the amplitude error and q is the radian phase error. For example, given an amplitude imbalance of

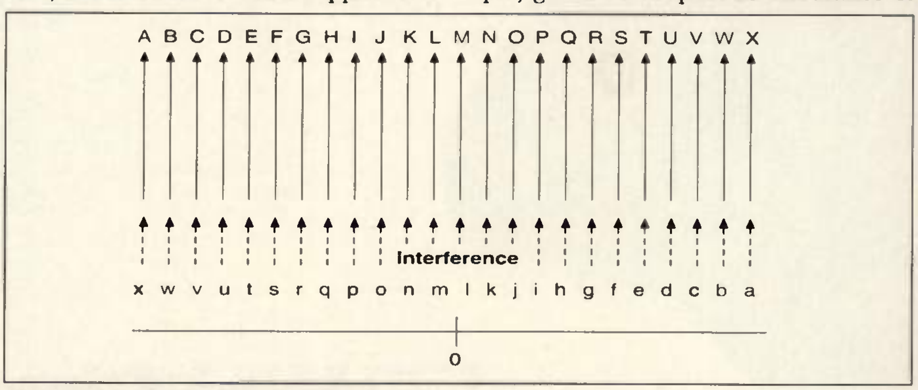


Figure 5. FDM Leakage Carrier Pairing

Appendix: Quadraphase LO Sideband Suppression

Let the LO signal be expressed as s(t) = a(t)+jb(t) where b(t) = $\sin(\omega_0 t)$ and a(t) = $(1-A)\cos(\omega_0 t + \theta)$. Notice that the term a(t) contains both the phase and amplitude error. By straightforward substitution of the exponential expression for the sine and cosine, we can decompose s(t) into a left spectral shifting function and a right spectral shifting function as shown below.

$$s(t) = \left[\frac{1}{2} + \left(\frac{1+A}{2}\right)e^{-j\theta}\right]e^{-j\omega_o t} + \left[\left(\frac{1+A}{2}\right)e^{-j\omega} - \frac{1}{2}\right]e^{jw_o t}$$

The sideband suppression is given as the ratio of the magnitude squared of the arguments of the exponential terms and is expressed in dB as:

$$\gamma_{dB} = 10\log\left(\frac{2 + A(A-2) - 2(1-A)\cos\theta}{2 + A(A-2) + 2(1-A)\cos\theta}\right)$$

If θ is small (i.e. θ<<1 radian), we can approximate the cosine term as:

$$1 - \frac{\theta^2}{2}$$

In addition, if A<<1 we can approximate γ as:

$$\gamma_{dB} = -6 + 10\log\left[A^2 + \theta^2\right]$$

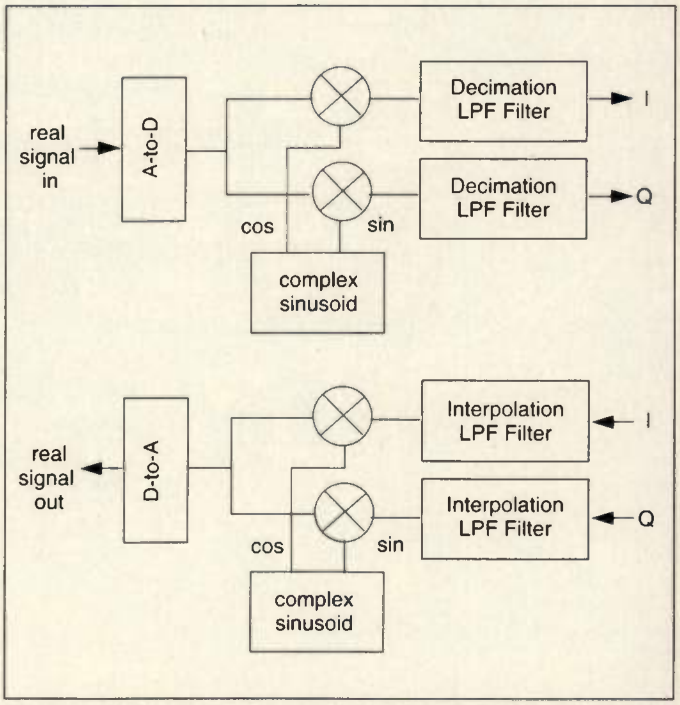


Figure 6. Digital down/up conversion technique using DSP processing.

0.35 dB (A = 0.04) and a phase imbalance of 0.065 radians, the sideband suppression is –28 dB. As is explained below, this imbalance may not allow enough performance margin required for a particular application, especially if the digital modulation on each FDM carrier is high order QAM.

FDM Cross Channel Interference

The spectrum of Figure 2 emphasis the lack of spectral symmetry with respect to the bandpass center frequency. This is especially the case for FDM, where perhaps the level of each carrier in the FDM spectrum is the same but the information content of the modulation per carrier is completely uncorrelated. Thus, with the introduction of an aliasing sideband, two or more carriers will pair up with each other causing spectral overlap as shown in Figure 5.

Assuming that the modulation on each of the FDM carriers is digital in nature, the net result will be degraded bit error rate performance of the desired signal. Even if a reasonable level of correct decisions on the desired signal is maintained, cross interference cancellation will require complicated signal processing between the desired signal and the interfering signals. It is important to note that the case for FDM is different than that for QAM. In QAM, the spectral content of both the I and Q signals completely fall within the demodulator passband. In this case, trigonometric relationships can be derived that show how a simple lattice network can be inserted in the I/Q arms to undo the signal distortion caused by poor I/Q quadrature.

DSP Frequency Translation

An alternative technique to the traditional analog I/Q modulator and demodulator for doing the frequency translation is the NCOM (numerically controlled oscillator/modulator), an example of which is the Harris HSP45116, in conjunction with the appropriate interpolator or decimator. Figure 6 shows a scheme for both upconversion and down conversion. Notice that the analog to digital interface occurs on a bandpass waveform (i.e. direct IF sampling) which allows the quadraphase characteristics of the frequency conversion to be determined solely by the precision of the digital processing. A-to-D subsampling techniques [3] can be used to introduce a digital IF prior to baseband down conversion to minimize sampling clock speeds and hence reduce power consumption. The precision of the overall process is arbitrarily high which results in determinable sideband rejection.

The Harris HSP50016 Digital Down Converter (DDC) is an example of a highly accurate single chip down converter that integrates the LO, the mixer and the decimating lowpass filters all in one package. Its LO serves as an example of the current commercial state-of-the-art in digital LO technology. Table 1 lists the measured sideband suppression for the Harris HSP50016 digital downconverter.

Carrier Frequency	Suppression dB
Fs/8	118.88
Fs/5	118.80
Fs/4	116.04
Fs/3	117.87

Table 1. HSP50016 Measured Sideband Suppression Carrier Frequency Suppression dB

Conclusion

Analog I/Q complex waveform modulators/demodulators have finite sideband suppression due to amplitude and/or phasing errors between the I/Q arms. These errors can cause unwanted sideband leakage which, for an FDM waveform, causes interference between carrier pairs with respect to zero Hertz. DSP techniques exhibit much higher ratios of sideband suppression and the DSP processing of the FDM waveform yields much lower carrier interference ratios. In many cases, the DSP approach will be more attractive than the traditional analog approach when high sideband suppression ratios are required. *RF*

References and Notes

1. Orthogonal FDM and/or DMT (Discrete Multitone)
2. Real simply means a "real-world" analog signal with resulting symmetry between the positive and negative frequency spectrum.

3. Groshong, R. and Stephen Ruscak, "Undersampling Techniques Simplify Digital Radio", *Electronic Design*, May 23,1991.

About the Author

Richard Roberts has a PhD and MSEE From the Florida Institute of Technology and a BSEE From the University of Wisconsin. For the last 16 years he has worked for Harris Corporation where he is currently a communications systems engineer in the Semiconductor Sector. He is involved with both analog and digital modem design and has several patents and publications in the area of signal processing. He can be reached at (407) 724-7022 or via E-mail at rrober02@harris.com.

INFO/CARD 30

A Spread Spectrum Sliding Correlator System for Propagation Measurements

By: William G. Newhall, Theodore S. Rappaport, Dennis G. Sweeney
Mobile & Portable Radio Research Group
Virginia Tech

The design of a wireless communication system is dependent upon the propagation environment in which the system is to be used. Factors such as the time delay spread and the path loss of a radio channel affect the performance and reliability of a wireless system. These factors can be accurately measured through RF propagation measurements in the environments in which anemerging wireless technology is to be deployed.

This article describes the design of an RF channel measurement system based on the spread spectrum sliding correlator technique. Presented first are discussions on propagation time delay measurements and three techniques which may be used to measure RF channel responses. The article then focuses on the sliding correlator technique, and explains system parameters and hardware which implements the sliding correlator system used at the Mobile and Portable Radio Research Group (MPRG) at Virginia Tech. Our goal is to make the theory and implementation better understood for RF engineers.

Channel sounding, the process of determining the radio propagation delays and attenuation, has become an important part of the design of modems for new frequency bands or new operating environments. In the past, channel sounding has been carried out by scientists and research labs, but with the demand for wireless applications and systems, channel sounding is becoming important for engineers who work with the design, development, and installation of new wireless systems.

Time Delay Measurements

Typical radio channels suffer from time dispersion due to reflecting objects and scatterers in the propagation environment. Reflectors and scatterers create multiple propagation paths (multipath) between the transmitter and receiver, each path having a different physical length. Paths having different physical lengths induce different propagation delays between the transmitter and the receiver, causing intersymbol interference and limiting data rate. This time dispersion exhibited by typical RF channels can be measured by observing the propagation delays which a transmitted signal experiences.

Because of the importance of the multipath structure in determining the propagation delay and the fading effects, a number of wideband (i.e., pulse) channel sounding techniques have been developed. The term "wideband" is used to denote the fact that the measurement system is able to resolve multipath by using a wider bandwidth than the intended radio system. Wideband channel sounding techniques may be classified as direct pulse measurements, swept frequency measurements, and sliding correlator measurements [1].

Direct Pulse System

A simple channel sounding approach is the direct RF pulse system. This technique allows one to determine the power delay profile of an RF channel [2] [3]. A direct pulse system is essentially a wideband pulsed bistatic radar, transmitting a pulse of width τ seconds, and uses a receiver with a wide bandpass filter (BW = $1/2\tau$ Hz). The pulse is repeated every second or fraction of a second so that it may be averaged at the receiver. The received signal is amplified, detected with an envelope detector, and displayed and stored on a high speed oscilloscope. This gives an immediate measurement

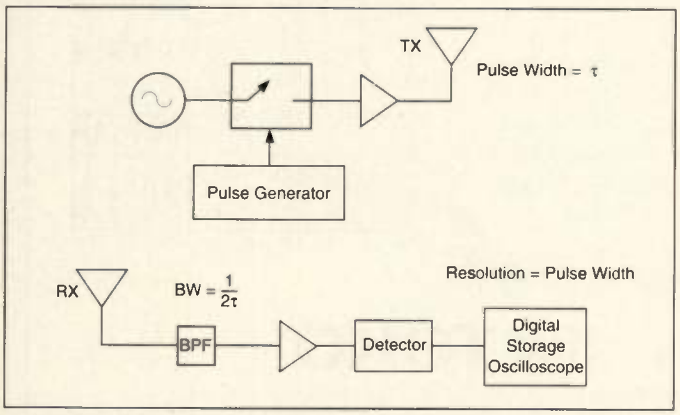


Figure 1. Direct pulse RF Channel measurement system.

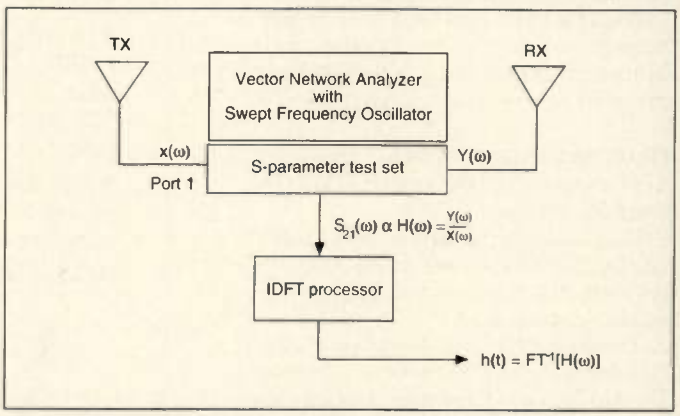


Figure 2. Frequency domain channel sounder

of the square of the channel impulse response convolved with the probing pulse. If the oscilloscope is set on averaging mode, then this system can provide a local average power delay profile. An attractive aspect of this system is the lack of complexity, since off-the-shelf equipment may be used. A block diagram of the direct pulse system is shown in Figure 1.

The main problem with this system is that it is subject to interference and noise, due to the wide filter passband required for multipath time resolution. Also, the pulse system relies on the ability to trigger the oscilloscope on the first arriving signal. If the first signal becomes blocked due to the channel, it is possible for the system to miss the first arriving multipath.

Frequency Domain Channel Sounding

Because of the dual relationship between the time domain and the frequency domain, it is possible to measure the channel impulse response using frequency domain techniques. Figure 2 shows a frequency domain channel sounder. A vector network analyzer controls a synthesized frequency sweeper, and an S-parameter test set is used to monitor the frequency response of the channel. The sweeper scans a particular frequency band stepping through discrete frequencies. Due to the Fourier transform, the number and spacings of these frequency steps impact the time resolution of the impulse response measurement. For each frequency step, the S-parameter test set transmits a known signal level at port 1 and monitors the received signal level at port 2. These signals allow the analyzer to determine the complex response (i.e., transmissivity $S_{21}(\omega)$) of the channel over the measured frequency range. The transmissivity response is a frequency domain representation of the channel impulse response, and is converted to the time domain using inverse discrete Fourier transform (IDFT) processing, giving a band-limited version of the impulse response. In theory, this technique works well, providing amplitude and phase information in the time domain. However, the system requires calibration and hard-wired synchronization between the transmitter and receiver, making it useful only for very close measurements (e.g., indoor work). Another limitation with this system is the non-real-time nature of the measurement. For time-varying channels, the channel frequency response can change rapidly during a sweep period, giving an erroneous impulse response measurement.

Spread Spectrum Sliding Correlator Channel Sounding

The most popular channel sounding technique is based on a spread spectrum sliding correlator (see Figures 3 through 6). The advantage of a spread spectrum system is that while the probing signal may be wideband, it is possible to detect the transmitted signal using a narrowband receiver preceded by a wideband mixer, thus improving the dynamic range of the system as compared to the direct RF pulse system.

In a spread spectrum channel sounder, a carrier signal is "spread" over a large bandwidth by mixing it with a wideband pseudo-noise (PN) sequence. The power spectrum envelope of the transmitted spread spectrum signal is the classic $\sin(f)/f$ shape and has a null-to-null bandwidth of $BW=2R_c$ where R_c is the PN sequence code clock rate (chip clock rate) [4]. Typical chip rates are several megabits per second, which results in a transmitted bandwidth several MHz wide.

The spread spectrum signal is then received, filtered, and "despread" using a PN sequence generator identical to that used at the transmitter. Although the two PN sequences are identical, the transmitter chip clock is run slightly faster than the receiver chip clock. Mixing the chip sequences then implements a "sliding correlator" [4]. When the PN code of the transmitter catches up with the PN code of the receiver, the two chip sequences are aligned, giving maximal correlation. When the two sequences are not maximally correlated, mixing the incoming spread spectrum signal with the unsynchronized receiver chip sequence spreads this signal into a bandwidth at least as large as the receiver's reference PN sequence. In this way, the narrowband filter that follows the correlator can reject almost all of the

INFO/CARD 33

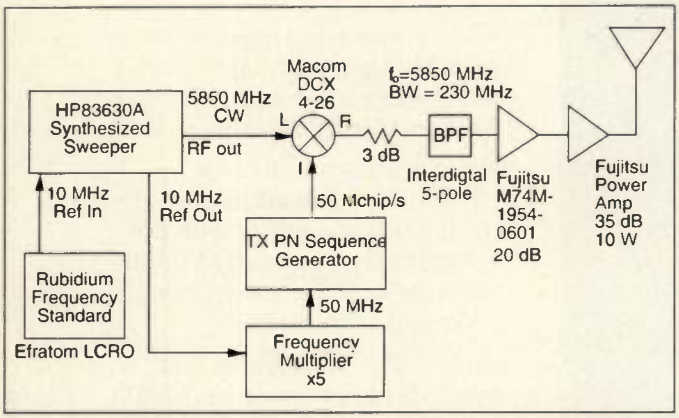


Figure 3. Sliding correlator measurement system transmitter configured for 5850 MHz (50 MHz chip clock)

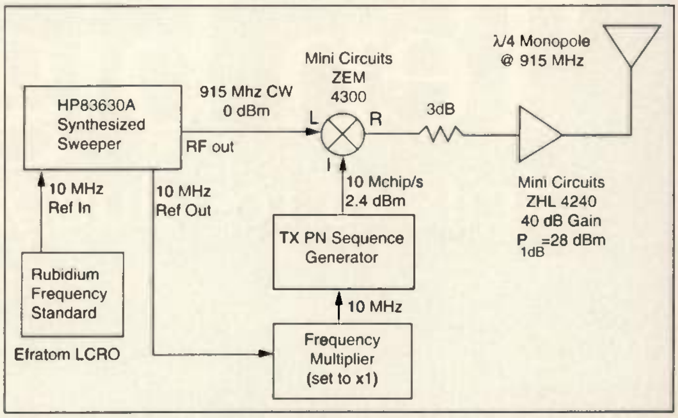


Figure 5. Sliding correlator measurement system transmitter configured for 915 MHz (10 Mhz chip clock)

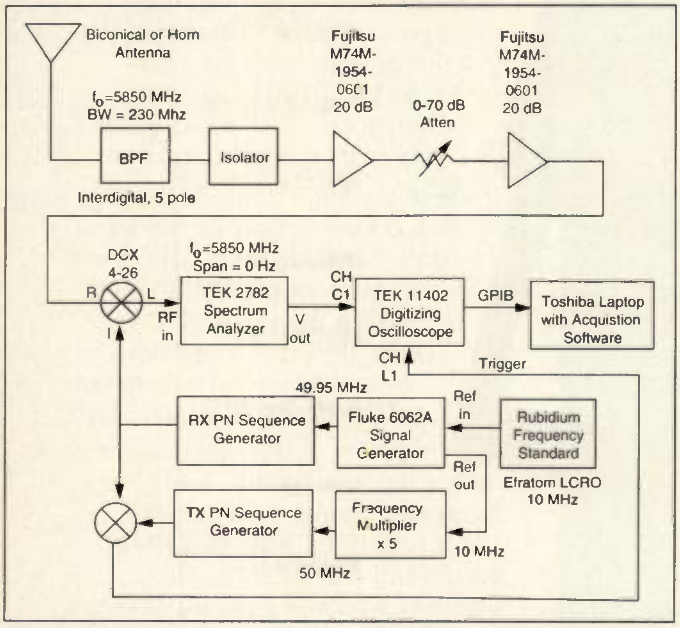


Figure 4. Sliding correlator measurement system receiver c onfigured for 5850 MHz (50 MHz chip clock)

incoming signal power. This provides the processing gain realized in all spread spectrum systems and allows the receiver to reject passband interference, unlike the direct RF pulse sounding system or the swept frequency system.

When the incoming signal is correlated with the receiver sequence, the signal is collapsed back into the original bandwidth (i.e., "despread"), envelope detected, and displayed on an oscilloscope. Since different incoming multipaths have different time delays, they maximally correlate with the receiver PN sequence at different times. The energy of these individual paths pass through the correlator at different time depending on the propagation time delay. Therefore, after envelope detection, the channel impulse response convolved with the pulse shape of a single chip is displayed on the oscilloscope. When expressed in units of power, the pulse shape shown on the oscilloscope is called the power delay profile of the channel, from which the path loss and RMS delay spread can be calculated. Cox [5] first used this method to measure channel impulse responses in outdoor suburban environments at 910 MHz.

Devasirvatham [6, 7] used a direct sequence spread spectrum channel sounder to measure time delay spread of multipathcomponents and signal level in office and residential buildings at 850 MHz. Bultitude [8] has also used this technique for indoor and microcellular channel sounding work, and MPRG researchers have used this technique for a range of measurements in buildings, cities, and train yards.

Sliding Correlator System Parameters

Explained in this section are the parameters used for the sliding correlator measurement system. These parameters are set to achieve the desired time resolution, slide factor, processing gain, and maximum unambiguous range capabilities of the system.

The time resolution Δt of multipath components is defined as the amount of time by which the components must be separated in order to resolve individual components in a measured profile and is given by

$$\Delta\tau \approx 2T_c = \frac{2}{R_c}$$

where T_c is the chip period and R_c is the chip rate. In actuality, the time resolution is smaller than $2T_c$ and can be estimated as T_c. The slip rate R_{slip} is defined as the difference between the transmitter and receiver chip rates, and can be expressed as:

$$R_{slip} = \alpha - \beta$$

where α is the transmitter chip rate and β is the receiver chip rate [1]. (R_c is equal to α and is approximately equal to β for time resolution calculations.) An important quantity in sliding correlator measurements is γ, called the slide factor, which relates observed multipath delay time at the receiver to the actual propagation delay time. The slide factor γ is defined as:

$$\gamma = \frac{\alpha}{\alpha - \beta}$$

and can be simply expressed as the transmitter chip rate α divided by the slip rate R_{slip}. The slide factor relates actual propagation time $t_{propagation}$ to observed oscilloscope time $t_{observed}$ as:

$$t_{propagation} = \frac{t_{observed}}{\gamma}$$

This means that if the slide factor γ is 1000, then a 100 µs delay observed between two multipaths at the receiver is actually a delay of 100 ns in propagation time between the multipaths.

A narrowband filter is realized using the spectrum analyz-

er by setting its resolution bandwidth equal to the desired bandwidth. For sliding correlator measurements, the choice of resolution bandwidth is determined by:

$$ResBW = 2(\alpha - \beta)$$

to obtain the processing gain realized by the narrowband filter. The *ResBW* parameter determines the detector bandwidth required for proper display of the received multipath.

The unambiguous range of the system is the maximum excess path length of a multipath component which can be measured by the system. Since the PN sequences at the transmitter and receiver repeat periodically, and have virtually the same period, a received multipath component must have an excess delay less than the period of the sequences in order to be correctly interpreted. In other words, the apparent delay of a multipath component may not be the true delay if the true delay exceeds the delay corresponding to the maximum unambiguous range. The period of the PN sequence is:

$$\tau_{PN} = T_c l$$

where l is the number of chips in the PN sequence. Multiplying this quantity by the speed of light yields the unambiguous range dr of the system:

$$d_r = T_c l c$$

For example, if the transmitter uses a chip rate of 50 MHz, and the PN sequence length is 2047 chips, then the maximum unambiguous range would be about 12.2 km.

The dynamic display range can be defined as the difference between the maximum measurable correlation peak and the noise floor displayed on the oscilloscope. The dynamic display range of the sliding correlator system is limited by the one or a combination of the following factors: the index of discrimination of the system, the LO-RF isolation of the mixer, and system thermal noise. The dynamic display range for the current MPRG system is estimated to be between 20 dB and 25 dB, and is limited by the isolation of the mixer.

The MPRG Spread Spectrum Channel Sounder

A sliding correlator measurement system has been in use at the Mobile and Portable Radio Research Group at Virginia Tech for several years and has been redesigned for greater flexibility and use at higher bands. It uses "plug-in" amplifier and filter stages to accommodate the desired carrier frequency and bandwidth. The system is used to sound RF channels at 900 MHz, 1900 MHz, 2450 MHz and 6 GHz; however, the capability of measuring 9 GHz, 18 GHz, and 26 GHz bands are planned.

Two typical configurations of the MPRG measurement system are shown in Figures 3 through 6. Figures 3 and 4 show the system used to sound channels at 6 GHz, and Figures 5 and 6 show the system configured to sound the 902 MHz to 928 MHz ISM band.

Baseband Hardware

It is clear from Figures 3 through 6 that the baseband processing remains the same for different RF configurations. An Efratom rubidium frequency standard is used as a 10 MHz frequency reference at both the transmitter and receiver. At the transmitter, the rubidium standard drives the 10 MHz reference input of the HP86360A sweeper, and the frequency multiplier derives the transmitter chip clock from the 10 MHz reference output of the sweeper. The frequency multiplier was built at MPRG and can select 10 Mchip/s, 20 Mchip/s, 50 Mchip/s, and 100 Mchip/s chip rates. The eleven stage ECL shift register clocked by the output of the frequency multiplier produces a PN sequence 2047 chips in length.

At the receiver, another rubidium frequency standard drives the reference input of the receiver signal generator, a Fluke 6062A signal generator. Two PN sequence generators are used at the receiver, both produce the same sequence but are clocked at slightly different rates. The 'RX PN' and 'TX PN' sequence generators are identical, except that the TX PN sequence is clocked at the same rate as the transmitter PN sequence generator, and the RX PN sequence is clocked at a slightly slower rate (the RX PN clock signal is produced by the Fluke 6062A, whereas the TX PN clock at the receiv-

Four believable features of this RF spectrum analyzer.

1 Uncover small signals close to carriers with -105 dBc/Hz internal phase noise.

2 Built-in frequency counter and ± 2 kHz accuracy eliminates signal drift and the need for a separate frequency counter.

3 Separate closely spaced signals with 10 resolution bandwidth filters.

4 Measure signals directly with 145 dB amplitude measurement range.

$8,900

And one that's unbelievable.

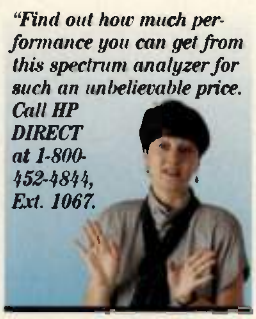
The HP 8590L spectrum analyzer family gives you the superior performance you probably expect from HP. At a price you probably don't.

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. 1067***.

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 1-800-276-8661, Dept. 147

There is a better way.

HEWLETT® PACKARD

INFO/CARD 36

er comes directly from the rubidium source using a frequency multiplier). The RX PN signal drives the IF port of the mixer to despread the received spread spectrum signal. The Tektronix spectrum analyzer, set to zero span at the carrier frequency, acts as a receiver and narrowband filter and displays received power versus time. The oscilloscope trace shows the vertical output of the spectrum analyzer, a voltage which is proportional to the log10 of received power, versus time. The waveform shown on the oscilloscope is the power delay profile of the RF channel being measured, and is recorded using the Toshiba PC via the GPIB bus. Figure 7 shows a sample power delay profile for a 915 MHz channel using a chip rate of 10 Mchip/s.

The TX PN generator at the receiver and the use of the rubidium frequency standards permit absolute time delay measurements. The RX PN sequence generator at the receiver drives a second mixer at the receiver which correlates the output of the RX PN sequence generator with the TX PN sequence generated locally at the receiver. The result is a correlation peak which is used as a trigger pulse for the oscilloscope displaying the power delay profile.

Before the system is used for measurements, the TX PN sequence generator at the transmitter and the TX PN sequence generator at the receiver are synchronized. If the receiver reference frequency is exactly the same as the one in the transmitter and the two TX PN generators (the one in the transmitter and the one in the receiver) are synchronized together, then the TX PN generator in the receiver will produce exactly the same code as the one in the transmitter at the same time. In this way, the TX PN sequence generator in the receiver replicates the time at the transmitter. When the transmitter and receiver are separated, the trigger pulse produced by the correlation of the RX PN sequence and the TX PN sequence corresponds to time zero, and propagation time for line-of-sight or multipath components can be referenced to the trigger pulse.

In order to keep the TX PN sequence generated at the transmitter synchronized with the TX PN sequence generated locally at the receiver, a highly stable frequency standard is required. The Efratom LCRO rubidium frequency standards suit this need. Without the use of the rubidium oscillators, a reference cable connecting the transmitter and receiver would be required throughout measurements, and would make long-distance propagation measurements impractical. With the frequency standards, only the link budget limits the transmitter-receiver (T-R) separation of the system.

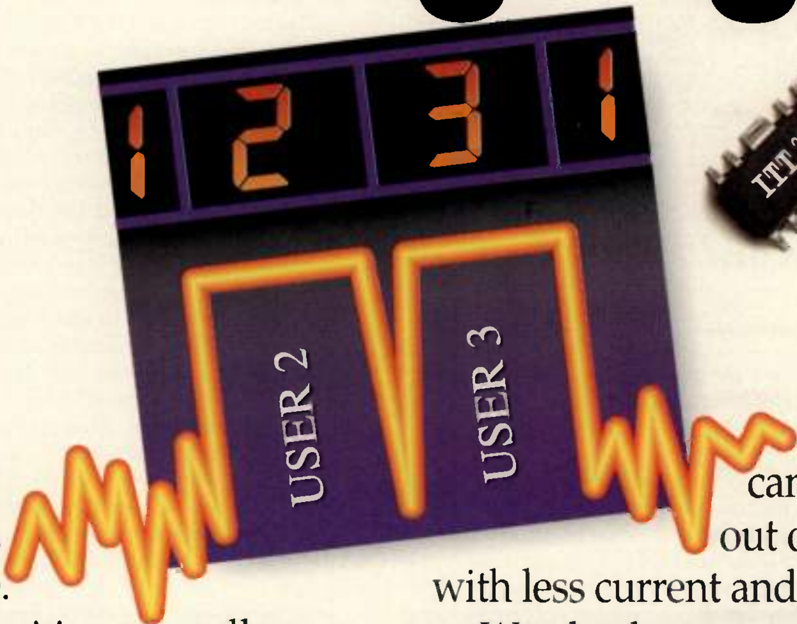
Sychronization Circuit

Figure 9 is a simplified circuit for the TX PN sequence generator which includes the synchronizing circuits. The sync circuit permits synchronizing two TX PN generators so they produce the same code at the same time. One TX PN generator is at the transmitter and one is at the receiver, and they rely on the transmitter and receiver rubidium oscillators to remain sufficiently stable so that the receiver TX PN generator replicates the exact state of the TX PN generator at the transmitter.

The sync circuit consists of U5 which is a pair of ECL D-type flip-flops (FFs). U5A is configured as a Set/Reset (R/S) FF. This R/S FF is connected to the stop/run switch. When the switch is placed in the "stop" position, the Q output of U5A is forced HI and the D input of U5B goes HI as well. At the next clock transition, this HI is transferred to U5B's *Q* output. Due to the wired-OR nature of ECL, pin 13 of U4 in the PN shift register will now remain HI independent of the inputs on pins 14 and 15 of U4. This forces the shift register to fill with "1s" and "1s" will continue to circulate as long as the switch is in the "stop" position. In addition, U5B's *Q* output goes LOW and the LED lights. The LED is on in the stop mode.

When the switch is placed in the "run" position, U5A's *Q* output is now forced LOW. This LOW is transferred to the U5B's *Q* output at the next clock transition. The U4 pin 13 output now controls the operation of the shift register and the PN sequence generator begins normal operation. The sync circuit provides the eleven stage PN sequence generator illustrated in Figure 9 a way to begin from the state: 11111111111.

We speak your language.



We're talking TDMA. It's here. It's hot. It's huge. And the opportunities are endless.

At ITT, we're ready to help you take advantage of those opportunities with our new 333104BD dual mode RF IC power amplifier just for Digital AMPS applications. No mere retrofit, we built this 4.6V amplifier from the ground up to provide excellent linearity and efficiency for applications using the TDMA-based IS-54/IS-136 standards.

Unlike most dual mode solutions, this amplifier's efficiency in the analog mode has not been compromised. In either mode, this device ensures high reliability and consistent performance, so you can squeeze more out of your products with less current and lower weight.

ACTUAL SIZE

We also have new power amplifiers for the Enhanced Total Access Communications System (ETACS) and 3-stage amplifiers for Ardis or AMPS applications…all available for demo board and IC sampling right now.

So, if you want power amplifiers that open up a world of opportunity, let's talk... no matter what language you speak.

Call us at 540-563-3949 or fax us at 540-563-8616 for more information.

ITT GTC
7670 ENON DRIVE
ROANOKE, VA 24019

ITT GTC

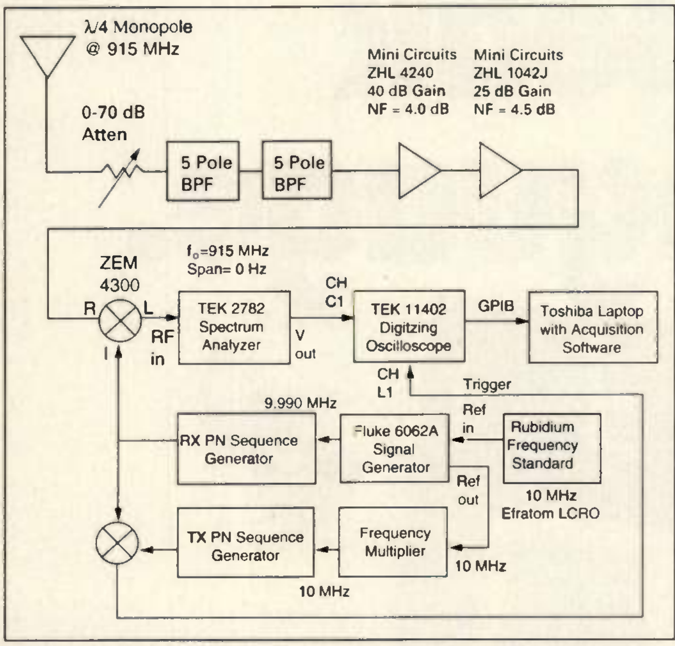


Figure 6. Sliding correlator measurement system receiver configured for 915 MHz (10 MHz chip clock)

The two TX PN sequence generators are synchronized by connecting the run/stop switch in each generator in parallel through a cable. The switches have a center-off position, and with one off, the other will control both PN generators. Now, when the controlling switch is set to "run" mode, the two TX PN sequence generators will start together from the same state. After this simple "back-to-back" calibration procedure, the transmitter and receiver may be separated to make measurements without a cable connecting them together.

RF Hardware

The transmitter (see Figures 3 and 5) uses the HP86360A synthesized sweeper to generate a CW carrier at the center of the band being measured. This carrier is BPSK modulated by the PN sequence using a mixer, and the output at the RF port of the mixer is amplified and transmitted into the channel. The attenuator placed after the mixer dampens reflections due to impedance mismatches in the system. The RF signal produced at the transmitter may be band-limited by a bandpass filter, depending on the channel being measured and the power levels used. An omnidirectional antenna is used at the transmitter, usually a biconical antenna or λ/4 monopole tuned to the band of interest.

The 915 MHz transmitter configuration shown in Figure 5 was used for a recent ISM band propagation measurement campaign, where a 10 MHz chip clock rate was used to sound RF channels. This configuration uses a Mini Circuits ZEM4300 mixer as a BPSK modulator, and a Mini Circuits ZHL4240 amplifier as a final amplifier. The transmitter antenna used for the 915 MHz configuration is a λ/4 monopole. Figure 8 shows the output of the transmitter.

The 6 GHz system in Figure 3 uses a Macom DCX4-26

Innovative Antenna Solutions For Today's Wireless Products

If your company is designing products for the new wireless world, you need antennas. Your success depends in part on integrating an antenna that offers reliability and performance - at the right price.


Bar Code Scanner


Video Surveillance


Mobile SATCOM


Rural Telecom

To get the best you can get, tap into 25 years of antenna expertise. Leading companies in the areas of LAN, cellular, SATCOM, POS, broadcast and video surveillance products have found that Tecom saves them time and money by offering antennas with optimum performance and minimum size to fit their unique packaging needs.

We can work with you to custom design a solution - or select from our catalog of stock products. Either way you have quick access to what you need, at a price that makes your products commercially viable.

If you haven't investigated how Tecom can help with your antenna needs, do it today. Call for our free product catalog or ask to speak directly with an applications specialist.

900 MHz • 1.9 GHz • 2.4 GHz • 5.8 GHz

TECOM INDUSTRIES, INC.
9324 Topanga Canyon Blvd., Chatsworth CA 91311
(800) 730-4010 • Fax (818) 718-1402

TECOM

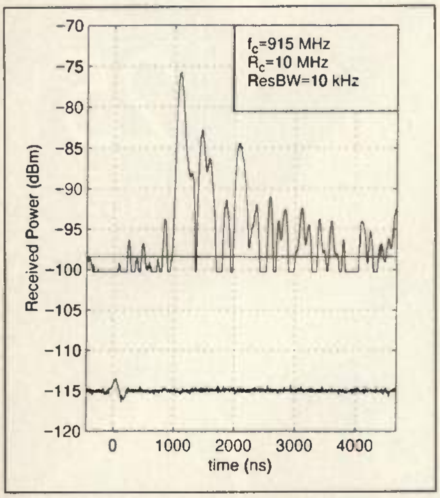


Figure 7. Sample power delay profile

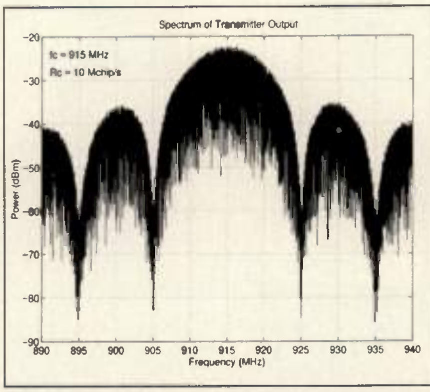


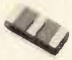
Figure 8. (right) Spectrum of transmitter output with f_c=915 MHz and R_c=10 Mchip/s.

mixer to BPSK modulate the 5850 MHz carrier. The BPSK signal is band-limited by an interdigital bandpass filter centered at 5850 MHz, which prevents transmitting energy below approximately 5700 MHz and above approximately 6000 MHz. The output of this filter is fed to a 20 dB gain amplifier which increase the power to approximately 5 dBm to drive the power amp. The power amplifier can supply up to 40 dBm.

For measurements above 2 GHz, the transmitter uses a KinTronic Laboratories wideband biconical antenna for omnidirectional measurements, and a different antennas are used at the receiver. For example, recent 6 GHz measurements have used a specially designed rectangular horn antenna with 17 dBi gain in conjunction with an antenna rotor to determine multipath angle of arrival.

Recent 915 MHz measurements used a $\lambda/4$ monopole at the receiver. Attenuation at the front end of the 915 MHz receiver is increased for close measurements to reduce the PN noise floor caused by the transmitter PN sequence. Two five-pole interdigital bandpass filters are used at the input to reject cellular signals below 894 MHz and paging signals around 930 MHz, since narrowband signals within the pass band of the receiver reduce the dynamic range of the system. Two Mini Circuits ZHL series amplifiers provide 65 dB of gain prior to the ZEM4300 mixer, were the received signal is demodulated.

The 6 GHz receiver configuration (see Figure 4) uses a bandpass filter identical to that used at the transmitter, rejecting signals below 5700 MHz and above 6000 MHz so signals in the radar and communications bands do not overload the receiver. The isolator provides about 20 dB of attenuation in the reverse direction to reduce the effect of an impedance mismatch between the bandpass filter and the amplifier. The signal is amplified in a



HDD Shock Sensor – PKGS Series
Incline angle of primary axis offered in 0, 25 and 45 types. Output voltage of 1.95 mV/G and resonant frequency of 20KHz offers excellent sensitivity.

SMD Resonator
Economical and rugged alternative to quartz crystals for frequency control applications. SMD available up to 50MHz.

Monolithic Chip Caps
Ultra-miniature sizes – all the way down to 0402. New ceramic extended capacitance range up to 10 microfarads for replacement of Tantalums.

455KHz – 2nd I.F. Filter
SFGCG series offers excellent sensitivity, optimum stop band attenuation and high stability for wireless applications. Also available in SFEC 10.7MHz Series for 2nd I.F.

SMD Thermistor – NTH5G Series
0805 size ideal for temperature sensing for overcharge protection in a rechargeable battery pack; temperature compensation circuits. Resistance range from 220-100K Ohms.

SMD Inductor – LQP Series
Outstanding high-Q characteristics with ±2% tolerance for high frequency resonant circuits – sizes down to 0603 with .5mm height ideal for low-profile PC Card applications.

SMD Ferrite Chips – BLM Series
Effectively prevents unwanted noise in HF circuits, up to 1GHz. Sizes down to 0603.

Compact VCO
Small size and low power consumption. Frequency range from 400MHz-2.4GHz. Stability of ±2MHz from -35°C to +80°C.

A few of the important components of the new environment for doing business.

A notebook PC, a wireless modem, a connection to your network and a spectacular mountain view. You don't have to be in the office to be in the center of things any more. And Murata can provide some of the most important components of today's computers and wireless communications devices, from microwave functional devices for RF front ends, to thermistors for battery circuit protection and shock sensors for hard drives. For the latest developments in components for convergence applications — look to Murata. The devices you're designing today will shape the business environment tomorrow. And we intend to be a big part of that ever-changing landscape.

For a free wireless poster, as well as Murata catalogs, call 1-800-831-9172, ext. 238.

muRata
Innovator in Electronics

INFO/CARD 44

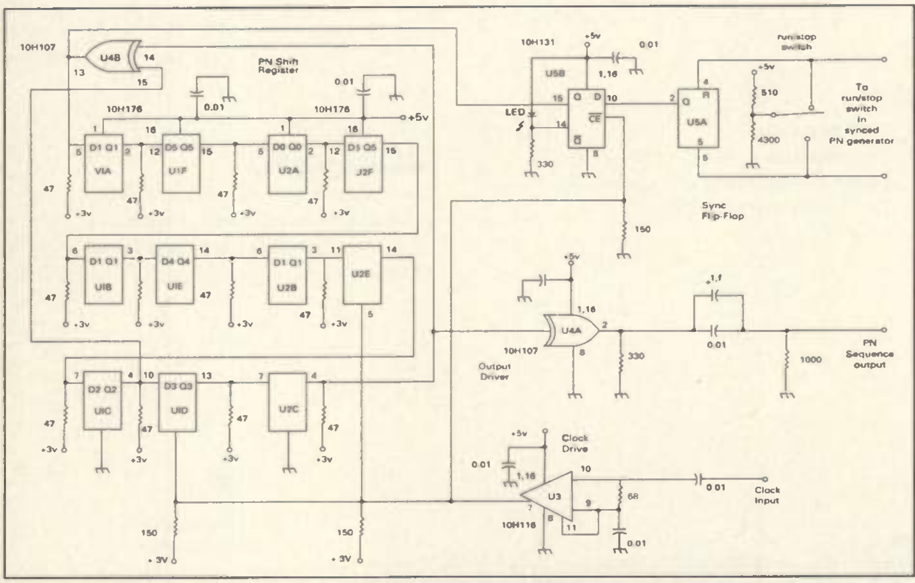


Figure 9. Schematic of the spread spectrum sliding correlator.

20 dB gain low noise amplifier and then passed through a step attenuator and an additional 6 GHz amplifier. The two 6 GHz amplifiers have approximately 40 dB gain. The gain is necessary to overcome the high noise figure of the spectrum analyzer that is used as the receiver and the loss in the balanced modulator used as the correlator. The total system noise figure is approximately 5 dB to 10 dB, depending upon the length and type of the antenna cable.

Other frequency bands are sounded by replacing filters, amplifiers, and mixers with components meeting the specifications required by the new band. System parameters, such as chip rates, slip rate, and resolution bandwidth, must also be set appropriately to sound the new band.

Favorable System Parameters

Many combinations of system parameters may produce satisfactory measurement data, MPRG researchers have found through experience that certain combinations obtain the most accurate representation of a channel response. The most recent 6 GHz measurements were performed using a transmitter (TX PN) chip rate α of 50 Mchip/s to obtain a time resolution $\Delta\tau$ of 20 ns, and a receiver (RX PN) chip rate b of 49.95 MHz. These chip rates imposed a slip rate R_{slip} of 50 kHz, a slide factor γ of 1000, and a maximum unambiguous range d_r of about 12.2 km. A spectrum analyzer resolution bandwidth and video bandwidth of 30 kHz was used.

Measurements made during the recent 915 MHz campaign used a transmitter (TX PN) chip rate α of 10 Mchip/s to achieve a time resolution of 100 ns while confining most of the transmitted energy within the 902 MHz to 928 MHz ISM band. This configuration used a receiver (RX PN) chip rate β of 9.990 MHz, imposing a slip rate R_{slip} of 10 kHz, and a slide factor of 1000. This yields a maximum unambiguous range d_r of approximately 61 km. The resolution and video bandwidth of the spectrum analyzer was 10 kHz.

Conclusion

The sliding correlator technique is a popular and effective method to measure RF channels, and has been used in the past by several researchers to characterize the delay spread of different environments. This article has described Virginia Tech's MPRG channel sounder, which is a sliding correlator system that can be easily configured for several different bands. The system described here has been used recently to study multipath as a function of receiver antenna angle in an urban environment at 6 GHz, and has been used to measure the 902 MHz to 928 MHz ISM band in a large train yard, a propagation environment which had not been well characterized for time dispersive characteristics. MPRG students and staff have provided propagation measurements for a wide range of sponsors, and are able to conduct field studies and propagation analysis in rapid fashion. A future article will discuss one such project, which characterized propagation conditions in an active train yard, and demonstrate how to analyze received data for modem design work. ***RF***

Acknowledgements

This work was sponsored by the Office of National Drug Control Policy and Wireless Valley Communications.

References

1. T.S. Rappaport, *Wireless Communications, Principles and Practice*, Prentice Hall, 1996.
2. S.Y. Seidel, et. al., "Path loss, scattering, and multipath delay statistics in four European cities for digital cellular and microcellular radiotelephone," *IEEE Transactions on Vehicular Technology*, Vol. 40, No. 4, pp. 721-730, Nov. 1991.
3. T.S. Rappaport, et. al., "900 MHz multipath propagation measurements for U.S. Digital Cellular Radiotelephone," *IEEE Transactions on Vehicular Technology*, Vol. 39, No. 2, pp. 132-139, May 1990.
4. R.C. Dixon, *Spread Spectrum Systems*, 2nd Edition, John Wiley and Sons, New York, 1984.
5. D.C. Cox, "Delay Doppler characteristics of multipath delay spread and average excess delay for 910 MHz urban mobile radio paths," *IEEE Transactions on Antennas and Propagation*, Vol. AP-20, No. 5, pp. 625-635, Sept. 1972.
6. D.M.J. Devasirvatham, "Time delay spread and signal level measurements of 850 MHz radio waves in building environments," *IEEE Transactions on Antennas and Propagation*, Vol. AP-34, No. 2, pp. 1300-1305, Nov. 1986.
7. D.J. Devasirvatham, et. al., "Radio propagation measurements at 850 MHz, 1.7 GHz, and 4.0 GHz inside two dissimilar office buildings," *Electronic Letters*, Vol. 26, No.7, pp. 445-447, 1990.
8. R.J.C. Bultitude, G.K. Bedal, "Propagation characteristics on microcellular urban mobile radio channels at 910 MHz," *IEEE Journal on Selected Areas in Communications*, Vol. 7, pp. 31-39, Jan. 1989.

About The Authors

Bill Newhall is a graduate student at Virginia Tech performing research with the Mobile and Portable Radio Research Group. He is active in propagation measurements, RF hardware development, and wireless communications consulting.

Ted Rappaport is a Professor of Electrical Engineering at Virginia Tech and the Founding Director of the Mobile and Portable Radio Research Group. He is active in teaching, research, and consulting in wireless communications.

Dennis Sweeney received his Ph.D. from Virginia Tech in 1993 and is a research associate at Virginia Tech. He is active in the design and development of RF hardware and systems.

They can be reached at MPRG, Bradley Department of Electrical Engineering, 840 University City Blvd., Point West Commons, Suite 1, Blacksburg, VA 24061-0350.

xpertise in RF/microwave technology is helping manufacturers and their customers around th world. With the industry's broadest product line of innovative ired and unwired network connectivity solutions. So no matter what RF applications you'r eveloping for the home, call M/A-COM. And just ask us how.

RF/microwave network connectivity solutions for the home.

Motion detection/sensing components for RF security systems.

A broad array of RF solutions for cellular and PCS networks – from semiconductors to antennas.

RF electronics for interactive TV, wireless CATV and satellite TV networks. And more.

M/A-COM
an AMP company

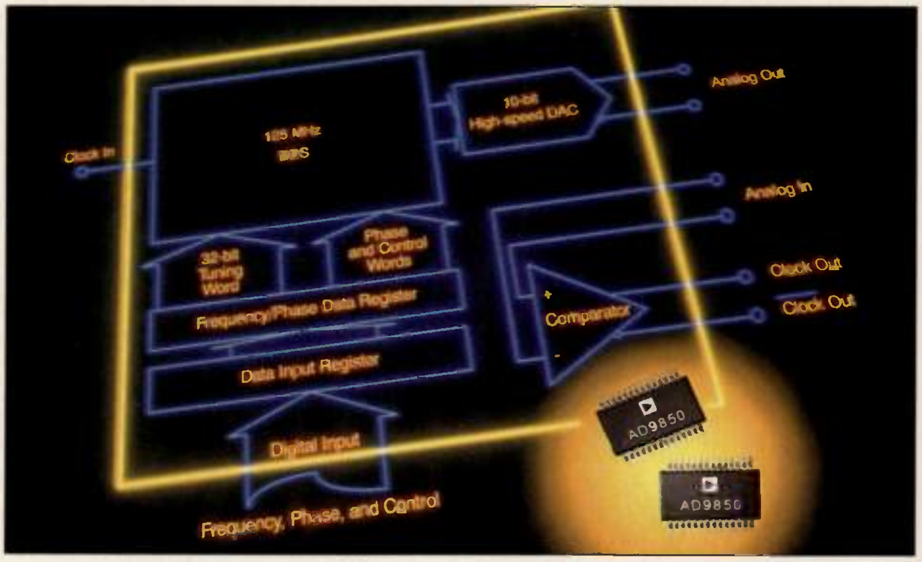
Sales offices in 33 countries around the world.

High Level Integration and Performance Comes to DDS

By Dave Crook and Jim Surber
Analog Devices, Inc.

Analog Devices' AD9850 is the world's first complete monolithic 125 MHz high-performance Direct-Digital-Synthesis (DDS) system. This innovative CMOS device integrates a proprietary high-speed 32-bit DDS core, with a performance-optimized 10-bit D/A converter (DAC) and high-speed, low jitter comparator. The AD9850 shatters the barriers associated with existing DDS and DAC synthesizer solutions by providing major advancements in virtually every feature and specification category: level of integration, power dissipation, size, speed, dynamic performance, ease-of implementation and price.

DDS has long been recognized as a premier technology for generating frequency-agile waveforms (please refer to reference [1] for technical discussion on the basic operation of DDS). DDS technology excels at delivering extremely precise digital-control of its synthesized output frequency, fast frequency "hopping," and high frequency accuracy in its output. However, previous 100 MHz DDS solutions have been relatively expensive and necessitated the selection and implementation of a companion reconstruction DAC. This additional design burden, coupled with the undesirable aspects of previous discrete high-speed DDS solutions (i.e., complex interface requirements, high relative expense, and high power dissipation), has relegated high-speed DDS technology to applications in high-end industrial, instrumentation, and military systems. The AD9850 re-writes the DDS/DAC frequency synthesizer story.



What is the AD9850?

The individual functional blocks contained within the integrated AD9850 device, as shown in Figure 1, are innovations in their own right. The numerically-controlled oscillator (NCO) core uses a highly-efficient proprietary algorithm to calculate and implement the required phase-to-sine conversion function "on the fly," reducing the additional processing steps and circuitry associated with the traditional RAM or ROM look-up table implementation of phase-to-sine conversion. This algorithm minimizes the power consumption and size required for the NCO function.

The D/A converter (DAC) block within the AD9850 likewise sets a new standard. This 10-bit DAC core is optimized for wide-band spurious-free dynamic range (SFDR) and advances the state-of-the-art for 125 MHz CMOS DAC distortion performance. Innovative analog design techniques coupled with an advanced fabrication process have yielded a segmented

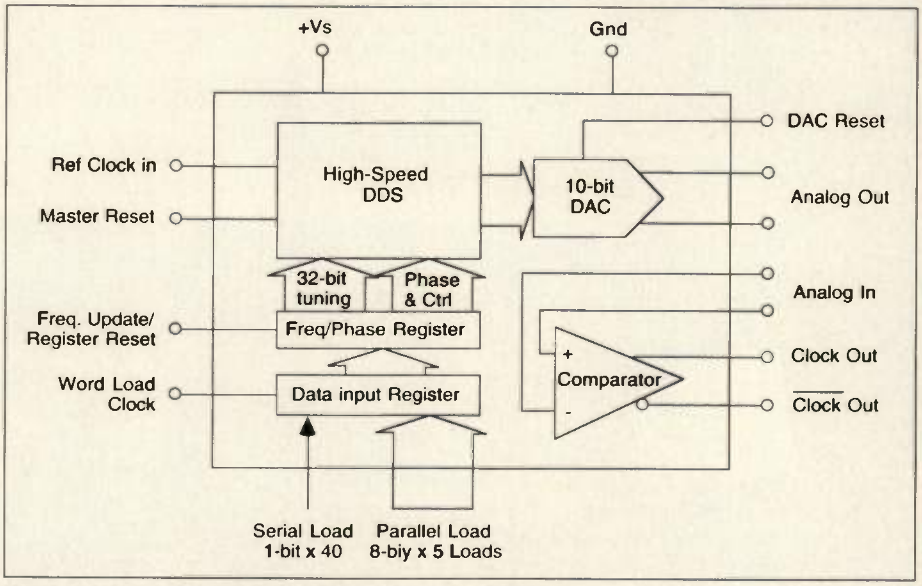


Figure 1. Functional block diagram of the AD9850.

DAC architecture that delivers >50 dB of wideband SFDR at a 40 MHz output frequency (125 MHz clock rate). This optimized CMOS DAC core is singularly responsible for the high level of dynamic performance delivered by the AD9850. As a side note, this core is spawning a new Analog Devices product family of high-speed, low-cost, discrete CMOS DACs. These "transmitter-quality" DACs will be targeted specifically at communications applications where high dynamic performance and an economical price are required.

DDS Demystified

The AD9850 has eradicates one of the stigmas usually associated with discrete DDS and DAC solutions: complex implementation. Discrete DDS technology has been considered by many system designers to be saddled with a formidable learning curve — more of an exotic art form than an exact science. The AD9850 will change the perception of DDS technology for the following reasons:

- The AD9850's DDS core is an integrated functional block of a complete synthesizer solution
- The DDS is deliberately implemented in such a way that the user need not understand DDS theory to use this device to its fullest extent (no learning curve)
- The AD9850 completely eliminates the non-trivial, and somewhat overwhelming, task of successfully selecting and implementing a high-speed reconstruction DAC to support a discrete DDS solution
- The device contains a straightforward set of control functions and input words that greatly simplifies its operation as compared to previous DDS/DAC solutions
- The AD9850 is priced to make digital frequency synthesis a viable alternative to analog synthesis implementations

Easy-to-Use Digital Frequency Synthesis

The external support components and user control interface required to implement the AD9850 are of minimal complexity. It requires only an accurate input reference clock, a word-load clock, and a 40-bit control/data word to achieve complete operation. The 40-bit load word function contains the 32-bit frequency tuning word, 5-bit phase modulation data, power-down enable, and the selection of the serial or parallel data load format. The parallel-load format requires five loads of an 8 bit data word. This 8-bit iterative load format reduces pin-count and allows the AD9850 to be packaged in its ultra-small 28-pin package (25 mil pin spacing) — the smallest footprint available for this function. The 8-bit data bus format is relatively easy to implement and it enables an output frequency change rate of up to 23 million changes-per-second. The reduced pin count, and resulting small package size, directly contribute to the AD9850's low cost.

AD9850 Applications

Frequency Synthesizer — The AD9850 is a highly flexible, high-performance device that will serve many of the traditional DDS markets and applications. However, its breakthrough attributes, including size, price, functional integration and performance, makes it uniquely positioned to bring DDS technology into high-volume, consumer-oriented communications applications. The two foremost applications for the AD9850 are: 1) low-distortion, frequency-agile synthesizer and, 2) frequency/phase-agile clock generator. These applications will be individually discussed in greater detail.

The AD9850 was designed to perform as a superior frequency-agile synthesizer. The device's 42 MHz output bandwidth is appropriate for many communications applications, including frequency-agile local oscillators, digital modulators, and carrier-generators. In these applications, the wideband distortion characteristics of the frequency output are most important; these characteristics are directly determined by the performance of the internal DAC. As was previously described, the internal DAC of the AD9850 was designed for optimum wideband dynamic performance over its Nyquist output range. The SFDR performance at several output frequencies is shown in Figures 2a, b, and c. The AD9850 is clocked at 125 MHz in all of these examples.

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

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

3V

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 product literature, call your nearest CEL Sales Office. Or better yet, call anytime, 24 hours a day:

CEL/Fax 800-390-3232

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

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

new

PART*	NF (dB)	G_A (dB)	V/IC	f_{TEST}(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

CEL California Eastern Laboratories

NEC

CEL Headquarters 4590 Patrick Henry Drive, Santa Clara, CA 95054-1817; (408) 988-3500 FAX (408) 988-0279 http//www.cel.com
Sales Offices 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 (770) 978-4443 Altamonte Springs, FL (407) 774-7682

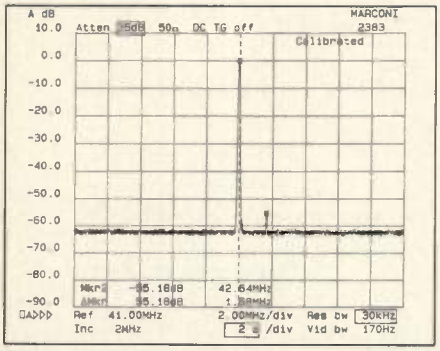


Figure 2a. ADC9850 output SFDR measurement at 41 MHz.

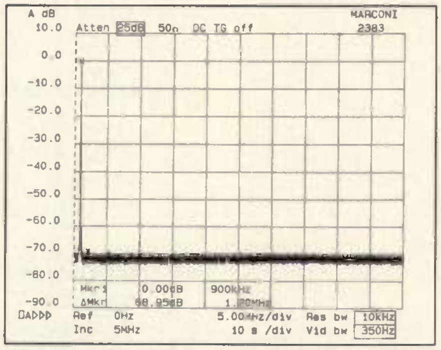


Figure 2b. ADC9850 output SFDR measurement at 15 MHz.

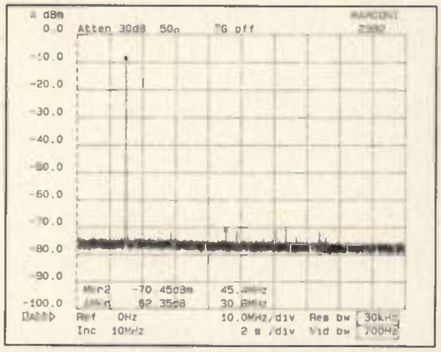


Figure 2c. ADC9850 output SFDR measurement at 1 MHz.

The >50 dB of wideband SFDR performance at 40 MHz analog out delivered by the AD9850, sets a new benchmark for 10-bit CMOS DAC performance. Some frequency synthesizer applications, however, are more interested in the spectral characteristics close-in to the fundamental (narrowband). Figure 4 shows a plot of a 4.5 MHz output fundamental being clocked at 20.5 MHz. In this plot, the spectrum analyzer is displaying a 10 kHz frequency span and the SFDR of the output frequency is greater than 80 dB over this span.

Frequency-Agile Clock Generator

In the AD9850's clock generator application, the device's internal comparator is utilized. The NCO and DAC blocks generate a frequency-selectable 0- 1 Vp-p output sinewave that is brought off-chip for external low-pass filtering. This filtering is necessary because the DAC output is a quantized (stepped) sinewave that contains significant energy at the aliases of the fundamental frequency. Aliased images occur at the sum and difference of the fundamental and multiples of the clock frequency. The lowpass filter helps to attenuate the amplitude of the aliased energy and smoothes the quantized steps. The filtered sinewave is then brought back on-chip and applied to the input of the internal comparator, which is configured as a +0.5 V threshold comparator (half of the DAC's fullscale output voltage). The comparator's +0.5 V reference level can be conveniently generated by averaging the complimentary DAC outputs across a resistor divider and filtering with a .01 μfd. capacitor (see Figure 4).

The comparator functions as a sinewave-to-squarewave converter and its squarewave output serves as a CMOS-compatible clock source, with a rise and fall times of 2.2 ns into a 15 pF load. The DAC outputs and comparator inputs are differential but they can be driven either in single-ended or differential mode. As a clock source, the AD9850 can be digitally-tuned to any frequency up to 42 MHz (approximately one-third of the 125

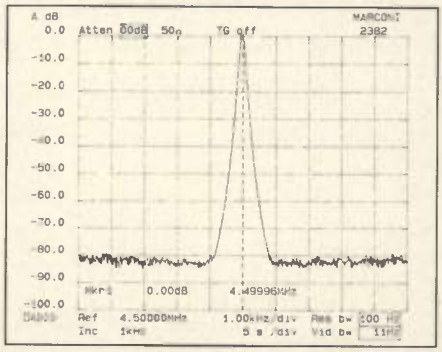


Figure 3. 4.5 MHz output viewed narrowband (1 kHz/div.).

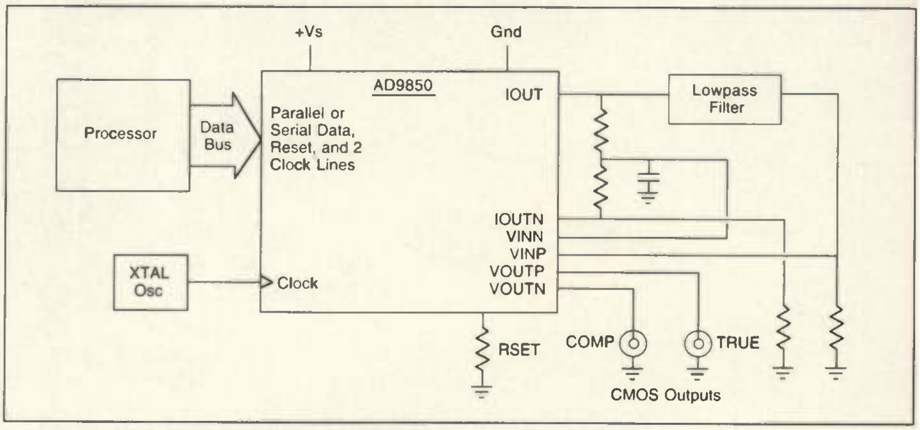


Figure 4. AD9850 in a clock generator application.

MHz clock rate), and it delivers an output frequency resolution of .029 Hz. Furthermore, the output clock can be phase-modulated in increments of +180°, +90°, +45°, +22.5°, +11.25°, and any combination thereof.

Output switching characteristics and jitter are obviously important specifications for clock generator applications. The internal comparator of the AD9850 always sees a full-scale DAC output swing and it was designed with adequate hysteresis to insure clean output switching (no "chatter") with low frequency/low slewing input signals. Figure 5a shows the AD9850's comparator output switching characteristic with an input signal frequency of 1 kHz. Note the absence of output chatter as the input relatively slowly slews through the comparator's threshold level. Figure 5b shows the comparator's output switching characteristic with a 41 MHz input signal.

The parameters of the external filter play an important role in the amount of overall output clock jitter. Figure 6 shows the jitter plot for the output of the AD9850 under the following conditions: 40 MHz output pulse, 125 MHz reference clock, +3.3 V supply voltage, and a 5th order 45 MHz low-pass filter with 200 ohm input/output impedance. By storing consecutive samples of the output pulse on a storage oscilloscope, the output jitter is demonstrated to be approximately 300 psp-p which well supports its major application as a clock generator in a spread-spectrum digital communication systems.

Spread-Spectrum Application

An example of the AD9850 as a clock generator in a spread-spectrum receiver in shown in Figure 7. This is the block diagram of the I&Q digitizer section of Loral Communications Systems' EB 200 spread-spectrum modem. The Loral system utilizes a DDS-based clock generator function to lock the receiver onto the chip rate of the transmitter. This allows the entire spread-spectrum system to quickly re-optimize its TX-RX data transfer delay and timing to compensate for fluctuating transmission media characteristics such as that presented under changing atmospheric conditions, or as posed by system operation within a mobile/portable environment.

In a spread-spectrum receiver application, the EB-200 system accepts an RF input and generates I&Q IF signals via a quadrature down converter stage. A pair of high-speed A/D converters digitize the IF I&Q channels at the chip rate of the spread data. An on-board ASIC, Loral's PA-100 chip, performs the basic despreading and baseband demodulation of the I&Q data as well as decoding its chip rate. The PA-100 device generates a 32-bit frequency control word corresponding to the chip rate, which is applied as the frequency tuning word to the AD9850. The AD9850, in turn, generates an encode command pulse frequency for the dual A/D converters that is locked to the chip rate of the transmitted data. As transmission conditions change, the AD9850 clock generator function allows the receiver to be digitally tuned for continued optimum performance.

The features and attributes of the AD9850 complement and enable the full potential of the EB-200 spread-spectrum modem. The EB-200 is a highly flexible digital demodulator function that fully supports many different modulation schemes: BPSK,

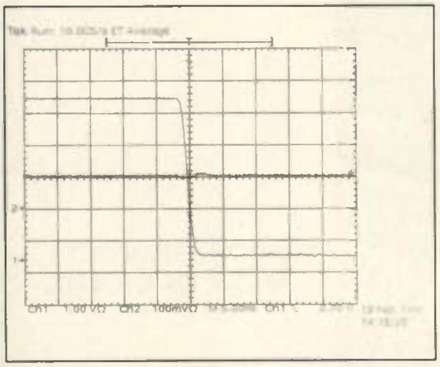


Figure 5a. Comparator output waveform at 1 kHz.

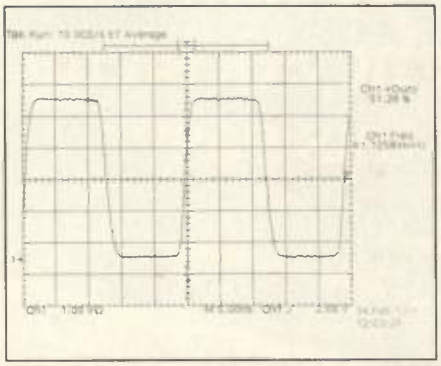


Figure 5b. Comparator output waveform at 41 MHz.

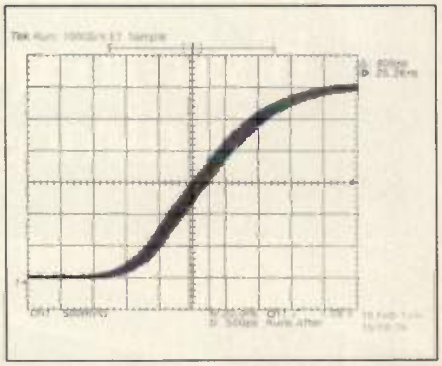


Figure 6. Output clock jitter plot.

QPSK, and OQPSK — at data rates from 9.6 k to 40 Msymbols/s. The AD9850, as the supporting clock generator function, allows the EB-200 to target many commercial spread-spectrum applications such as RFID, wireless telephony, wireless LAN, and high-speed data modems. For additional information on Loral's EB-200 spread-spectrum digital demodulator system, contact Kent Erickson at Loral Communications Systems, 640 N. 2200W, Salt Lake City, UT, 84116 (801/594-2044).

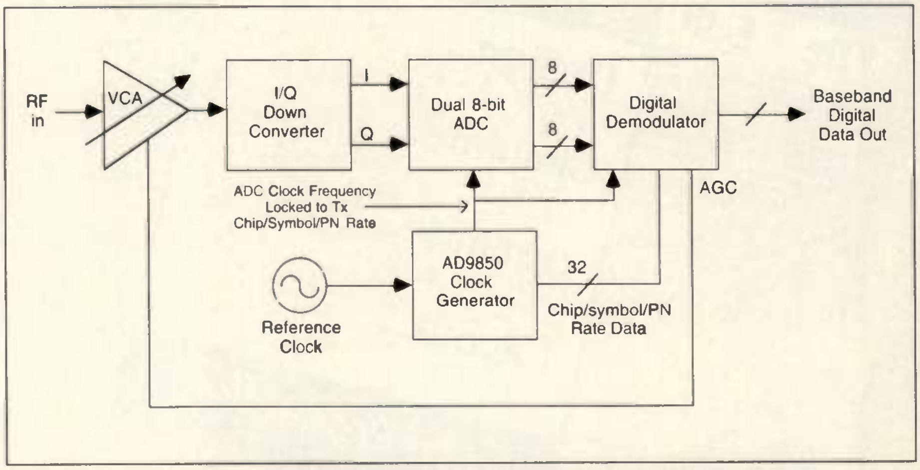


Figure 7. AD9850 as a clock generator in a spread-spectrum receiver.

User-Friendly AD9850 Evaluation Board Available

An evaluation board for the AD9850 is available which carries the concept of simple DDS interface a step further. The evaluation board interfaces to the printer port of a PC and includes control software that operates under WindowsTM. This provides an extremely user-friendly "point-and-click" control format for operating the device. Two versions of the evaluation board are available: the AD9850/FSPCB and the AD9850/CGPCB. The FS version is configured as a frequency synthesizer with the AD9850's DAC output connected to a BNC connector and terminated in 50 ohms. The AD9850/CGPCB evaluation board configures the AD9850 as a clock generator function and includes a 43 MHz low-pass filter between the DAC output and the comparator input. The AD9850 comparator's squarewave output is connected to an output BNC jack for timing analysis. Both versions are available from stock with a cost of $98.50, which includes AD9850 device and operating software.

More DDS to Come...

The AD9850 is the flagship product for a new family of DDS-based products from Analog Devices. In addition to forming the core of higher-resolution frequency synthesizer products, the AD9850's CMOS DDS and DAC blocks will be further integrated with mixers and digital filters to form complete digital modulator devices. One such immediate follow-on product is a QPSK digital modulator device that will provide an optimum low-cost solution for the 5-40 MHz return path TX function as required in the emerging HFC cable modem industry.

For additional information, contact Analog Devices at 1-800-ANALOGD — or circle Info/Card #250. *RF*

References

1. Allen Hill and Jim Surber, "Using Aliased-Imaging Techniques in DDS to Generate RF Signals" *RF Design*, September, 1993.
2. Allen Hill and Jim Surber, "Digital Synthesis Generates Analog Signals Yet Eases Frequency Hopping", *Personal Engineering and Instrumentation News*, August, 1994.
3. EB-200 Spread Spectrum Modem Preliminary Data Sheet, published by Loral Communications Systems, 1996.

About the Authors

David Crook is a Development Engineer in Analog Devices' High Speed Converter group located in Greensboro, N.C. He has been with the company for nine years and has most recently been involved with the development of BiCMOS A/D converters and high-speed CMOS DAC and DDS architectures.

Jim Surber is a Strategic Marketing Engineer with the High Speed Converter group of Analog Devices, located in Greensboro, N.C. Surber has been with Analog Devices for 20 years and has previously worked in the areas of manufacturing test, applications engineering, and tactical marketing.

With our new PC software, high-frequency design is almost this easy.

HEWLETT® PACKARD

Introducing HP EEsof Series IV/PC: Total integration from a single software package.

Okay, so you can't get your high-frequency designs all the way to production just by pointing and clicking. But thanks to HP EEsof Series IV/PC, designing for manufacturability is almost that simple.

You see, HP EEsof Series IV/PC is a truly integrated high-frequency circuit design solution, bringing schematic capture, simulation, analysis and layout together in a single software package. That means you can now simulate and tune your designs directly from layout. And you only have to learn one tool.

HP EEsof also features the world's largest parts libraries — over 90,000 models in all. So you not only get the highest performance simulators money can buy, you get the accurate models you need.

In fact, the Discrete Value Optimizer lets you fully analyze your designs with actual, not theoretical, parts. Making product development time shorter than ever.

For more information on Series IV/PC, or the other innovative solutions HP EEsof is bringing to high-frequency design, call 1-800-452-4844, Ext. 1396* or your local sales representative today for a free brochure.

Taking your designs from concept to production has never been easier.

There is a better way.

*In Canada, call 1-800-276-8661, Dept. 255.

http://www.hp.com/go/hpeesof

INFO/CARD 52

HP EEsof Series IV/PC lets you solve real world problems using real world parts.

Smallest, Thinnest Trimmers Added to Product Line

Sprague-Goodman Electronics has added the smallest and thinnest models to its line of SURFTRIM® Surface Mount Trimmer Capacitors. The two models in this new GKP series meausre just 2.2 × 3.1 mm and feature an extremely low profile — height is 1.2 mm above the mounting surface. Capacitance range for Model GKP10066 is 3.0-10.0 pF; Model GKP20066 covers 4.5-20 pF. Drift after setting is less than ±1 percent, and the Q is 200 minimum at 1 MHz. Temperature coefficient of capacitance is NPO ±500 ppm/°C for GKP10066 and N750 ±500 ppm/°C for GKP20066. Operating tempeature is rated at –25°C to +85°C, the voltage rating is 25 volts with dielectric withstanding voltage of 55 volts. Insulation resistance is 10^4 Megohms minimum, and tuning torque is 10-100 g-cm (0.2-1.39 oz-in.). Carrier and reel packaging is standard. Pricing is $1.15 per piece for a 2000-piece reel. Sample quantities are available from stock. 12-week delivery on initial quantities.
Sprague-Goodman Electronics
INFO/CARD #187

T/R Amplifier Subsystems

LCF Enterprises is now manufacturing a line of T/R amplifier subsystems covering 1 MHz to 2 GHz. These systems deliver high performance, with flexible design features in a compact size. Customers can select from a list of components with specific gain performance (8-40 dB) and connector size (Type N, TNC, SMA), and customize the subsystem for their application. The components available include a

power amplifier; preamplifier; control logic for current limiting, thermal shutdown and autoswitching; TX/RX switching; EMI filtering; and DC-DC converter. All subsystems include a power connector and come with options including heat sink and dual power outputs.
LCF Enterprises
INFO/CARD #188

CDMA Mobile Station Test System

Noise Com introduces the WIS-98 and WIS-018 CDMA mobile Station Test Systems for cellular and PCS applications, respectively. The combined Wireless Impairment System Model WIS-98/018 is used for simultaneous cellular and PCS testing. Systems are integrated

test solutions with emulation of impairments such as Additive White Gaussian Noise (AWGN), multipath fading and CW interference. These systems, combines with a mini-cell or base station simulator, provide comprehensive testing for verification of product performance to meet the CDG Stage 1, IS-98, and ANSI-J-STD-018 standards. The units are provided in 19-inch rack systems.
Noise Com, Inc.
INFO/CARD #189

Low-Cost 4 GHz Signal Generator

Expanding their HP 8648 line of signal generators, Hewlett-Packard announces the HP 8648D, a low-cost 4 GHz synthesized model designed for RF communications systems testing. New applications require higher frequency operation than was previously needed, and this model offers low cost in the 3 GHz to 4 GHz range, where available instruments have generally been high-end products.

With 9 kHz to 4 GHz range, the HP8648D is useful for general receiver testing, or for personal communications system (PCS), wireless local area networks (WLAN) and fixed-radio access (FRA). The unit is also available with an optional variable-modulation generator for audio-band testing using 10 Hz to 20 kHz modulation in sine, square, triange and sawtooth shapes. Price of the HP 8648D is $11,000 and Option 1E2 variable-modulation generator is $400.
Hewlett-Packard Company
INFO/CARD #190

Microcell Power Amplifier

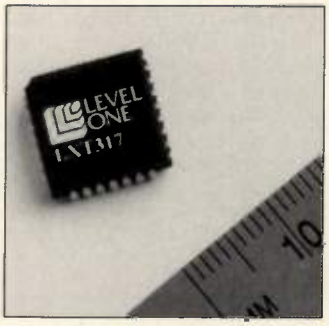
Advanced Control Components introduces the ACAM-7911, 7912 and 7914 RF power amplifiers designed as drivers in microcell base stations operating

in the 800 MHz band, as well as systems operating in the 915 MHz ISM band. The amplifiers deliver 36 dB of gain, flat to ±0.5 dB, with a third order intercept point typically +56 dBm. Gain versus temperature is ±1 dB (typically +0.6, –0.8 dB). Input and output VSWR is 1.5:1. The ACAM-7911 covers 869-894 MHz, the ACAM-7912 covers 890-915 MHz, and the ACAM 7914 covers 940-956 MHz. All models operate from +15 VDC at 3.3 A. Advanced Control Components manufactures detectors, limiter-detectors, RF amplifiers and custom RF and microwave subsystems.
Advanced Control Components
INFO/CARD #191

SEMI-CONDUCTORS

Wireline Transceiver for DECT

Level One Communications announces a fully integrated long-haul transceiver for a DECT base station. In addition



to DECT PBX/central office interface applications, the LXT317 can bbe used for a wireless PABX interface, Network Termination Unit (NTU), wireless LAN interface, LAN bridge or private network data pump. The device includes on-chip adaptive equalizer, transmitter, receiver and HDB3 encoder/decoders. In 100-unit quantities, the price is $15.48.
Level One Communications
INFO/CARD #192

1-Watt RFIC Power Amplifier

Pacific Monolithics introduces the PM2105 1-watt power amplifier for operation over the 800-2000 MHz frequency range. With extrnal matching, high performance can be obtinaed within 30 to 100 MHz bandwidth anywhere in the specified frequency range. The PM2105 is designed for operation in either linear or saturated power applications. P_{1dB} is 29 dBm, while saturated power is 30.5 dBm (typical). Bias pins either Class AB or Class C operation. The device ratings are specified with a 5 VDC supply, but the device is usable over 3 to 6 VDC.
Pacific Monolithics
INFO/CARD #193

SSTs Target HF and CATV Return Uses

New silicon FET amplifiers from MicroWave Technology are designed for low/medium power applications at frequencies from 0.2 to 100 MHz, including HF communications, test instrumentation, and CATV reverse channels. The LPS-0151 covers 1-50 MHz with more than 0.5 watt of linear power output in a 75 ohm system. The LPS-0150 is a 1-watt, 50 ohm device for 1-50 MHz, and the LPS-0110 is a broadband 0.2-110 MHz device providing 0.5 watts into 50 ohms. All models are internally matched and biased, requiring only power and decoupling circuitry, and are specified for operation at 12.5 VDC.
MicroWave Technology
INFO/CARD #194

3-Watt GSM Amplifier

Anadigics has introduced the AWT0904 GaAs monolithic power amplifier, delivering 3 watts from a single +5.8 VDC supply. Provided in a low-cost IC package, the device uses three amplification stages to achieve 34 dB gain, 35 dBm output, 50% efficiency, and low receive-band noise. Similar amplifiers are being developed for the U.S. PCS band.
Anadigics Inc.
INFO/CARD #195

IC Combines Mixer and I/Q Modulator

TEMIC has released the U2891B, providing a 2.5 GHz mixer and 30-500 MHz I/Q modulator in a single package — operating at a supply as low as 2.7 volts. Accuracy of the I/Q phase shifter is 0.5°, providing sideband suppression of 45 dB and LO suppresison of 40 dB. The mixer section has an output compression point of –7 dBm and a third order intercept of –6 dBm with a 50Ω load. Conversion gain is 9 dB.
TEMIC Telefunken
INFO/CARD #196

Single-Frequency Synthesizer

Motorola announces the MC12179, a highly-integrated synthesizer IC for operation at up to 2.5 GHz output. The division ratio is fixed at ÷256, and the chip includes a reference oscillator, phase detector, and charge pump. A crystal and VCO are the only required addtions. $4.97 in 1000s.
Motorola SPS
INFO/CARD #197

TEST EQUIPMENT

Enhanced Model RF Voltmeter

Boonton Electronics has improved the Model 9200C RF voltmeter with a new front panel display. The 9200C offers complete microprocessor control, a voltage range of 200 μV to 3V, from 10 Hz to 2.5 GHz. Features include auto-zero function, an additional channel for differential measurements, DC recorder output, IEE-488 interface and a 3-1/2 digit voltage or dB display with 0.01 dB resolution. Starting price of the 9200C is $3,600.
Boonton Electronics Corp.
INFO/CARD #198

Cellular Base Station Emulator

The TAS 6600 Wireless Communications Analyzer from Telecom Analysis Systems offers complete cellular base station emulation, including: a mainframe analyzer with

EAMPS emulation, the TAS-6600-CAP Cellular Audio Processor (CAP) module, and the TASKIT®/6600 software for Windows. The compact unit simplifies, integrates and enhances the testing of cellular communications products.
Telecom Analysis Systems, Inc.
INFO/CARD #199

PC-Based Arbitrary Waveform Generator

Gage Applied Sciences has introduced the CompuGen 1100, a PC-based arbitrary waveform generator with 12-bit resolution DAC and conversion rates up to 80 MSPS. The ISA bus card instrument is provided with control software that allows user-defined mathematical functions or waveforms from the software library. Output signals with up to 20 MHz bandwidth can be generated. With standard 512k memory (expandable to 8 million samples), the price is $4,995. Software drivers for popular compilers are $250.
Gage Applied Sciences
INFO/CARD #200

10 MHz Data Acquisition Board for Workstations

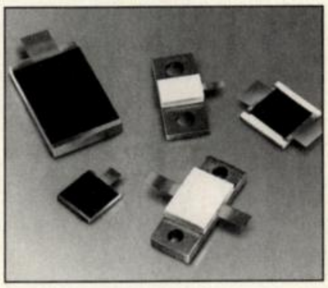
Ultraview Corporation has developed an SBus data acquisition board that can continuously acquire analog data at 10 MSPS and 12-bit precision, including baseband and low-frequency RF signals. Real-time analysis of scientific, medical and communications signals is the primary application. A special pipeline mode allows the entire 16 MBytes of RAM to be used for outputting 16 MBytes of analog data, while siultaneously inputting 16 MBytes of data. This allows immediate measurement of response to stimulus, useful for testing high-speed RF, disk drives, and MMICs. Single-unit price is $4495 for the combined A/D and dual D/A board. Other models range from $2995 to $3995.
Ultraview Corporation
INFO/CARD #201

INFO/CARD 56

SIGNAL PROCESSING COMPONENTS

Copper-Based Passive Components

Bird Component Products introduces passive RF devices using a new cost-effective coppre-based T^2 Technology. These



devices are less prone to leaching during soldering than silver technology components. A complete line of attenuators, resistors and terminations is available using this technology.
Bird Component Products
INFO/CARD #202

Chip Lowpass Filters for 800-2600 MHz

The LTF Series of chip lowpass filters from Toko America can be used to reduce harmonics of a system PA or LO. Provided in a miniature 1206 footprint (3.2 × 1.6 mm) and only 1.4 mm high, these filters provide a minimu of 30 dB attenuation at $2 \times f_0$ and 18 dB at $3 \times f_0$. Standard frequencies are available for standard wireless communications band from 836.5 MHz through 2450 MHz, including cellular, 900 and 2400 MHz ISM bands, PDC-1.5, PCS-1900, DCS-1800, DECT and PHS.
Toko America, Inc.
INFO/CARD #203

SAW Filters for Wireless Systems

A new family of SAW filters for wireless applications is now available from Mitsubishi Electronics. The MF1009S is designed for the 869-894 MHz AMPS cellular receive band, and the MF1010S series is designed for the 824-849 MHz AMPS transmit band. The new SAW filter has a small footprint of 3.8 × 3.8 × 1.25 mm, and are offered optimized for either insertion loss (3.1 to 3.5 dB) or for stopband rejection (24-55 dB). Low amplitude ripple and wide temperature range operation are additional features of the SAW filter line.
Mitsubishi Electronics
INFO/CARD #204

Dual Celluar Bandpass Filter

K&L Microwave offers a dual cellular bandpass filter, model X10FV50-920/X80-N/N with center frequencies of 897.5 MHz and 942.5 MHz. –3 dB bandwidth at each frequency is 36 MHz, with insertion loss of less than 1.5 dB. Rejection at 860 and 980 MHz is greater than 40 dB, and greater than 70 dB at 920 MHz.
K&L Microwave
INFO/CARD #205

DISCRETE COMPONENTS

Chip Inductors

Pulse offers a new series of 1008 wirewound RF chip inductors, with a ceramic core that provides exceptional Q performance, thermal stability and self-resonant frequencies reaching up to 6 GHz. The inductors are available in industry-standard values from 4.7 nH to 4700 nH, and are also available in the 0805 size. Both are designed for pick-and-place assembly. Q and inductance and S-parameter information are available in disk format for easier circuit modeling. In 100,000-piece OEM quantities, pricing is typically $0.13 each.
Pulse
INFO/CARD #206

1 kV Ceramic-Plate Capacitors

Philips Components has added a new series of 1 kV ceramic-plate capacitors in a wide range of values from 0.47 pF to 3300 pF, available in tolerances from 5% to 20%. High temperature versions are available, as are low-loss models for minimum dissipation.
Philips Components
INFO/CARD #207

Product Focus — Crystal Oscillators

Vacuum OCXO Increases Performance

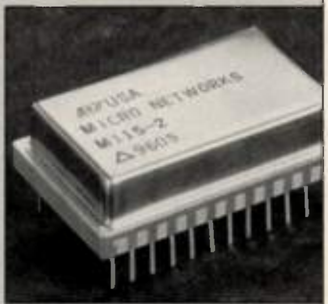
A new generation of OCXO technology, the Evacuated Miniature Crystal Oscillator (EMXO) uses the insulating properties of vacuum, with a cold weld enclosure to provide improved performance over conventional OCXOs. Steady-state power consumption is <1.2 watts at –55°C, with warm-up time at that temperature of two minutes. Stability is available to $\pm 1 \times 10^{-8}$ over –55 to +85°C.
Vectron Labs
INFO/CARD #208

High-Stability SATCOM TCXO

Model 6202 from Oscillatek is based on the poular 6024 and 6079 SATCOM TCXO series. The 6202 is a 10 MHz model that will maintain ±1 ppm 0 to +50°C including aging for 10 years. Pricing is $65.00 each at 1000 pieces, and other performance options are available.
Oscillatek
INFO/CARD #209

Programmable Master Clock Oscillator

Micro Networks introduces a parallel-programmed master clock oscillator for frequencies from 40 MHz to 1 GHz. The M115 Series has



eight models that can be programmed over a wide range. For example, the M115-1 covers 40-80 MHz in 100 kHz increments, while the M115-8 covers 800 MHz to 1 GHz in 200 kHz steps. Stability is 35 ppm (0-70°C), with other specifications available. Prices start at less than $155 in sample quantities, OEM pricing less than $100.
Micro Networks
INFO/CARD #210

Microprocessor Crystals

Ecliptek now offers the ECCM3 and ECCM4 µP crystals, with high stability needed for use in clock and reference oscillators for wireless, satellite and telecommunications. They are available in frequencies from 11 to 120 MHz, with ±10 ppm tolerance and ±5 ppm stability over –20 to +80°C. The ECCM3 and ECCM4 are provided in SMT packages designed for automatic assembly.
Ecliptek Corporation
INFO/CARD #211

SUBSYSTEMS

Distribution Amplifier

Frequency Electronics has introduced the FE-7923A 10-channel sinewave distribution amplifier, operating at 1 to 10 MHz. Designed to meet stringent satellite ground station requirements, the unit offers low phase noise, low amplitude noise bursts, and isolation of more than 100 dB. The FE-7923A is provided in a 19-inch rack mount case.
Frequency Electronics
INFO/CARD #212

Wireless Data Transceiver/Modem

Advanced Digital Systems (ADS) and Tait Electronics have jointly developed a rugged, cost-effective mobile data package that marries a data-ready Tait mobile transceiver with a high-speed ADS "Smart Packet Modem." The D2000/SPM modem system transmits and receives data from 1200 to 9600 bps. The D2000 mobile transceiver is a synthesized four-channel radio, remotely con-

Product Focus — Crystal Oscillators *continued*

Surface Mount VCXOs for Communications

Champion Technologies introduces the K1526 Series of voltage-controlled crystal oscillators (VCXOs), available in a compact ceramic SMT package. The VCXOs are compatible with today's phase-locked loop applications in wireless telecommunications. Available in frequencies from 2.0 to 55.0 MHz, the VCXOs offer overall frequency stability tolerance as tight as ±25 ppm over 0 to 70°C, and ±50 ppm from –40°C to +85°C. Deviation range is available from 60 ppm to 150 ppm with a control range of 0.5 to 4.5 V. Typical pricing is $19.000 each in 1,000-piece quantity.
Champion Technologies, Inc.
INFO/CARD #213

OCXO Series Developed from Satellite Applications

Model 106 from Reeves-Hoffman is an oven controlled crystal oscillator (OCXO) that was originally designed for high reliability Satellite Rescue (SARSAT) applications, with low power consumption comparable to a TCXO. Temperature stabilities are as tight as ±0.05 ppm over 0-70°C, and ±0.1 ppm over –40 to ±70°C. Power consumption is approximately 200 mW at

–40°C, ideal for battery-power applications. The Model 106 is packaged in a standard CO-08 package, and aging rates as low as 0.3 ppm per year are avilable.
Reeves-Hoffman
INFO/CARD #214

SMD Clock Oscillator

Vectron Technologies offers a fixed frequency crystal oscillator in a leadless chip carrier (LCC) package, for TLL and CMOS applications. Tape and reel as well as tube packaging is available. Typical applications include providing clock signals for digital signal processing (DSP), microprocessors (µP) and disk drive circuitry.
Vectron Technologies Inc.
INFO/CARD #215

Super-Low-Profile OCXO

Oak Frequency Control Group's new 4853 OCXO is available for the 10-50 MHz range, and features a low-profile package with dimensions of 1.0 × 1.0 × 0.45 inches. Temperature stability is $\pm 8 \times 10^{-8}$ over –20 to +70°C. Warm-up power is 2.5 watts, and steady-state power consumption at +25°C is 1 watt. Typical phase noise at 100 MHz is –130 dBc/Hz. An SC-cut crystal version is available.
Oak Frequency Control Group
INFO/CARD #216

trolled by the modem. VHF and UHF models are offered for 136-174 and 400-470 or 450-520 MHz, respectively.
Tait Electronics — USA, Inc.
INFO/CARD #217

Radio Data Transceiver

The Pathfinder Explorer 9600 from Metric Systems Corp. is an intelligent UHF 9600 bps radio data transceiver for industrial control, monitoring and data acquisition systems. The unit offers 3-wire or RS-232 interface, packetized or transparent mode, individual station addressing (up to 64,000 addresses), full error correction, and the CSMA point-to-multipoint networking prtotocol. The Pathfinder Explorer 9600 is available in seven frequency bands from 403 to 512 MHz.
Metric Systems Corp.
INFO/CARD #218

Microwave Microcells

3dbm has announced the availability of the MMC series of Microwave Microcells. The units are designed to improve the capacity and coverage of cellular systems. Typical uses for coverage imporvement include shopping malls, convention centers, office buildings, tunnels, subways and indoor garages. They can be combined with 3dbm's SZS Microcell Zone Selectors to form intelligent microcell clusters.
3dbm, Inc.
INFO/CARD #219

CABLES & CONNECTORS

Flexible Microwave Cable Assemblies

Low-cost microwave cable assemblies for applications up to 14 GHz are available from Richardson Electronics. Made by Gore, the assemblies are offered in 4-inch to 60-inch lengths, with straight or right-angle SMA male connectors. The cable features low loss RF characteristics and performance similar to semi-rigid cable, but in a more flexible alternative.
Richardson Electronics Ltd.
INFO/CARD #220

Minimum-Profile F Type Jack

Connect-Tech Products now offers the CTP-169 minimum-profile F-type jack which mounts directly to the edge of a printed circuit board, supported by a slot in the jack. The edge slot can be changed from the standard .062 p.c. board thickness to any other required dimension. Applications include cable TV, LAN networks, TV interface, satellite and other communications. Unit cost of the CTP-169 in high volume is under $0.35 each.
Connect-Tech Products
INFO/CARD #221

High-Power Connectors

A line of high integrity quick connect and disconnect SQ connectors, receptacles and cable assemblies is offered by Tru-Connector. These connectors are used in sputtering, wafer processing and other high-power applications. The Tru-Connector models feature a spring-loaded sleeve on the male member which has self-contained balls which mate to the corresponding groove on the female connector. The connectors are capable of handling 7000 volts, or 5 kW power at 50 ohm impedance. Pricing is according to style, cabling requirements and quantity.
Tru-Connector Corp.
INFO/CARD #222

INFO/CARD 63

Active Filter and Other Op Amp Circuits for RF Applications

By Gary A. Breed
Editor

Active filters and other high-frequency and high-speed op amp circuits have only recently become practical for RF applications. The development of the current-feedback operational amplifier in the 1980s, and subsequent improvements in the design and fabrication of all types of op amps and buffers have combined to make active circuits viable replacements for some passive R-L-C circuits.

A series of example circuits are presented in this month's tutorial, taken from past articles published in *RF Design*. These circuits are good representatives of the types of active circuits that are practical for RF applications.

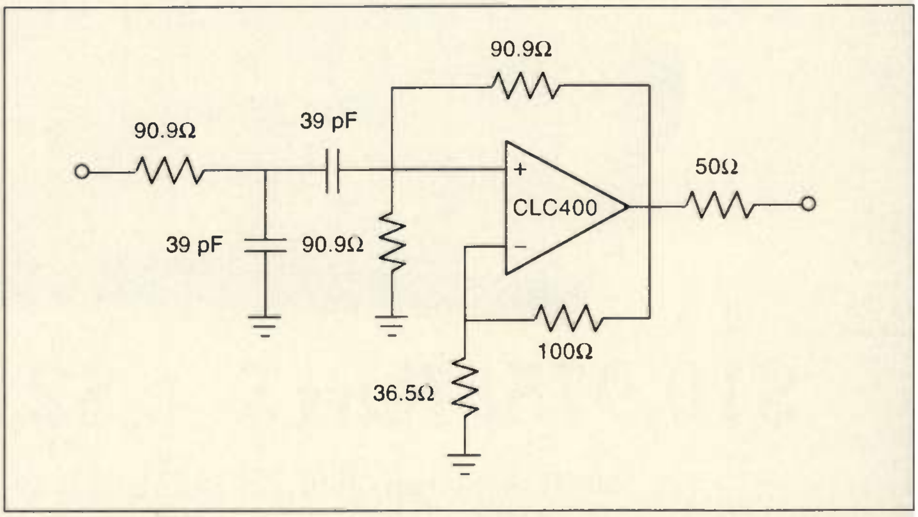


Figure 1. A practical 40 MHz active bandpass filter circuit with no active elements in the feedback path.

An Active Bandpass Filter

The first circuit is an active bandpass filter using a wideband current-feedback op amp, the Comlinear CLC400 [1]. A 1987-era product, the CLC400 has a –3 dB bandwidth of 200 MHz, and is designed for stability in low gain applications (A_v = ±1 to 8). The topology of the amplifier in Figure 1 was chosen to avoid placing reactive components in the feedback path, thus maintaining stability. While not a high-Q topology, the design provides predictable "peaked" response that is useful for reducing broadband noise, performing a spectral "clean-up" following an oscillator or amplifier, or providing a tuned response to detectors or other test circuitry.

When designing this type of filter, the op amp cannot be assumed to be ideal, unless the filter center frequency is well below the –3 dB bandwidth of the amplifier. In the case of the CLC400, the time delay of 1.6 ns through the device must be included in design calculations.

25 MHz Tunable Active Filter

Figure 2 is the functional block diagram of the Krohn-Hite Model 35 tunable active filter [2]. This product was state-of-the-art in 1991, offering 4-pole Butterworth lowpass response, tunable from 170 Hz to 25.6 MHz. This type of filter is useful for EMI testing, Part 68 telecommunications testing, prefiltering for various instruments, ultrasonics and high-speed tape or disk drive testing.

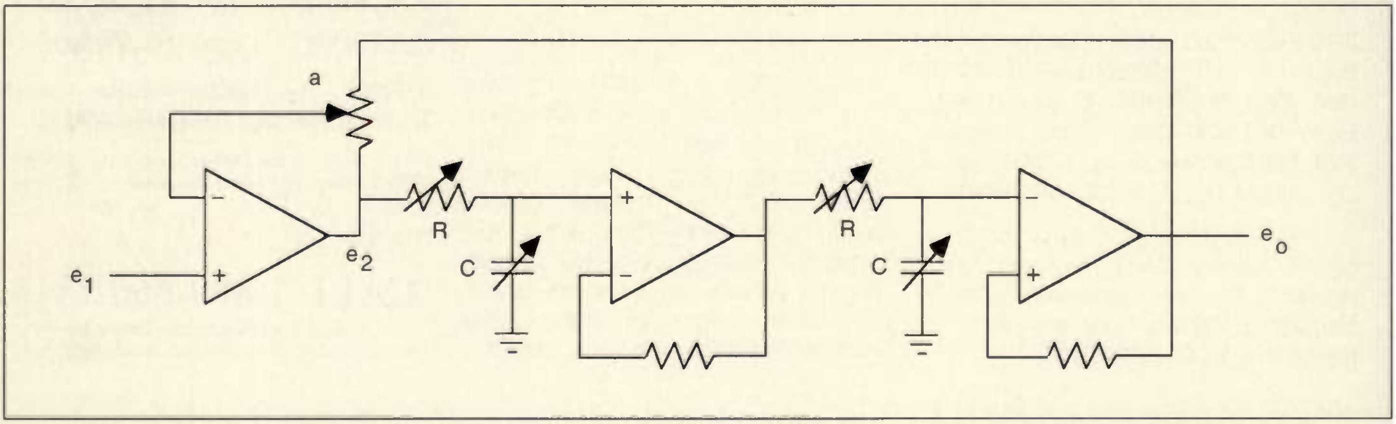


Figure 2. Functional block diagram of a commercial tunable active filter with 25 MHz bandwidth (Krohn-Hite Model 35).

FILTERS

low pass, high pass, bandpass dc-3GHz from $11.45

• less than 1dB insertion loss • greater than 40dB stopband rejection • surface mount • BNC, Type N, SMA available • 5-section, 30dB/octave rolloff • VSWR less than 1.7(typ.) • rugged hermetically sealed pin models • constant phase • meets MIL-STD-202 tests • over 100 off-the-shelf models • immediate delivery

Mini-Circuits®

US 64 INT'L 93
CIRCLE READER SERVICE CARD

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 *INTERNET* http://www. minicircuits. com

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

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

F 209 Rev Orig

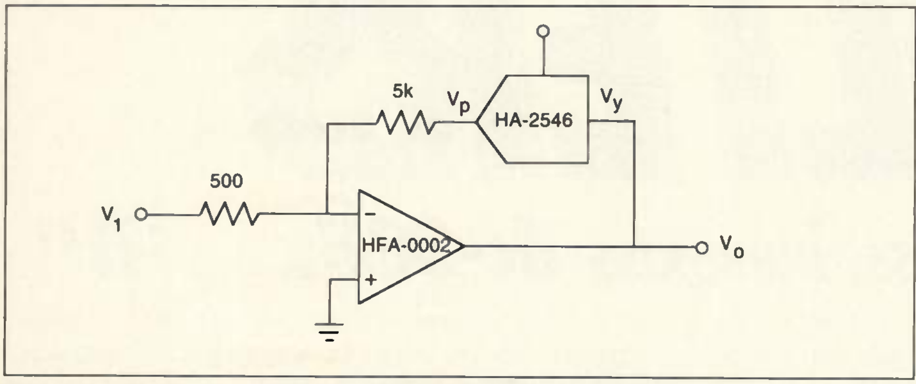


Figure 3. Wideband voltage-controlled amplifier (VCA) circuit.

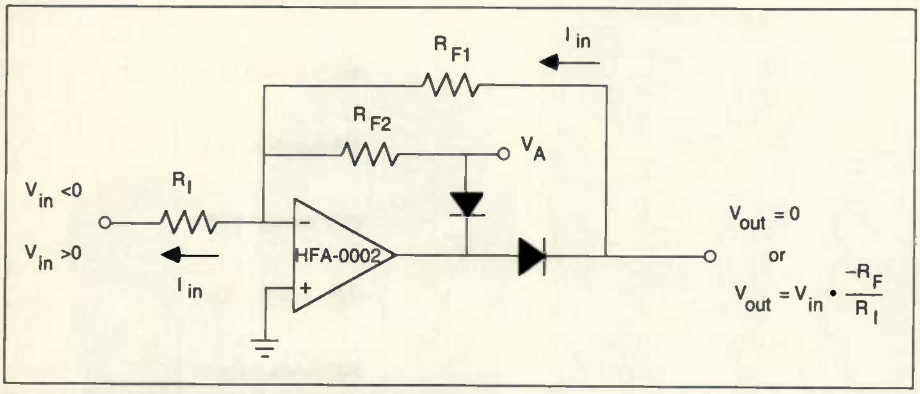


Figure 4. A high-speed precision rectifier

Wideband VCA and Rectifier

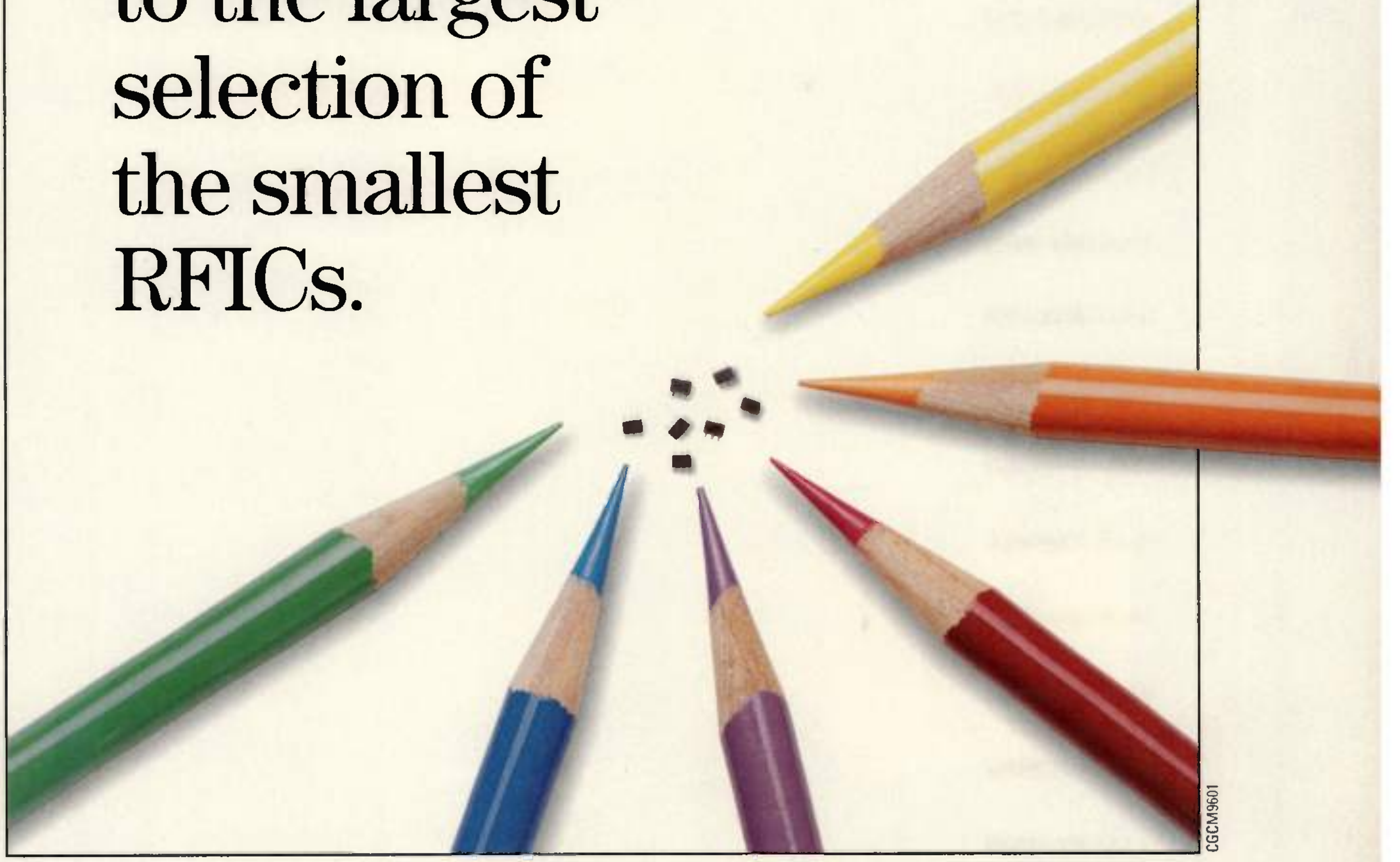
Mathews and Reimer described a series of high-speed op amp circuits in their 1989 article [3]. One of those circuits is shown in Figure 3, a wideband voltage-controlled amplifier (VCA) using a high-speed analog multiplier in the feedback loop. The multiplier acts as an attenuator, controlling the gain without having the control element in the direct path. A gain control range of 60 dB can be achieved.

The other circuit (Figure 4) is a precision rectifier, which can be used in a fast AGC detector or other high-speed amplitude monitoring application. The 0.1 dB bandwidth of this rectifier circuit using the HFA 0002 is 2.3 MHz, with about 40 ns response time from input AC to output DC.

Circulator/Isolator Circuit

The 1991 winner of the RF Design Awards Contest [4] submitted the circuit of Figure 5, which uses the phase accuracy of high-speed op amps to make a three-stage "circulator" for low frequencies. The circuit provides about

Everything points to the largest selection of the smallest RFICs.



CGCM9601

Introducing more of the world's smallest 3V RFICs – with the price, performance and size you need for wireless applications.

Now there's an easy way to get the building blocks you need for emerging higher-frequency applications, such as PCS, PHS, wireless data and Wireless Local Loop .

We've expanded our SOT-363 RFIC family with cost-effective downconverters and driver amplifiers that complement our LNA and gain block lines.

The versatile new MGA-81563 and MGA-82563 medium-power amplifiers deliver excellent dynamic range and high efficiency.

And our new IAM-91563 downconverter provides high conversion gain and linearity, with surprisingly low noise figure.

Plus, you can specify our new RFICs with confidence because they're backed by HP quality and proven high-volume manufacturing capability.

Our stocking distributor Penstock has 20 offices nationwide staffed with engineers to support your design applications.

Call HP at 1-800-537-7715, ext. 1430 for a Selection Guide and Data Sheets.

Or get right to the point and call 1-800-PENSTOCK for information on *free samples*.

In Northern California, (408) 745-8100
In Canada, (613) 592-6088

Typical Performance

Part Number	Description	Frequency Range (MHz)	Voltage (V)	Current (mA)	NF (dB)	Gain (dB)	IP3 (dBm)
▶ **IAM-91563**	Downconverter	800-6000	3	9	8.5	9	+2.5
INA-51063	Gain block	DC-2400	5	12	3.0	20.5	+6
INA-52063	Gain block	DC-1600	5	30	4.0	22	+15
▶ **MGA-81563**	Driver amp	100-6000	3	42	2.7	12	+27
▶ **MGA-82563**	Driver amp	100-6000	3	84	2.2	13	+31
MGA-86563	LNA	1500-6000	5	14	1.6	22	+15
MGA-87563	LNA	500-4000	3	4.5	1.6	14	+8

▶ New product for '96

PENSTOCK®
RF/MICROWAVE DISTRIBUTION
AN AVNET COMPANY

HEWLETT® PACKARD

INFO/CARD 66

40 dB isolation between ports using low-inductance precision resistors. This broadband performance level cannot be achieved by passive circuit.

The author's initial application of this circuit was to measure *output* return loss of an oscillator while in operation, which requires isolation of the circuit output from the measuring instrumentation. Low-level amplifier, mixer or multiplier testing are other useful applications for this isolator. **RF**

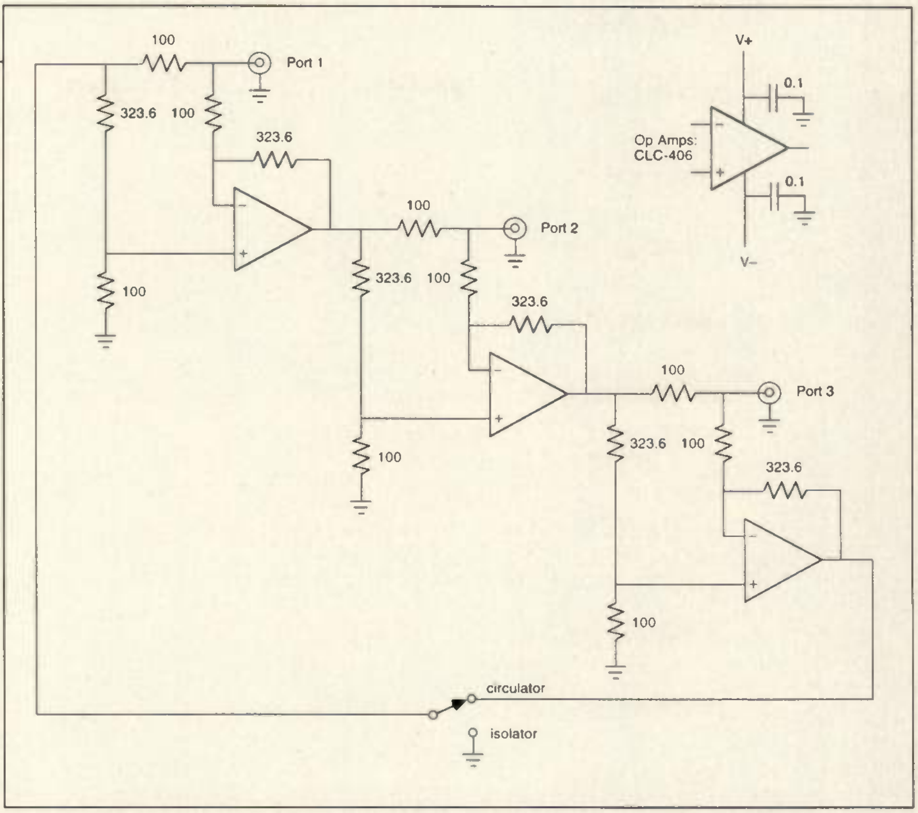


Figure 5. An active circulator/isolator for "low" frequencies (<100 MHz).

References

1. Scott Evans, David Potson, "High Speed Monolithic Op Amps: New RF Building Blocks," *RF Design*, January 1988, p. 27.
2. Bill Kulas, "Tunable Active Filter Reaches 25 MHz," *RF Design*, June 1991, p. 41.
3. Brian Mathews, Dave Reimer, "High Frequency Op Amp Makes Precise Detector and AGC," *RF Design*, November 1989, p. 76.
4. Charles Wenzel, "Low Frequency Circulator/Isolator Uses No Ferrite or Magnet," *RF Design*, July 1991, P. 39.

New Products — page 91

EMC TEST & DESIGN

April 1996

FEATURE

DEPARTMENTS

*Info/Cards, Company Index, and Advertiser Index can be found on the designated pages in the issue of *RF Design* which contains this *EMC Test & Design* supplement.

EMC Test & Design is published three times a year as a supplement to RF Design magazine. August 1995, Vol. 7, No. 2. *EMC Test & Design* is a registered trademark of Argus Inc. Copyright 1996 by Argus Inc., a division of Intertec Publishing, 9800 Metcalf, Overland Park, KS 66282-2960. 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 122 .

Calendar

June 17-20

Conference on Precision Electromagnetic Measurements

Braunschweig, Germany

Information: Sabine Rost, Conference Secretary, Physikaliche-Technische Bundesanstalt, Bundesalee 100, D-38116 Braunschweig, Germany. Tel: +49 531 592 2129; fax: +49 531 592 2105; E-mail: erich.braun@ptb.de

July 21-26

1996 IEEE AP-S International Symposium and URSI Radio Science Meeting

Baltimore, MD

Information: Ms. Libby Croston (1 W 316), The Johns Hopkins University, The Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20723-6099. Tel: (301) 953-5225.

ESD Tutorials

April 30-1	Schaumburg, IL
May 6-7	Andover, MA
May 23-24	Bloomnington, MN

Information: ESD Association, 7902 Turin Rd., Suite 4, Rome, NY 13440-2069. Tel: (315) 339-6937; Fax: (315) 339-6793.

Multi-feature 500-watt solid-state amplifier covers 10 kHz to 100 MHz band.

A new broadband amplifier, Model 500A100, from Amplifier Research, offers 500-watt output over four decades of bandwidth (10 kHz to 100 MHz), and many features not found in comparable units.

Complete control and preamplification functions are built into the all-solid-state 500A100: automatic leveling threshold; detected rf input and output; pulse input capability; remote-control interface. A front-panel power meter monitors both forward and reflected power.

The full bandwidth is available instantly for sweep testing without need for bandswitching or tuning. The amplifier is totally immune to damage from load mismatch, and is able to operate under worst-case VSWR conditions without oscillation or foldback. Its 500-watt output rating is stated as a minimum cw figure across the bandwidth. Minimum gain is 57 dB. Flatness with internal leveling is ±0.5 dB. Delivery 30 days ARO.

INFO/CARD 135

New ultra-broadband 30-watt rf amplifier

An all-new solid-state rf power amplifier from Amplifier Research delivers 30 watts of cw power from 25 MHz to 1 GHz.

The Model 30W1000M7 is specially designed for susceptibility and other rf testing applications requiring level, consistent output power over the test bandwidth. A front-panel gain control with a range of 10 dB minimum allows the operator to conveniently adjust power level and radiated field strength during shielded-room testing. At the maximum gain setting, the amplifier provides 30 watts minimum over the entire bandwidth, even in cases of infinite VSWR or open or shorted terminals. It is 100% immune to load mismatch and will not fold back or shut down under such circumstances.

Remote control is accessible through a connector on the rear panel. Full bandwidth is available without bandswitching or tuning. Delivery 3 weeks ARO.

INFO/CARD 136

Class A rf amplifiers deserve Class A directional couplers.

10 kHz to 1,000 MHz, 50 to 15,000 watts cw, to 50 kW pulse

Twenty-five years of building outstanding rf power amplifiers has taught us a thing or two about couplers, too. Things that give weight to the following recommendation: To monitor the output of any power amplifier (even some other brand) in the ranges shown above, couple it to your power meter, scope, spectrum analyzer, DVM, or other measuring instrument through one of the AR dual-directional couplers listed below.

With all our couplers, you can monitor both forward and reflected power—very important in the harsh VSWR environment of EMC susceptibility testing. And, even if you may accidentally have bought someone else's power amplifier, you can still enjoy the excellent coupling factor, directivity, and low loss of your AR dual-directional coupler. Plus delivery from stock and the two-year AR warranty.

Call toll-free (800-933-8181)
and talk it over with the applications
engineer who'll answer the phone.

	DC2500	DC3001	DC3010	DC4000	DC5000	DC6000	DC6180	DC6280
Frequency range	10kHz-220MHz	100kHz-1000MHz	10kHz-1000MHz	10kHz-100MHz	220-400MHz	400-1000MHz	80-1000MHz	80-1000MHz
Power (max. watts)	2500 cw 5000 peak	50 cw 1000 peak	50 cw 1000 peak	15,000 cw 50,000 peak	2500 cw 5000 peak	1500 cw 3000 peak	600 cw 1000 peak	1500 cw 3000 peak
Coupling factor	50 ± 1 dB	40 ± 0.6 dB	40 ± 0.6 dB	60 ± 1 dB	50 ± 1 dB	50 ± 1 dB	60 ± 1 dB	63 ± 1 dB
Directivity typical minimum	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB	25 dB 20 dB
Insertion loss, max.	0.15 dB	0.5 dB	0.6 dB	0.1 dB	0.2 dB	0.2 dB	0.15 dB	0.15 dB

13147

AMPLIFIER RESEARCH

160 School House Road, Souderton, PA 18964-9990 USA; phone 215-723-8181; fax 215-723-5688. In Europe, call EMV: Munich, 089-612-8054; London, 01908-566556; Paris, 1-64-61-63-29.

INFO/CARD 72

News

NIST Helps Power Grids Make 'Lightning Saves'

A NIST Technique has been incorporated into the latest version of an electrical standard used to test the ability of electric power grid high-voltage equipment to survive lightning strikes. Now a part of IEEE Standard 4-1995, "Standard Techniques for High-Voltage Testing," the technique improves the measurement of specific high-voltage impulse waveforms that simulate lightning. Such test waveforms subject the equipment to up to 10 times its normal operating voltage. To certify that power grid equipment is lightning-proof, engineers must evaluate the strength of the waveform. They use a "high-voltage divider" device to scale the voltage down to levels that can be measured. However, the process can produce a distorted reading. The NIST technique improves the measurement process by enabling testers to mathematically estimate the distortion. For more information, contact Gerald J. FitzPatrick, B344 Metrology Bldg., NIST, Gaithersburg, MD 20899-0001. Tel: (301) 975-2737; E-mail: fitzpa@eeel.nist.gov.

New European Automotive EMC Directive

The Automotive Directive 72/245/EEC as changed by 95/54/EC of October 31,1995, is about EMC Type Approval of vehicles and automotive electronic components including after-market accessories. The Automotive Directive is a Single Directive per 89/336/EEC and applies beginning January 1,1996. The transition period is through October 1,2002. Requests EEC Type Approvals for vehicles, units or components are now subject to the new Directive of January 1. The labeling requirement is "e plus Country Code etc." for "CE." Electric powered vehicles, fork-lifts etc. are exempt and remain under the EMC Directive 89/336/EEC. Dual-Voltage equipment is subject to both directives resulting in "CE" plus "e" marking. EMCC Dr. Rasek, located at Moggast, D-91320 Ebermannstadt, Germany, was nominated as the first "Competent Body" for the full scope of EMC and was accredited as the first EMC test laboratory covering the new Directive requirements. Tel: 49 9194 9016; Fax: 49 9194 8125.

Power Quality Fellowship at Texas A & M University

Current Technology, Inc., the leading manufacturer of electrical transient suppression filter systems and other power conditioning products, has announced that the company will provide Texas A&M University with a $7,500 Power Quality Fellowship for the 1996-1997 academic year. The funding will support graduate student research in the university's Electrical Engineering Power Quality Laboratory, which is presently under construction on the Texas A&M main campus in College Station.

New North American Headquarters

Technology International Incorporated announces the formal opening of their new North American Headquarters. Their new address is: 609 Twin Ridge Lane, Richmond, VA 23235. Tel: (804) 560-5334.

New Magnetics Technology Center

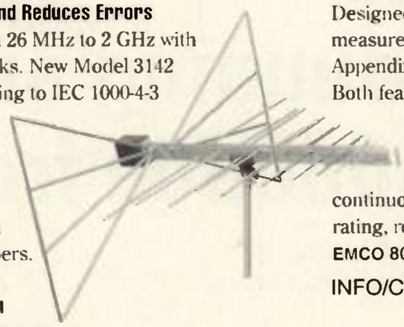
Walt Benecki, President of The Arnold Engineering Company in Marengo, Illinois, has announced the completion of their new Magnetics Technology Center (MTC). This state-of-the-art, 16,800 sq. ft. magnetics development laboratory will be used for new product and improved process development by Arnold Engineering and their customers. The MTC was developed to assist Arnold's customers in minimizing their product-cycle time and costs. It will house a multitude of process and analytical equipment making it the most complete magnetics laboratory in the united States.

Berndt Associates Named New Representative

Lindgren RF Enclosures, Inc. has named Berndt Associates, Inc. of Arlington Heights, Illinois, as its representative managing the sales of Lindgren EMI/RFI shielding systems for the Midwest. These states include Illinois, Iowa, Indiana, Minnesota, North Dakota, South Dakota and Wisconsin. Berndt Associates will represent Lindgren's line of industrial shielding systems including double electrically isolated (DEI) Screen and solid rooms, cell type enclosures, welded enclosures, and anechoic chambers for EMC testing.

EMC Antenna Tower Improves Test Accuracy
New Model 2071 Tower complies with antenna pointing requirements of CISPR 16 for EN 55022, also ANSI C63.4. Patented "Bore Sight" design continuously aims antenna directly at designated test point during height scans. Other features include fiber optic control lines and centerline polarization.
EMCO
800.253.3761
INFO/CARD 138

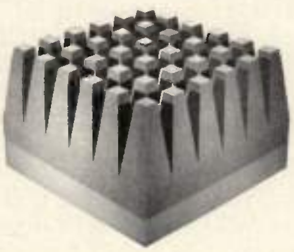
BiConiLog™ Antenna Saves Time and Reduces Errors
Sweeps from 26 MHz to 2 GHz with no bandbreaks. New Model 3142 ideal for testing to IEC 1000-4-3 immunity, EN 55022 emissions. Compact design fits in small chambers.
EMCO
800.253.3761
INFO/CARD 141



Two New LISNs Meet European Standards
Designed for conducted emissions measurements to CISPR 16, Appendix E, for EN 55022. Both feature earth line choke and artificial hand connection. CSA approved Model 3810 provides 10 A continuous current rating. Model 3816 has 16 A rating, remote switching and high pass filter.
EMCO 800.253.3761
INFO/CARD 142

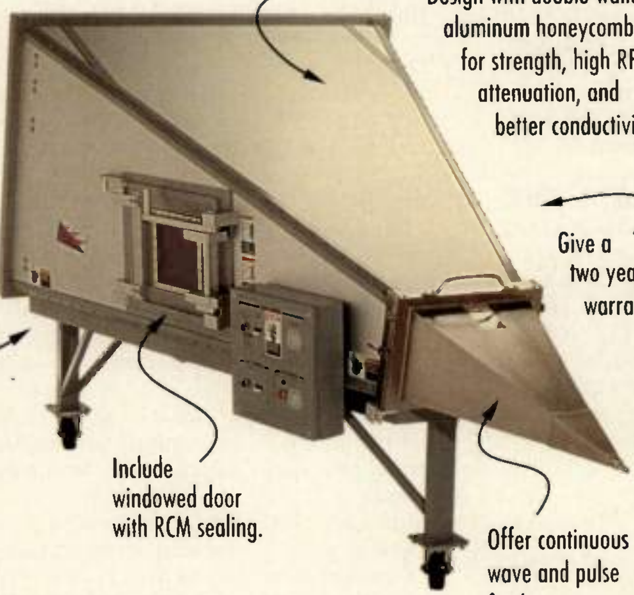
Reference Radiator Useful For Performance Evaluations
New Model 4630 "RefRad" is a field strength transfer standard that performs evaluations of RE test sites, chamber comparison testing, shielding effectiveness testing, normalized site attenuation, antenna calibration and more. Features 10 kHz to 1 GHz frequency range with user-selectable frequency spacing. Includes remote control, fiber optic link and GPIB.
EMCO
800.253.3761
INFO/CARD 139

FerroSorb™ Worthy Alternative To Traditional Absorber
Applications include IEC 1000-4-3, EN 55022, ANSI C63.4 (Class B), and MIL-STD 461/462D. FerroSorb combines ultra-broadband, 30 MHz to 40 GHz frequency performance, high return loss values, and 200 V/m power handling – all in compact 41 cm (16 in) size. 80% smaller than traditional absorber, test volume increases while performance improves. Consider for retrofits or new installations.
Rantec 800.253.3761 INFO/CARD 140



How to Build a Better GTEM!

for EMC Compliance Testing



World Class Design
Quality engineered and precision manufactured, EMCO's GTEM!™ enables you to perform ANSI C63.4, IEC 1000-4-3, EN 55022, and other tests quickly, accurately and repeatably. Five models available for various EUT sizes. Call to receive our new twenty page color brochure.

Some of the equipment shown is optional at extra cost and may not be available on all models. Manufactured under license from Asea Brown Boveri, Baden, Switzerland. US Patent 4,837,581

800.253.3761

USA 512.835.4684 Tel 512.835.4729 Fax
EUROPE 49 89 856 20 71 Tel 49 89 859 77 85 Fax

EMCO

EMC TEST SYSTEMS – an ESCO Electronics Subsidiary

INFO/CARD 74

Grounding and Radiation Reduction from PCBs

By David A. Weston
EMC Consulting Inc.

David A. Weston operates EMC Consulting Inc. Canada. For the last fifteen years he has specialized in all aspects of EMC including analysis, EMI problem solving and PCB layout. He has designed commercially available output power line filters for switching power supplies which can make almost any switcher as quiet as a linear supply. Mr. Weston can be reached at EMC Consulting Inc, P.O. Box 496, Merrickville, Ontario, Canada, K0G 1N0. Tel: (613) 269-4247; Fax: (613) 269-2045.

The importance of grounding in reducing radiated emissions from PCBs has been demonstrated in practical terms in a number of EMI investigations. This article describes an experiment which was conducted to prove the point and also to quantify the effect in one specific example of poor grounding. The article also describes two PCB grounding EMI case studies.

The PCB grounding experiment was tried during measurements made to characterize the radiation from thirteen different PCB layout configurations using six logic types. The results of these measurements were published in Reference 1.

The thirteen different layouts included:

- Transmission line (signal and signal return traces located either side by side on one surface of the PCB or one trace on the upper surface and one trace on the lower surface of the PCB)
- Microstrip (signal trace located above a ground plane which is used to carry the signal return current)
- Image plane (a transmission line, i.e. signal and return traces, on one surface of the PCB with a conductive plane on the other side connected to the signal return at one location only)
- Interleaved image plane (a microstrip configuration with image plane interleaved between the signal trace and a lower ground plane)
- Partial stripline (a microstrip with a narrow upper ground plane connected to the lower full ground plane using vias either side, and down the length, of the signal trace. The radiation was measured with the distance between the vias at 3.3 mm, 6.6 mm and 13.2 mm.
- Large stripline (the same basic configuration as the partial stripline but with the upper ground plane extending almost to the edge of the lower ground plane)
- Full stripline (the same basic configuration as the partial stripline but with the upper ground plane extending over the same area as the lower ground plane)
- Full stripline with additional vias (The same as the full stripline but, in addition to the rows of vias either side of the stripline, with vias, connecting lower and upper ground planes together, at 13.2 mm intervals around the edge of the PCB)

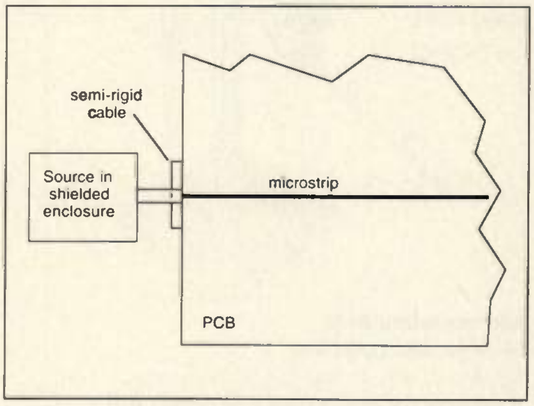


Figure 1. Connection of the semi-rigid line, used with the ECLinPS device, to the microstrip ground plane.

- Microstrip with a right angle bend constructed from either one 90° bend or two 45° bends

As expected the experiments showed that the major source of radiation from the PCBs was common mode current flow with a large, 56 dB, difference between a high emission level type PCB and a low emission level type PCB. In addition to the different layouts the investigation included a look at circuit level reduction techniques such as RC and RLC networks at the signal source end of the trace to slow down clock edges and reduce the high frequency radiation from the PCB.

The signal source used to drive the PCB trace, terminated in a passive RC load, comprised a battery, regulator, clock oscillator and driver IC contained in a shielded enclosure. The shielded enclosure ensured that only the radiation from the PCB was measured and not that from the clock and driver IC. Two versions of the enclosure were built. One contained the 74XX04 type devices and the second was used to house the ECLinPS device. The difference between the two enclosures was in the method used to make the signal and signal return connections to the PCB. The ECLinPS device is designed for a 50 ohm load and should be connected to the load by the use of a structure with a 50 ohm characteristic impedance.

The ECLinPS device was tested only with the microstrip PCB layout and a piece of 50 ohm semi rigid cable was used to connect the output of the driver to the PCB under test.

Low Pass EMI Filters

Spectrum control offers the most complete line of low pass EMI filters for commercial and military use. Spectrum's low pass filter line has the industry's widest breadth of qualifications for MIL-F-28861, MIL-F-15733 and MIL-C-11015 specifications. Products include miniature solder-in, solder-in, resin sealed bolt-in, high current/high voltage resin sealed, and hermetically sealed filters.

SPECTRUM CONTROL, INC.

INFO/CARD 131

High Current Surface Mount Filters

New surface mount filter effectively eliminates EMI/RFI on printed circuit boards operating at currents up to 20 Amps. PSM series filters replace conventional thru-hole filters at these higher currents, allowing designers to create an "RF fence" without expensive RFI bulkheads. PSM filters are available with capacitance values up to 10,000 pF and provide excellent high frequency noise suppression.

SPECTRUM CONTROL, INC.

INFO/CARD 130

Ferrite Filtered Connectors

A new line of EMI/RFI ferrite filtered connectors provide superior filtering of high frequency interference at a low cost. Series 400 connectors allow you to replace individual ferrite bead filters with a .318" footprint connector. These connectors offer both pin-to-ground and pin-to-pin filtering and are interchangeable with standard D-subminiature connectors.

SPECTRUM CONTROL, INC.

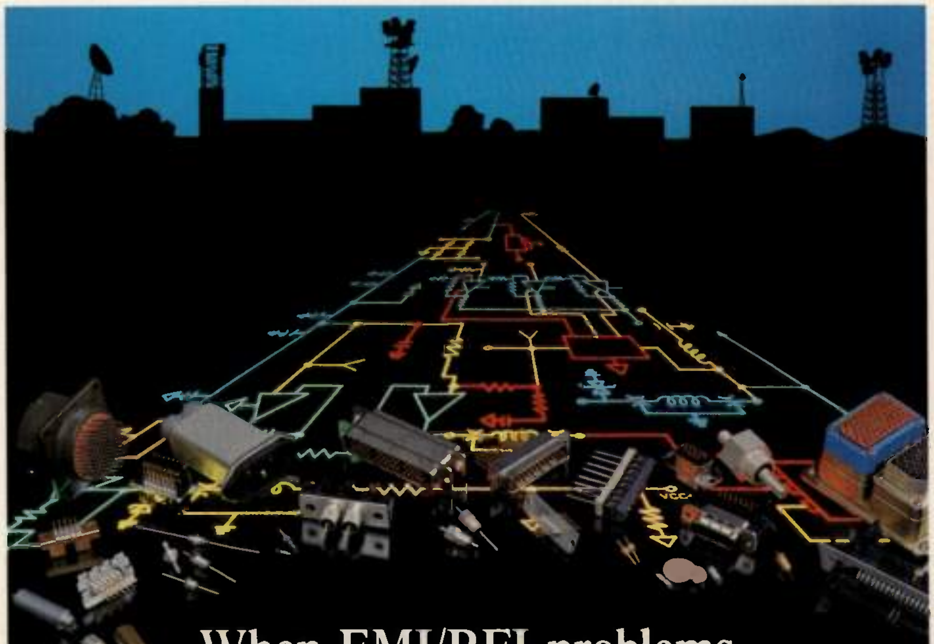
INFO/CARD 132

.318 Footprint Filtered Connectors

A new line of EMI filtered D-subminiature connectors offer a .318 footprint for 90 degree PCB connectors and a low profile housing on straight PCB connectors. Series 500 filtered D-subs are "drop-in" replacements for standard unfiltered D-sub connectors. These connectors use tubular capacitors for high performance EMI filtering. Popular board lock and thread options are available. Series 500 connectors complement Spectrum Control's extensive line of filtered D-sub connectors.

SPECTRUM CONTROL, INC.

INFO/CARD 133



When EMI/RFI problems are on the horizon, let Spectrum Control provide your filter solution.

Designing your electronic system to meet the EMC requirements of agencies such as the FCC, VDE, EC and Japan's VCCI has never been more difficult. Spectrum Control can help. We've developed an integrated approach to EMC problem solving ...from diagnostic testing to engineering to a complete line of EMI/RFI filtering products.

Don't let EMI/RFI cloud your horizons. Turn to the leader in filter solutions.

ISO 9001

Electromagnetic Division

SPECTRUM CONTROL INC.

Corporate Headquarters
6000 West Ridge Rd., Erie, PA 16506
Phone: 814-835-4000 Fax: 814-835-9000

European Headquarters
Spectrum Control GmbH
Hansastrasse 6, 91126 Schwabach, Germany
Phone: 49-9122-795-0 Fax: 49-9122-795-58

INFO/CARD 75

The shield of the semi rigid was soldered to the enclosure at the location where the line penetrated the enclosure. At the PCB end the semi rigid was soldered to a copper plate and this plate was soldered to the ground plane of the microstrip PCB as shown in Figure 2. Although the ECLinPS device was only tested with the microstrip layout so were the remaining seven different logic types and a comparison between the logic types is possible. A color plot was made of the relative emission levels using the eight logic types with the microstrip PCB. Plots were also made of the thirteen different PCB layouts with one baseline type of 74XX04 device. Thus a comparison can be made between the emission profile of the baseline type of device with the microstrip and any other logic type. This comparison can then be used to correct the emission profile of any PCB layout for a different logic type, including the ECLinPS type.

In the construction of the shielded enclosure used to contain the 74XX04 devices the enclosure must be connected to the ground planes or the image plane in the microstrip, stripline or image plane PCB layouts. Whereas in the transmission line PCB layout the signal return is isolated from the enclosure. Figure 2 illustrates the connection of the enclosure to the signal wire from the source and the ground/image plane. The signal return connection is made from the PCB plane to the feedthrough in the enclosure via a short length of wire, as is the signal connection to the signal trace. To minimize radiation from these short lengths of wire a small copper dog house enclosure covers both the feedthrough connections and the lengths of wire. This dog house extension can be seen in Figure 2 and is used to connect the enclosure to the ground/image plane of the PCB. In the connection of Figure 2 none of the signal return current flows in the connection between the enclosure and the PCB ground plane.

The grounding experiment involved connecting the enclosure to the PCB via a short length of wire which was connected to the feedthrough and then via the signal return wire to the PCB. This grounding technique is illustrated in Figure 3 and it can be seen that the signal return current does flow on the connection between the enclosure and the PCB ground plane.

The radiated emissions from the different types of PCB layout were measured with this alteration in grounding. The level of radiation from the low emission type PCBs increased from 56 dB below high emitter types to 6 dB below these types.

The reason for this dramatic increase is that an RF potential difference is developed between the enclosure and the ground plane/s or image plane. This potential difference is caused by the signal return current flow on the short (5 mm) length of wire used to connect the PCB to the enclosure. Although the wire is short it exhibits significant inductance and it is across this inductance that the voltage is developed.

Whereas in the grounding connection shown in Figure 2 the enclosure to ground plane connection is low impedance, it does not carry the signal

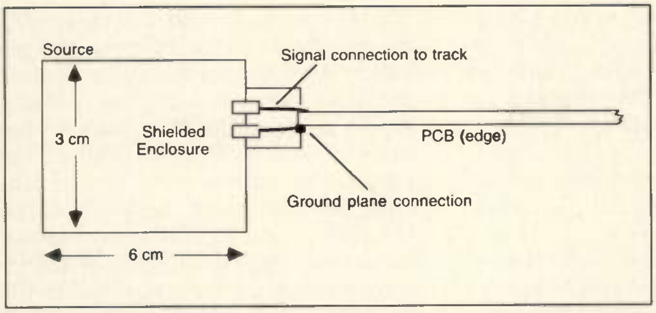


Figure 2. Connection of the source to a microstrip, stripline or image plane PCB layout.

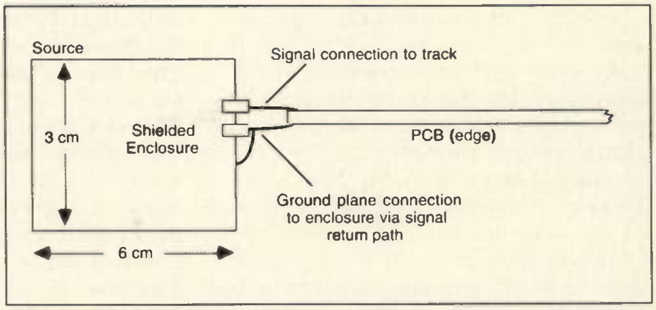


Figure 3. The signal return is used as the connection between the PCB ground plane and the enclosure.

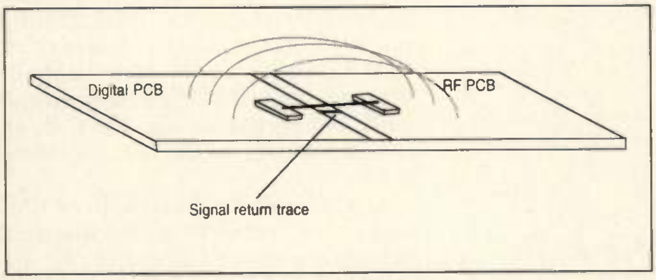


Figure 4. PCB with digital and RF ground planes connected together with a thin trace.

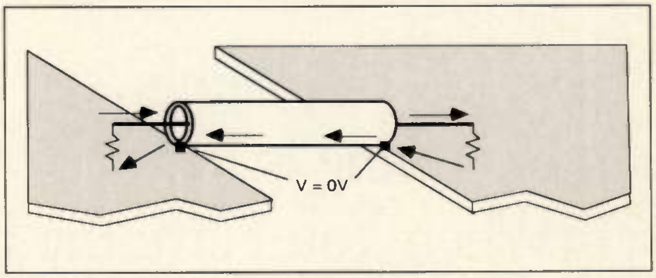


Figure 5. The use of semi-rigid cable to connect the ground planes together.

return current and so no RF potential is developed.

Why is the same problem not seen with the semi rigid cable connection shown in Figure 1? The reason no potential difference is developed on the outside surface of the semi rigid shield is due to both the mutual inductance between the center conductor and shield and due to the skin depth effect. The skin depth ensures that above some relatively low frequency the majority of the return current flows on one surface of the shield and the mutual inductance ensures that this is the inside surface of the shield. This effect is illustrated in Figure 5.

The problem of RF voltages developed between PCB grounds and equipment grounds or the enclosure has been seen in a number of practical EMI cases and two of these are presented as follows:

The first case study involved radiation from a PCB, which contained digital and RF circuits, to a nearby PCB which contained sensitive RF circuits. The source PCB generated emissions which were, at certain frequencies, 40 dB above the FCC class "A" limits!

The board layout was however exemplary, it contained all the "good" features such as effective ground planes and stripline configurations for signals which were potential sources of emissions. The problem was due to a thin trace used to connect the RF and digital grounds together at a single point. The thin trace carried the return current of a digital signal driving a device on the RF board. The two PCB ground planes and single point connection are shown in Figure 4.

The return current generated a voltage drop in the inductance of the return trace and so an RF potential was developed between the ground planes. This is the same problem as seen in the grounding experiment, in which the potential was developed between the ground plane and the enclosure. Many modern PCB antenna designs use a similar layout, driving the antenna at a similar point, and achieve a high gain, that is efficient radiation.

A significant reduction in radiation was seen simply by widening the thin signal return trace. Widening the trace reduces the inductance and the voltage drop in the return path. The majority of the signal return current flows in the return path directly beneath the signal trace. This means that when the width of the return trace is five times or more the height of the signal trace above the return trace that an effective ground plane has been achieved, for that single signal connection. This concentration of current under the signal trace is again due to mutual inductance. The reason the digital ground plane is connected to the RF ground plane at a single point is to reduce digital noise current flow in grounds used by sensitive RF circuits. However the width of this single connection can be increased when sensitive circuits are located far away from the connection or when digital signal return current is routed away from the location of the single point ground. For example ensure that digital return current does not flow between devices located across the increased width of the ground plane connection.

An even more effective solution is the use of a semi rigid cable connection shown in Figure 5 or a stripline PCB structure installed across the gap. The stripline is not as effective as the semi rigid due to some leakage through the gaps between the vias used to connect the upper and lower ground planes together. Another potential solution is to disconnect the two ground planes and to use an opto-isolator to transfer the digital signal to the RF section. Separating the two ground planes is very effective in reducing current flow between them. However if an RF potential exists between the planes, as it almost certainly does, then the level of radiation may remain hiqh or even increase with separated grounds. The digital return current is forced onto a trace, which is disconnected from the RF ground, and the digital and RF grounds are tied together at a single point. Negligible current flows in this common connection and the two ground planes are close together in potential.

Another common example of RF potential developed between PCB ground planes is when signal and signal return connections exist between two or more PCBs. These connections are typically made via pins in edge connectors and a mother board or back plane. It is important that as many parallel signal return connections as possible are made. Also that these connections be as short and as wide as possible to reduce the inductance of the signal return, and therefore the potential difference between grounds.

If external cables are connected to the two PCBs then the RF potential between the two ground planes appears on the signal connections as a common mode voltage, regardless of whether the signal is balanced or unbalanced with reference to ground. The two cables result in a very efficient antenna as the RF potential between them drives one cable against the other, similar to the two rods of a dipole antenna. In this example the use of finger stock or a similar contact to connect the two ground planes together will reduce the RF potential between them. Ideally this common connection should be made at the location where the two cables leave the enclosure, or at least where they leave the PCB. To reduce radiation from the cables due to a potential difference between the PCB ground plane and the enclosure, finger stock or a direct connection may be made between the ground and enclosure. If a DC connection is not allowed, an RF (capacitive) connection should be made.

Another practical example of EMI was partially due to an RF potential between a ground plane on an approximately 8 cm × 4 cm digital PCB and an RF ground. The digital PCB was located approximately 0.5 cm away from a receiver contained in a small well shielded case. The small microstrip antenna connected to the receiver was approximately 2 cm from the digital board and was referenced to the receiver case. Due to radiated coupling between the digital board and the antenna the receiver exhibited desensitization and narrowband and broadband spurious response. Part of the problem was due to the RF potential between the digital ground plane and the RF ground (shielded case). By shorting the case to the digital ground plane at a number of points with finger stock material the radiated coupling reduced significantly, although not sufficiently to totally cure the problem.

Conclusion

In conclusion, the use of low emission type PCB layouts in conjunction with ICs which generate only low level emissions can reduce radiation to levels where shielding of the PCBs is not necessary to meet commercial radiated emission limits. However when PCB-to-PCB or PCB-to-enclosure/ground connections are high impedance and carry RF current then none of these reduction techniques may be sufficient without the use of an effective grounding scheme.

Reference

1. D.A. Weston, "PCB radiation due to high speed logic and emission reduction techniques," EMC Consulting, 1992.

Metallized Fabric Shielding Tape

3M now has a flexible metallized fabric shielding tape, expanding their line of shileding products. 3M 1190 tape combines copper-plated

"rip-stop" fabric from Monsanto with 3M's conductive acrylic adhesive, making a tape that is 75 percent lighter than one-ounce copper foil.
3M Electrical Specialties Div.
INFO/CARD #227

Low-Cost EMI Test System

Dynamic Sciences anounces the DSI-2020 EMI Test System, optimized for FCC-EN precompliance and certification testing over a 1 kHz to 1.9 GHz frequency range. The DSI-2020 consists of a single receiver and a power EMI software package that runs on the user's GPIB-equipped computer. Built-in spectral and oscilloscope displays eliminate the need for external equipment. Price of the system is $29,950.
Dynamic Sciences International
INFO/CARD #232

Portable Shielded Enclosure Test System

ASM Products offers the TS-450A, successor to the TS-450, with increased dynamic range (110 dB), longer battery life, and a more compact safety case for greater portability. The test system is designed for fast, repeatable measurements.
ASM Products, Inc.
INFO/CARD #235

Finger Stock Shielding Sets

Tech-Etch has new "Snap-to-Trac" RFI/EMI shielding sets that come ready-to-install with beryllium-copper finger stock and a mounting track complete with installed plastic rivets. This configuration allows installation of shielding without distortion during the assembly process. The design provides secure mechanical assembly and long life.
Tech-Etch, Inc.
INFO/CARD #229

Inexpensive EMC Software

Rohde & Schwarz is now offering EMI software ESxS-K1, designed for reilaible, fast and reproducible EMC measurements to be performed at small- and medium-sized companies. The software supports the Rohde & Schwarz test receivers of the ESHS/ESVS/ESS family, as well as the ESVD/ESVB/ESN/ESVN instruments for European standards.
Rohde & Schwarz GmbH & Co.
INFO/CARD #230

EMC Shielding Fingers

James Walker now offers ten designs of beryllium-copper alloy 25

finger strips, for EMI shielding. The Be-Cu material combines conductivity with spring action and durability. The strips are rated at better than 120 dB E-field from 1 MHz to 100 MHz. Tin and nickel plating is avail-

EMC/ESD Literature

Suppressor Product Data on Disk

Semtech Corp. announces the TVS Access Disk, an alternative to thumbing through catalogs and data sheets. The disk allows customers to locate the right transient voltage suppressor for their applications. The disk includes a tutorial on suppression of transient voltages, standards, a selection guide, and ordering information.
Semtech Corporation
INFO/CARD #223

Silicone Rubber Packaging Catalog

A new catalog from Fujipoly describes four silicone rubber product lines: RFI/EMI shielding and ESD grounding; ZEBRA elastomeric components; SARCON thermal management components; and custom moldings and extrusions. Technical background and mechanical details of each product are included.
Fujipoly America Corp.
INFO/CARD #224

Data Sheets on Shielded Doors

Lindgren RF Enclosures is offering a series of technical data sheets on its high performance EMI/RFI shielded doors. Among the offerings are the Doubler Knife Edge (DKE) Door, a manually operated door with performance superior to single knife edge doors, the Pneumatic Sliding Door (PSD) and Pneumatic Hinged Door (PHD).
Lindgren RF Enclosures, Inc.
INFO/CARD #225

Modular Shielding Guide

Ray Proof now has an updated Modular Shielding Specification Guide, featuring 25 standard enclosures for EMC and TEMPEST.
Ray Proof, EMC Test Systems
INFO/CARD #226

able for galvanic compatibility.
James Walker & Co. Ltd.
INFO/CARD #231

1206-Size Ferrite Beads

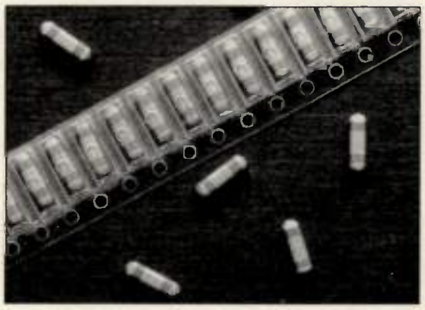
Dale Electronics has introduced a new series of 1206-size multilayer ferrite beads for noise suppression in high-spped, low-voltage electronic circuits. 10 models are available offering impedances from 19 ohms to 600 ohms ±25%. The ILB-1206 series has been proven effective over a frequency range of 10-500 MHz, with DC resistance of 0.1 ohm to 0.75 ohm maximum, and current ratings of 100-500 mA. Pricing is $0.17 each in quantities of 2500.
Dale Electronics, Inc.
INFO/CARD #228

Solid State Amplifier

The SMX 100 from IFI is a broadband laboratory amplifier covering 0.01 MHz to 1000 MHz for both radiated (IEC-801-3) and conducted (IEC-801-6) immunity testing. The unit provides 75 watts of linear power (100 watts saturated), and can generate fields in excess of 10 V/m. The SMX 100 includes a full set of protection and control features, including 40 dB of power control, LCD display, and IEEE-488 bus interface.
IFI, Inc.
INFO/CARD #233

Transient Voltage Suppressor in SMT Package

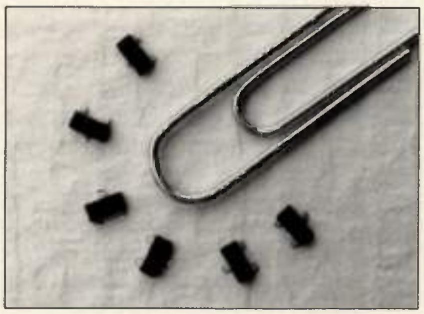
The PSOT series from ProTek Devices is a SOT023 surface-mount transient voltage suppressor de-



signed to provide ESD and EFT protection for low power switching power supply components aand PCMCIA cards. Specific voltage types are available from 3.3 to 24 volts, in single- or dual-junction for unidirectional or bidirectional applications. Prices start at $0.27 each in quantities of 10,000.
ProTek Devices
INFO/CARD #234

SMT EMI Filters

Tusonix Introduces the 4700 SMT EMI π-Filter in a space-saving .315 × .083 inch package. The 4700 series;

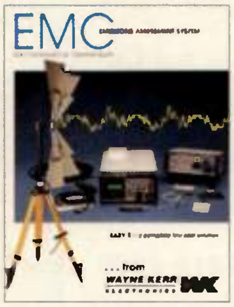


square, sectional body allows easy installation with common production soldering processes. The filters are available in capacitance from 100 pF to 5000 pF, operating up to 100 VDC at up to 125°C.
Tusonix
INFO/CARD #236

EMC TEST & DESIGN

LITERATURE & PRODUCT SHOWCASE

For quick response, circle number on Reader Service Card beginning on page 123



Easy 1 Emissions Assessment System

Wayne Kerr has released a 26-page literature collection detailing the components of their EASY 1 Emissions Assessment System for pre-compliance EMC testing. Included is data on the SSA1000A Spectrum Analyzer, Broadband antenna, Line Impedance Stabilization Networks, and EASY 1 Software. A demo disk for this turnkey system is also available.

***Contact:* Ken Harrison (800) 933-3919**

Wayne Kerr, Inc., 11 Sixth Rd., Woburn, MA 01801-1744

Tel: (617) 938-8390

Fax: (617) 933-9523

WAYNE KERR ELECTRONICS

INFO/CARD 100

AMP FILTER CONNECTORS

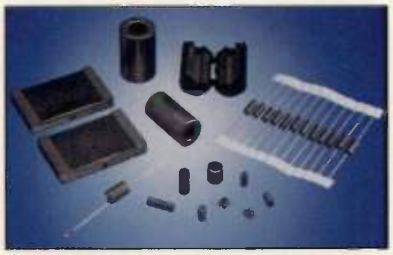
AMP offers a range of filter connectors using either ferrite; chip, planar, tubular, or film capacitors; or distributed element filters. Most versions are drop-in replacements to standard connectors such as D-sub, modular jack/multiport, CHAMP, mini-DIN, headers and adapters. Custom designs include plates, bolts and cable assemblies.

AMP

(800) 522-6752 • FAX (717) 986-7575

http://www.amp.com

INFO/CARD 101



CHO-SORB® Cable and Surface Ferrites Reduce Radiated Emissions

Chomerics offers 29 forms of CHO-SORB EMI suppression ferrites for reducing emissions on signal lines, power cables and PCBs without affecting data transmissions. CHO-SORB attenuators possess high magnetic permeability, which concentrates magnetic fields. Their high electrical resistivity limits current flow in the field.

Chomerics, Div. of Parker Hannifin

77 Dragon Court, Woburn, MA 01888

Tel:617-935-4850 Fax:617-933-4318

INFO/CARD 102

FREE Electronic Components Catalog

324 page catalog featuring complete product & pricing data for over 61,000 products from 120+ leading manufacturers including AMP, SGS Thomson, 3M, NEC, Littlefuse, Belden, Keystone, Switchcraft and dozens more. Complete line of semiconductors, passive components,electro-mechanical devices, resistors, capacitors, switches, wire/cable, connectors and more.

Same day shipping on all stocked products.

Mouser Electronics

958 N. Main St., Mansfield, TX, 76063

Sales (800) 346-6873 Catalog (800) 992-9943

Fax (817) 483-0931;

http://www.mouser.com.

INFO/CARD 103

Flectron® Metallized Materials

Flectron® Metallized Fabrics are ideal for EMI/RFI shielding applications and components requiring flexibility and durability. EMI profile gaskets, I/O gaskets, shield laminates and custom fabricated parts provide high performance, cost-effective EMI solutions throughout the electronics industry.

(800) 843-4556

or Fax (314) 344-9333

INFO/CARD 104

NEW!

800-214-7900

ANTISTATIC INDUSTRIES

ESD Anti-Static Drinking Cups For Use In Computer and Cleanroom Assembly Areas

ANTISTATIC INDUSTRIES announces a new ESD anti-static insulated foam cup for coffee, tea or soft drinks—FDA approved. Completely recyclable.

- *Available in 8, 12 or 16-ounce sizes*
- *ESD anti-static lids available to fit each size cup*
- *ESD-safe for hot or cold beverages*
- *FDA approval No 21 CFR 178 3400*
- *1000 cups per carton. Min. order 1 carton*

ANOTHER NEW PRODUCT FROM ANTISTATIC INDUSTRIES

ANTISTATIC INDUSTRIES, INC.

130 Gamewell St • P.O. Box 480

Hackensack, NJ 07602-0460

800-214-7900 / Local: 201-489-4400 / Fax: 201-489-7654

INFO/CARD 105

Conductive Thermoplastics Brochure

RTP Company has carved out a special niche as an independent compounder of thermoplastics. RTP Company compounds thermoplastics with a variety of conductive fillers to provide protection from electrostatic discharge (ESD) or shielding from electromagnetic and radio interference (EMI/RFI). In our conductive thermoplastics brochure, you'll learn about the materials we make and their role in your applications.

Send for Free Brochure:
RTP Company
580 E. Front Street
Winona, MN 55987
1-800-433-4787
or Email us at: "rtp@luminet.net"

INFO/CARD 106

EMI/RFI Suppression Connectors

New Full Line catalog features ferrite D-subs for EMI/RFI suppression (right angle, vertical, high density and stacked), shielded modular jacks, and fully shielded snap and lock mini-DINs. Full specification and technical drawings are included and samples are available upon request.

Kycon Cable & Connector, Inc.

800-544-6941

http://www.kycon.com/kycon

INFO/CARD 107

Structured Design of Third-Order, Type-2 and Type-3 PLLs

By Fu-Nian Ku

PLLs are ubiquitous, and many books and papers have dealt with the subject. In this paper, I present PLL characteristics in a graphical format so that people can readily see the characteristics in whole and get approximate results. The complicated mathematical formulae are in the Appendix, where they can be examined or used in the reader's choice of computer program.

Comprehensive study of PLLs is a very complicated task. There are different types of phase detectors, different requirements of lock-range and lock-time, different added-on filters. In addition, the real performance of devices must be considered, as must the noise rejection of PLL. Second-order PLLs have been thoroughly studied in past two decades [2], but there is still much to learn about the behavior of third-order and higher PLLs. Przedpelski's papers [3] have won wide acceptance in the last two decades, and they have made high-order PLL characteristics calculable.

This paper is an introduction. It does not touch non-linear phenomena, and does not try to predict capture-time, capture-range or other quantities. However, it does give a basic relation among all physical-interpretation-oriented parameters. I have simplified these complex formulae and extracted as few as possible parameters to show the physical meaning for easy design.

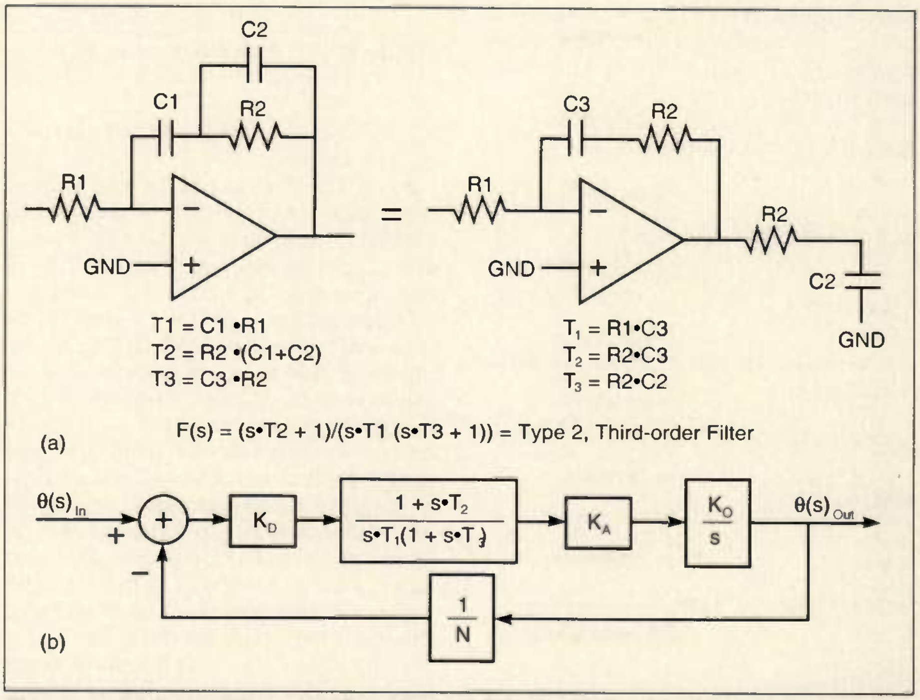


Figure 1. (a) Loop filter circuit and open-loop transfer function. (b) Block diagram of the loop.

Type 2 PLLs (Active Filter)

I use the conventional symbols and definitions. Let $\theta_e(t)$ be the phase difference of two input of phase detector, $\theta_e(t) = \theta_i(t) - \theta_o(t)/N$ Assume this is a linear system; the output of phase detector is $K_d\theta_e(t)$. If the initial $\theta_e(0) = 0$. The Laplace transform of this loop results in the following equation 1(a):

$$\frac{\theta_e(s)}{\theta_i(s)} = \frac{s^3 + \dfrac{s^2}{T_3}}{s^3 + \dfrac{s^2}{T_3} + sK\dfrac{T_2}{T_1T_3} + \dfrac{K}{T_1T_3}}$$

where,

$$K = \frac{K_d K_a K_o}{N} \tag{1b}$$

For the purpose of expressing parameters in a form that has physical meaning, we change the denominator in equation 1 to:

$$(s+\alpha)\left(s^2 + \frac{2s}{\tau} + \omega n^2\right) \tag{2}$$

There are three types of input reference signals:

- Case 1: The input reference is constant phase $\theta_i(s) = \phi/s$.
- Case 2: The input reference is constant frequency f_0, $\theta_i(s) = 2\pi f_0/s^2$.
- Case 3: The input reference is constant frequency ramp f_0, $\theta_i(s) = 2\pi f_0/s^3$

Case 1 is rarely used; sometimes people use case 3, but most people use case 2.

Appendix equations (a1) and (a2) give the solution for case 2 and case 3, where, $b = 1/T_3$.

In equations (a1) and (a2), there are trigonometric terms that have a common angle argument.

Let the argument:

$$\sqrt{\omega n^2\tau^2 - 1}\,\frac{t}{\tau} = 2\pi F_S\,\frac{t}{T_s} \tag{3}$$

where,

$$\tau = \frac{T_s}{2\pi} \qquad \omega n = \frac{\sqrt{1+F_S^2}}{\tau} \tag{4}$$

In this way, the argument has physical meaning. F_S is swing frequency. T_S is the time scaling factor. We still need another parameter. I suggest the maximum deflection angle of the open loop transfer function, ϕ, is another one [4]. The quantity ϕ is defined by:

$$T_2 = T_3\beta \tag{5}$$

and

$$\beta = \frac{\cos\phi}{1-\sin\phi} \tag{6}$$

When we define equation (2) as the denominator of equation (1), there is an relation between these three parameters, F_S, T_s and ϕ. Using this relation, we get:

$$B = \omega n^2 \cdot (1-\beta) + 4/\tau^2 \tag{7}$$

$$\alpha = \frac{\tau}{4}\left[-B + \sqrt{B^2 - \left(4\frac{\omega n}{\tau}\right)^2}\right] \tag{8}$$

$$b = \alpha + 2/\tau \tag{9}$$

α in equation (8) must be real, so ϕ has a limitation:

$$\phi_{min} < \phi < \pi/2 \tag{10}$$

where (11):

$$\phi\,\min(F_S) = \frac{\pi}{2} - 2\,\mathrm{atn}\left(\frac{1}{1+\frac{2}{\sqrt{1+F_S^2}}}\right)$$

When $F_S = 0$, ϕ_{min} has the largest value, 53.135°.

Given F_S, T_s and ϕ (ϕ satisfying equation 10), we can calculate α, τ, ω_n and b using the above equations. Then equations (a1) and (a2) are calculable. The time constants of the active filter are given by the following equations:

$$T3 = 1/(a + 1/\tau) \tag{12}$$

$$T2 = T3\,\beta \tag{13}$$

$$T1 = K/(T3\,\alpha\,\omega n^2) \tag{14}$$

where K is defined by equation (1b).

Analyzing the above three time constants, we discover that T1 is proportional to T_s^2. T_2 and T_3 are proportional to T_s. T_1/T_s^2, T_2/T_s and T_3/T_s are independent of T_s, leaving only the two parameters, F_S and ϕ. The following graphs show these relations.

First, F_S limits the range of ϕ by determining ϕ_{min} (equation 11). Figure 2 shows the relation between F_S and ϕ_{min}. The x-axis is F_S, and the y-axis is ϕ_{min} in degrees.

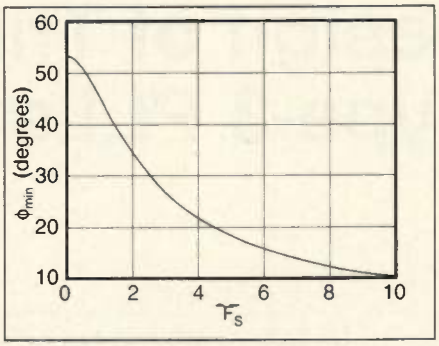


Figure 2. ϕ_{min} as a function of F_S.

F_S is the frequency in the scaled time base. A large F_S means rapid variation, and fast settling to steady state (i.e. fast locking). Fast settling is the advantage of a large F_S. Its disadvantage is that a loop with large F_S is less stable, and is more likely to be unlocked due to noise, interference, or other causes. Figure 2 shows that a larger F_S has a smaller ϕ_{min}. This means we can select ϕ from a bigger range. It does not give us more range of stability. Conventionally, engineers use phase margin to gauge stability. Large phase margin ensures good stability. Phase margin is defined as the difference between the phase angle of the open loop transfer function and π (or $-\pi$) when the amplitude of open loop transfer function is one. Using this defininition, phase margin is plotted in Figure 3.

The x-axis is F_S, and the y-axis is the phase margin in degrees. Different curves correspond to different values of ϕ. As mentioned before, the range of ϕ is limited by F_S. If ϕ = 20°, F_S can not be larger than 4.563. In Figure 3, the dotted curve corresponding to ϕ = 20° ends at F_S = 4.563. However, those curves corrseponding to $\phi \geq$ 253.135° do not break in the figure.

The y-axes of Figures 3(b,c,d) represent T_3/T_s, T_2/T_s and KT_s^2/T_1, respectively. The x-axis of all figures is F_S. Figures 3a through 3d each have five curves corresponding to different values of ϕ. Sometimes, two curves are very close in the display and graphics only shows the second curve legend. When ϕ approaches 90°, the third-order case degenerates to the second-order. In this case, T_3 = 0 (see Figure 3b). Using the ϕ = 89.99° curve, we can investigate the properties of second-order loops. Further analysis shows

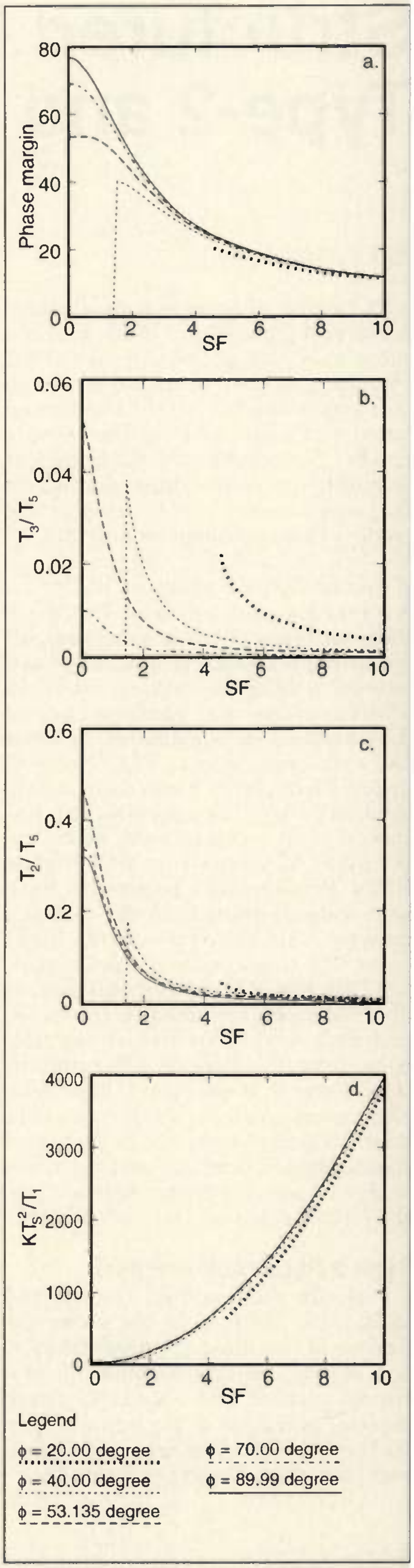


Figure 3. Various quantities as a function of F_S and ϕ.

that when the input reference is constant, $\theta_e(t)$ Case 2, equation (a1), is proportional to f_0*Ts, and $\theta_e(t)$ of Case (3), equation (a2), is proportional to $f_0T_s^2$. Now, we define $F_0 = f_0{*}T_s$. If we define F_S, ϕ and F_0, and use t/T_s as the time coordinate, equation (a1), denoted as $\theta_2(t)$, is independent of T_s. Meantime, the result of Case (3) (frequency ramp), denoted as $\theta'_2(t)$ is proportional to Ts. The curve $\theta'_2(t)/T_s$ is also independent on T_s, if we take t/T_s as the time axis.

In practicable design, selecting F_0 may be a problem. If F_0 is too big, the locking process will be slow, even it will not be locked (especially in analog phase detector). How to select F_0 is out of the scope of this paper. For safely quick locking, keep F_0 to a low value. The better way, but not necessary, is after selecting all F_S, ϕ and F_0, plot $\theta_2(t)$ and $\theta'_2(t)$/Ts of equations a1 and a2 versus the t/T_s axis. These two curves are independent of T_s. $\theta_2(t)$ displays the result of the input as a frequency jumping F_0 in an infinitesimal time. While $\theta'2(t)/T_s$ displays the result of input as a constant continuous frequency change, the rate of change is F_0 Hz in T_s second. When we design a real synthesizer, we use a crystal oscillator as the reference frequency generator. The reference frequency is not established instantly. So, the initial part of real description should resembles θ'2(t)/Ts curve. Later, after reaching a certain frequency it should stop increasing and settle to zero. The real transient is below $\theta_2(t)$ and settles to a steady state zero. In a Type 2 PLL, $\theta'_2(t)$ does not tend to zero. Nevertheless, $\theta_2(t)$ tends to zero. Using a digital phase detector, the PLL should be locked finally. If we hope it has a fast capture, the maximum value of transient should below 180° which is the linear range of digital phase detector. If it is too big, lower $\theta_2(t)$ by decreasing F_0 and/or changing F_S and ϕ properly.

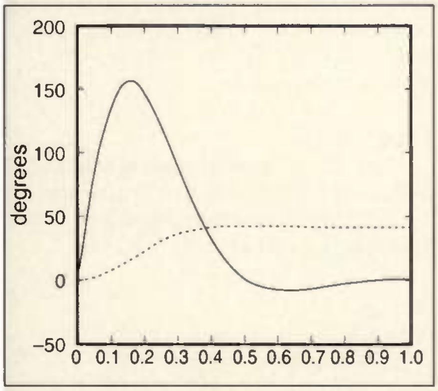


Figure 4. Phase error $\theta_e(t)$ of Case 2 and $\theta_e(t)/T_s$ of Case 3. The X-axis is $T_s(t/T_s)$; the Y-axis is in degrees.

Example

A 3rd order PLL using a Type 2 active filter produces an output of 16.95 MHz from a 5-KHz reference, F_0. The phase detector, active filter and VCO have the following factors:

K_d = 0.19 V/rad

K_a = 1

K_o = 10.6 1 o6 rad/slV

Divider ratio N = 16.95/0.005 = 3390

then, $K = K_d\, K_a\, K_o/\, N = 594.1$

INFO/CARD 78

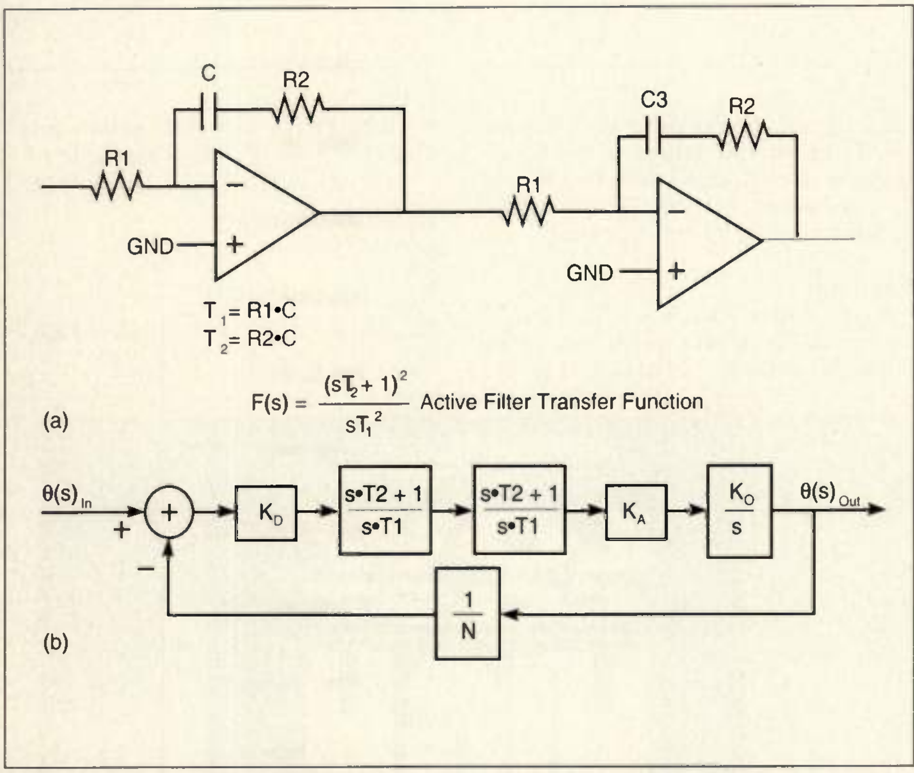


Figure 5. For the Type 3 PLL — (a) Loop filter circuit and open loop transfer function; (b) Block diagram of the loop.

Assigning F_S = 1.2, from Figure 2 or equation 11, we have ϕ_{min} = 42.6°. Select ϕ = 42.7° and $F_0 = f_0 T_s$ = 5. The phase margin is 42.69° which can be found in Figure 3 (approximately). Next, assume T_s to be any value. Using above formulae, we can calculate ωn, τ, α and b. Substitute all parameters in equations (a1) and (a2). Draw $\theta_2(t)$, in solid line, and $\theta'_2(t)/T_s$, in the dashed line, on Figure 4. The X-axis is in scale of $T_s(t/T_s)$, and the Y-axis in degrees.

The maximum value of $\theta_2(t)$ is about 150°. Because it is smaller than 180°, it is a fast locking one. Be reminded that the curves on Figure 4 are independent of T_s. First, we select T_s = 0.0165. From Figures 3(b,c,d) or equations (3,4,6-8) and (12-14), we have:

Tl =. 3.61×10^{-3} sec.
T2 = 3.66×10^{-3} sec.
T3 = 7.030×10^{-4} sec.

These data are equal to result of Przedpelski's [5] within a tolerance of 10%. Because, $f_0 = F_0/T_s = 5/T_s$ = 303 Hz. That means the initial jump of reference frequency is not bigger than 300 Hz. If the jump is much bigger than 300 Hz. The locking process will be slow.

Select $T_s = 10^{-3}$, f_0 = 5 kHz, this is the reference frequency. In the case of jumping 5 kHz instantly, we have

Tl =. 1.327×10^{-5} sec.
T2 = 2.22×10^{-4} sec.
T3 = 4.26×10^{-5} sec.

The locking speed is much faster than before, which is directly proportional to T_s. Because the time constant is much smaller, we must consider the frequency response performance of op-amp. If this device has sufficiently large gain bandwidth product, it is a good choice. Or, we increase T_s to make a compromise.

Type 3 PLL

I use the conventional symbol and definition. The Laplace Transform of Type 3, represented by Figure 8, is the following equation (15):

$$\frac{\theta_e(s)}{\theta_i(s)} = \frac{s^3}{s^3 + s^2K\left(\frac{T_2}{T_1}\right)^2 + s2K\left(\frac{T_2}{T_1^2}\right) + K\left(\frac{1}{T_1^2}\right)}$$

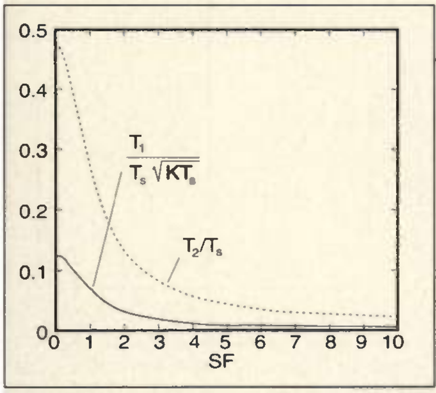


Figure 6. T_2/T_s (dashed line) and $T_1/K^{0.5}\ T_s^{1.5}$) (solid line) are functions of F_S (x-axis) only.

The above equation is correct, only the all initial conditions are zero. K is still defined by (1b).

As with Type 2, assume the denominator of equation (15) in the form of equation (2). Also, there are three cases of input reference signal:

- Case (1): The input reference is constant phase ϕ, $\Phi_i(s) = \phi\ /s$. Never deal with this case.
- Case (2): The input reference is constant frequency f_0, $\Phi_i(s) = 2\pi f_0/s^2$. The initial condition of $\theta_e(t)$: $\theta_e(0) = 0$, $\theta_{e'}(0) \neq 0$. In equation (a1),

$$b = K(T_2/T_1)^2 \tag{16}$$

- Case (3): The input reference is constant frequency ramp f_0, $\Phi_i(s) = 2\pi f_0/s^3$. The initial condition of $\theta_e(t)$: $\theta_e(0) = 0$, $\theta_{e'}(0) = 0$. In equation (a2),

$$b = 0 \tag{17}$$

Because the solution of $\theta_e(t)$ in Case 2 or Case 3 still uses (a1) or (a2), we define F_S and T_s as before, equations (3) and (4) are still effective. Due to variables in the denominator of (15) being only T_1 and T_2, parameter F_S and T_s are sufficient to determine this problem. Using the internal relationship of (2), we get:

$$\alpha = \frac{\omega n^2}{2\left(\omega n + \frac{1}{\tau}\right)} \tag{18}$$

$$T_2 = \frac{2\frac{\alpha}{\tau} + \omega n^2}{2\alpha\omega n^2} \tag{19}$$

$$T_1 = \frac{1}{\omega n}\sqrt{\frac{K}{\alpha}} \tag{20}$$

We have all equations now. Analysis shows T_2/T_s and $T_1/(K^{0.5}\ T_s^{1.5})$ are function of F_S only. In Figure 6, the dashed line represents T_2/T_s, and the solid line represents $T^1/(K^{0.5}\ T_s^{1.5})$. The X-axis is also F_S.

Phase margin is shown in Figure 7. X-axis is also F_S, and the Y-axis is phase angle in degrees. Further analysis proves the same behavior as Type 2 on the solution of two cases. Let the 3rd order Type 3 Case 2 solution (a1), with $b = K(T_2/T_1)^2$) be $\theta_3(t)$. $\theta_3(t)$ is proportional to T_s. If we define $F_0 = f_0{*}T_s$, and keep F_0 constant. $\theta_3(t)$ is only a function of F_S and F_0 on the T_s scaled time axis. The Case 3 solution (a2, with b=0) is denoted as $\theta'_3(t)$. $\theta'_3(t)/T_s$ is also independent of T_s.

Example

A 960 MHz transmitter is based on a

3rd order Type 3 PLL, the reference frequency is 15 MHz, where:

$K_d = 0.25$ V/rad
$K_a = 1$
$Ko = 3 \times 10^9$ rad/s/V

Calculate N = .960/15 = 64. Select F_S = 2.7. With Figure 10, we have phase margin 40.8°. Assume any T_s value, calculate ωn and τ with (3) and (4). Calculate a with (18). Calculate b for Case 2 with (19),(20) and (16). $F_0 = f_0 T_s = 7$. Substitute all parameters in (al) and (a2). We then get the curves of Figure 8.

We can see maximum value of solid line is about 140°. And both curves tend to zero. These curves are independent of T_s. We have the freedom to select T_s. Select $T_s = 0.001$. Using Figure 9 or (19) and (20), get the following results:

$T_1 = 2.31 \times 10^{-3}$ sec.
$T_2 = 9.37 \times 10^{-5}$ sec.

With this choice, f_0 = 7 kHz. If the reference frequency jumping more than 7 kHz instantly, the maximum swing of $\theta_e(t)$ may be bigger than 180°. That may cause slow locking. Selecting small T_s can reduce capture time, but that is limited by the performance of device.

Comparing Type 2 and Type 3, one more op-amp is needed in Type 3. However, continuous frequency ramp, Case 3, makes steady phase error $\theta_e(t)$ not zero in Type 2. *RF*

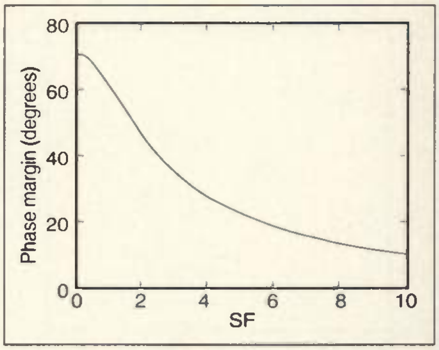


Figure 7. Phase margin versus F_S for the Type 3 PLL

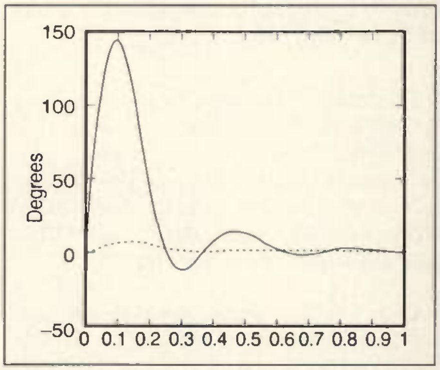


Figure 8. $\theta_e(t)$ for Case 2 (solid line) and $\theta_e(t)$ of Case 3 (dashed line) in degrees.

References

1. Fred Salvalti, "Technique eases design of high-order PLLs," *EDN*, June 9, 1994, pg 172
2. Roland E. Best, *Phase-locked Loops*, McGraw Hill, Inc., 1984
3. High Performance Frequency Conlrol Products, Motorola, Inc. 1993
4. U.L. Rohde, *Digital PLL Frequency Synthesizer Theory and Design*, Prentice Hall, 1983 ibid 3, page 142.

About the Author

Fu Nian Ku can be reached at 35 Violet Avenue, Mineola, NY 11501. He is currently working as a consultant at Mitsubishi's Advanced TV Lab. Previously, he worked at ADEMCO. He received BSEE and PhD degrees from Tsinghua and Peking Universities, respectively.

Appendix:

Equation (a1) — The function:

$$\frac{2\pi f_0(s+b))}{(s+\alpha)\left(s^2+\frac{2}{\tau}s+\omega n^2\right)}$$

has the inverse transform:

$$\frac{2\pi f_0\,\tau}{-2\alpha+\alpha^2\tau+\omega n^2\tau}\cdot\left|\begin{aligned}&e^{-\alpha t}(b-\alpha)\\&+\left(e^{-1/\tau}\,\frac{\tau\omega n^2+\tau ab-a-b}{\sqrt{\omega n^2\tau^2-1}}\right)\sin\left(\frac{1}{\tau}\sqrt{\omega n^2\tau^2-1}\right)\\&+e^{-1/\tau}(a-b)\cos\left(\frac{1}{\tau}\sqrt{\omega n^2\tau^2-1}\right)\end{aligned}\right|$$

Equation (a2) — The function:

$$\frac{2\pi f_0\left(1+\frac{b}{s}\right)}{(s+\alpha)\left(s^2+\frac{2}{\tau}s+\omega n^2\right)}$$

has inverse transform:

$$\frac{2\pi f_0}{-2\alpha+\alpha^2\tau+\omega n^2\tau}\cdot\left|\begin{aligned}&e^{-\alpha t}\left(\tau-b\frac{\tau}{a}\right)+b\left(\frac{\alpha\tau}{\omega n^2}+\frac{\tau}{a}-\frac{2}{\omega n^2}\right)\\&+\left[\frac{e^{-1/\tau}}{\sqrt{\omega n^2\tau^2-1}}\right]\left[\tau^2(\alpha-b)-\tau\left(1+\frac{\alpha b}{\omega n^2}\right)+\frac{2b}{\omega n^2}\right]\\&\cdot\sin\left(\frac{1}{\tau}\sqrt{\omega n^2\tau^2-1}\right)\\&+e^{-1/\tau}\left[-\tau+\frac{b}{\omega n^2}(2-\tau\alpha)\right]\cos\left(\frac{1}{\tau}\sqrt{\omega n^2\tau^2-1}\right)\end{aligned}\right|$$

INFO/CARD 82

ENGINEER'S NOTEBOOK

Simple Direct-Conversion Receiver Checks Frequency Counters

By Michael A. Covington
The University of Georgia

Many frequency counters use a 10 MHz precision crystal oscillator and include an "oscillator out" jack where this frequency can be sampled. The circuit presented here is a direct-conversion receiver that tunes in WWV on 10 MHz, using the frequency counter timebase as its local oscillator, thus providing immediate confirmation that the oscillator is on frequency.

The circuit is an adaptation of the American Radio Relay League's "Neophyte Receiver" [1] and can be built on a printed circuit board made for the receiver [2]. It has been modified to have a 9-volt supply, a 10 MHz front end, and no local oscillator. The audio section has also been simplified.

The two ICs are an NE602 mixer-oscillator (with the oscillator disabled) and an LM386 audio amplifier. Note that the LM386 is fed in differential mode by the differential outputs of the NE602. This greatly improves rejection of nearby AM signals. If the output of the NE602 were taken single-ended, it would include some audio from shortwave broadcasters in the 9.5 MHz band and possibly even some local AM stations.

Antenna requirements depend on location. In Georgia, a 7 MHz dipole mounted in an attic was found to be sufficient; a 10 MHz dipole would, of course, be better. Near the WWV and WWVH transmitters in Colorado and Hawaii, an indoor whip antenna might suffice. Radiowave propagation will affect the reliability of reception. With the low sunspot activity that is occuring in the present solar cycle, it is possible that WWV and WWVH will not be heard during nighttime hours. In periods of high solar activity, daytime reception of the stations at distant locations may be hindered by absorption.

In normal use, this receiver serves to confirm that the frequency counter has not drifted drastically, and it renders the timebase NIST-traceable. For critical adjustment of the TCXO, an oscilloscope can be connected across the speaker to observe the subaudible beat frequencies. Note, however, that the signal from WWV is reflected off the ionosphere. If the reflective layer is rising or falling at the time, Doppler shifts can change the frequency by 1 Hz or more. *RF*

References

1. John Dillon, "The Neophyte Receiver," *QST*, February 1988, pp. 14-18.
2. One source for the printed circuit boards is: FAR Circuits, 18N640 Field Ct., Dundee, IL 60118-9269; tel/fax: (708) 836-9148.

About the Author

Michael Covington is Associate Director of the Artificial Intelligence Center at the University of Georgia, Graduate Studies Research Center, Suite 111, Athens, GA 30602-7415; tel: (706) 542-0358; e-mail: mcovingt@ai.uga.edu

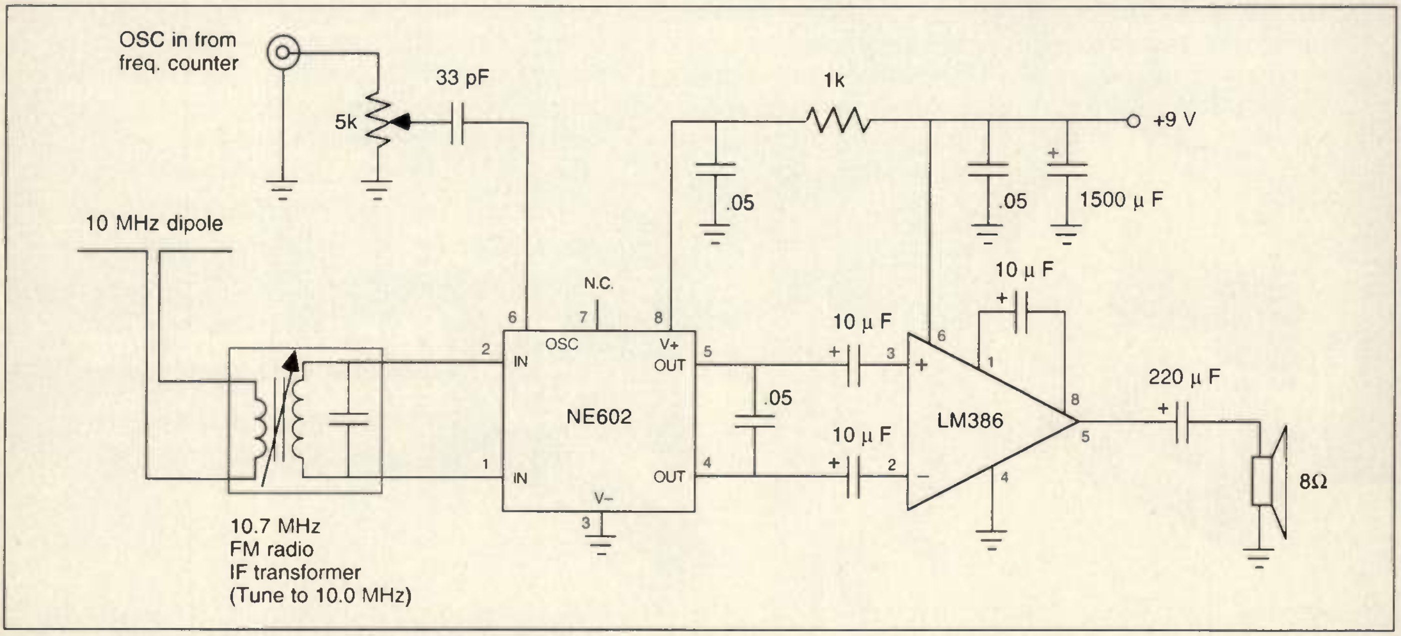


Figure 1. Circuit diagram of the WWV direct-conversion receiver.

One Event Designed to...

EXPAND YOUR WIRELESS COMMUNICATIONS COVERAGE

how do You SEE YOURSELF?

No one in wireless communications can afford to be uninformed about emerging technologies and their across-the-board effects. The International Wireless Communications Expo is the only event dedicated to delivering every aspect of two-way communications in one place, at one time, offering dealers, carriers, engineers, operators, end users and manufacturers a comprehensive look at today's - and tomorrow's - applications.

IWCE '96 will bring together the best minds on how to develop and implement effective strategies for the future of wireless communications. Join a cross-section of peers and professionals from around the world in Las Vegas.

Be a part of IWCE '96 -- delivering wider coverage for your wireless communications needs!

- Engineers
- Corporate, Industrial & Government End Users
- Sales & Marketing Executives
- Telecommunications Managers
- Systems Integrators
- Dealers & Service Providers
- Carriers & Operators
- Consultants & Agents
- Distributors & Manufacturers

what IWCE MEANS TO YOU!

For the past 19 years, the wireless industry has relied on the International Wireless Communications Expo to deliver the latest technology, insights and product introductions for wireless and mobile communications. Featuring over 350 companies showcasing the latest in wireless technologies, the exhibit floor has already surpassed last year's show!

In addition to a product-packed exhibit floor, IWCE's comprehensive education program delivers RF technical training, real-life case studies and expert forecasts of fast-moving trends that are invaluable for professionals looking to build their knowledge base in the domestic and international markets.

Opening Session: *Wednesday, April 24, 1996*

What is the Future Role of the Land Mobile Provider?

An overwhelming number of new wireless communications companies, products and services promise to propel traditional mobile communications into new directions. To prepare for the future is to know what is to come. These wireless leaders are positioning their companies to be leaders in the wireless world of tomorrow. Their strategies and technical approaches will redefine the business as we know it.

Closing Session: *Friday, April 26, 1996*

Establishing Identity Amid Convergence

With all the talk of alliances, technology integration and service convergence, it is hard to know how best to position your business and with whom to partner. This panel will explore the various business opportunities, niche markets and application strategies open to wireless service providers preparing for the future.

Dial our fax-on-demand for full session descriptions, program additions and schedules! 800-601-3858

Featured Educational Sessions:

Wednesday, April 24, 1996 - Friday April 26, 1996

Program Includes:

- Paging Technology Update
- Number Portability
- PCS Technology Shootout
- Future of Global Private Radio
- Satellites Poised for PCS Launch
- Narrowband PCS & Paging
- Dealers & Distributors in the PCS Arena
- RF Engineering Techniques
- APCO 25 Update
- Implementing Refarming - A Technical Overview
- Business Challenges for Deploying New Equipment
- The 800 MHZ SMR Transformation
- The Future of Global Private Radio: Forecasting International Market Growth
- The Regulatory Landscape: A Global View
- Mobile Data and Your Wireless Network
- Regulatory Issues: Washington Insider's Roundtable
- FCC Auction Update
- Int'l and Regional Agreements in Latin America
- State of Regulation in Latin America
- Siting Requirements for Tower Structures

... and much more!

20th Anniversary of IWCE

...is sponsored by: Mobile Radio Technology, Cellular Business, Cellular & Mobile International, RF Design, Satellite Communications, & Dealers' Product Source magazines

International Reception is sponsored by: International Mobile Telecommunications Association and E.F. Johnson

International Wireless Communications Expo '96

today is the day to STRENGTHEN YOUR FUTURE

Register now and plan to be a part of IWCE's 20th Anniversary. We want you to have your first choice of session picks, hotel rooms and discounted airfares. Make a positive move to insure your future in the wireless communications industry by signing up today. If, after considering this material, you have any questions as to how this conference can benefit you further, call the IWCE hotline at 770-618-0323 or our IWCE fax-on-demand at 800-601-3858.

EXHIBIT HOURS/PRODUCT INFORMATION

Wednesday, April 24, 1996

10:00am - 6:00pm Exhibits Open

4:00pm - 6:00pm Welcome Reception in Exhibit Hall Sponsored by Andrew Corporation

Thursday, April 25, 1996

9:00am - 6:00pm Exhibits Open

4:00pm - 6:00pm Cocktail Reception in Exhibit Hall

Friday, April 26, 1996

9:00am - 2:00pm Exhibits Open

The 20th Anniversary brings with it the largest exhibition in IWCE history! This one-stop-shop features over 350 suppliers showcasing the latest in wireless technologies. Experience this product-packed expo and participate in demonstrations featuring:

- Cellular Phones
- Consulting Services
- Crystals
- Dispatch/Voice Storage & Retrieval/Consoles
- Interconnect
- Microphones/Headsets
- Microwave Radios & Transmission
- Mobile Data Terminals
- Mobile/Portable Base Station Antennas
- Mobile/Portable Radios & Accessories
- Mounts/Installation Hardware
- Pagers
- Paging Terminals
- Satellites
- Scrambling/Encryption
- Software
- Test Equipment
- Tone Signaling & Control Equipment
- Towers/Shelters/Lightning Protection
- Transmission & Management Over Radio

...and much, much more!

RF design seminar series

Introducing the RF Design Seminar Series - the NEW WAVE of RF! RF Design magazine is proud to bring this special series to the International Wireless Communications Expo in Las Vegas, Nevada. These RF courses will run April 23rd through the 25th, with IWCE continuing through the 26th. In combination with IWCE's exhibit floor, (featuring the RF Technology Pavilion) this merger is sure to be the largest and most important technology mecca in both RF's and IWCE's history!

Special Course, Track One: Engineering Fundamentals

SC1 Part I: Fundamental Concepts
Tuesday, April 23, 1996, 8am - 5pm

SC2 Part II: Fundamentals of Amplifier Design
Wednesday, April 24, 1996, 8am - 5pm

SC3 Part III: Amplifier Design
Thursday, April 25, 1996, 8am - 5pm

Special Course, Track Two: Engineering Applications

SC4 Practical High Frequency Filter Design
Tuesday, April 23, 1996, 8am - 5pm

SC5 Oscillator Design Principles
Wednesday, April 24, 1996, 8am - 5pm

Special Course, Track Three: Advanced Techniques

SC6 Digital Modulation and Spread Spectrum for Wireless Communications
Tuesday, April 23, 1996, 8am - 5pm

SC7 RF Power Transistors and Amplifiers: Principles and Practical Applications
Wednesday, April 24, 1996, 8am - 5pm

1996 Registration Form

April 24-26, 1996 • Las Vegas Convention Center • Las Vegas, Nevada USA

One form per person. For additional forms please copy as needed. All sections must be completed.
Incomplete forms will not be processed. Must be 18 years of age to attend.

International Wireless Communications Expo IWCE Ninety Six

International Wireless Communications Expo '96

Sponsored jointly by :

Mobile Radio Technology
Cellular Business
Cellular & Mobile International
RF Design
Satellite Communications
Dealers' Product Source

GENERAL INFORMATION

Please print. All sections must be completed to be processed.

Last Name | First Name

Title

Company

Street Address

City | State/Province

Country | Zip Code/Postal Code

Phone Number (please include country/city codes) | Fax Number

REGISTRATION TYPES

A) IWCE Registration

		Pre-Reg. Before 4/1/96	On-site After 4/1/96	Amount Due
S	☐ IWCE Sessions & Exhibits	$425	$495	$ _____
E	☐ Exhibits Only	$15	$45	$ _____
W	☐ Exhibits & Wed. Sessions	$175	$225	$ _____
T	☐ Exhibits & Thur. Sessions	$175	$225	$ _____
F	☐ Exhibits & Fri. Sessions	$175	$225	$ _____

B) RF Special Courses

RF1	☐ One Course	$295	n/a	$ _____
RF2	☐ Two Courses	$525	n/a	$ _____
RF3	☐ Three Courses	$775	n/a	$ _____

(includes exhibit hall access and applicable course material)

Total of A&B $ _____

Select RF Special Courses you plan to attend:

Tuesday, April 23rd	☐ SC1*	☐ SC4*	☐ SC6
Wednesday, April 24th	☐ SC2*	☐ SC5*	☐ SC7
Thursday, April 25th	☐ SC3*		

*CEUs are available through the Georgia Institute of Technology School of Electrical Engineering for those attendees registering for **RF Special Courses** PRIOR to 4/1/96. Certificates of attendance will be granted. If you will be applying for CEUs, please enter your Social Security Number:

☐ Please contact me about special barrier-free accommodations. A company representative will call if checked.

JOB FUNCTION

(Please check as many as apply).

A. ☐ President/Owner
B. ☐ Director/VP
C. ☐ Sales & Marketing
D. ☐ Communications Manager
E. ☐ Technician/Service Supervisor
F. ☐ Engineer
G. ☐ Purchasing Manager
O. ☐ Other _________

PRODUCT INTERESTS

(Please check as many as apply).

A. ☐ International Markets
B. ☐ RF Engineering
C. ☐ Mobile Data
D. ☐ PCS
E. ☐ Pagers
F. ☐ Two-Way Radios
G. ☐ Antennas
H. ☐ Systems Integration
J. ☐ Satellites
O. ☐ Other _________

BUSINESS CATEGORY

A. End User of Radio Communications Equipment
B. Business Radio Dealer
C. Business Radio Dealer/ Service Shop
D. RCC/PCP
E. Cellular Operator/Carrier
F. Cellular Agent/Dealer
G. Public Safety
H. Exporter/Importer
J. Manufacturer's Rep
K. Distributor
L. Consultant
M. Manufacturer
N. SMR
P. Association Academia
Q. Press
O. Other _________

METHOD OF PAYMENT

Checks or Credit Card Payment Only (no invoices issued and no P.O.s accepted)

☐ Enclosed is a check, money order or wire transfer for US $ ____________________

☐ Charge US $____________________ to: ☐ American Express ☐ Visa ☐ MasterCard

Account # | Exp. Date

Name of Card Holder ____
(Please print as shown on credit card)

Authorized Signature ____

Cancellation Policy: Full refunds, less a 25% administrative fee, will be given if request is received in writing prior to April 1,1996. Absolutely NO REFUNDS after April 1, 1996. No refunds or credits will be issued to no-show registrants. This cancellation policy is strictly enforced. No exceptions.

Pre Registration Deadline:
April 1, 1996. After April 1, 1996 please plan to register on site.

Mail to:
IWCE '96 Registration
c/o Intertec Presentations
6151 Powers Ferry Rd., NW
Atlanta, GA 30339-2941

For immediate registration (credit card payment only) fax to: **770-618-0441**.
If faxed please do not mail additional copy.

IWCE '96 is produced and managed by Intertec Presentations, a division of Intertec Publishing.

Analog Tool Delivers Breakthrough in Oscillator Design

Avista Design Systems announces the 1B release of Avista Spectre/XL, "the what-if solution for analog circuit design™." Avista Spectre/XL embeds accurate circuit simulation inside Microsoft Excel, the world's most popular analysis and presentation package. Avista Spectre/XL's special features give analog designers a flexible tool for developing, escalating and optimizing circuit designs.
Avista Design Systems
INFO/CARD #246

Universal Synthesizer Controller Software

SERSYNTH software enables RF engineers to easily program wireless synthesizer IC's using an IBM PC/compatible computer. It eliminates the frustrating task of interpreting manufacturer's data sheet and days of trial and error software/hardware debugging.
SERSYNTH
INFO/CARD #247

Wireless Engineering Software

Comsearch introduces its IQ line of software developed to address every phase of PCS design. IQ Clear for microwave relocation; IQ Signum for RF planning and design; and IQ Link for microwave interconnection. IQ Clear quickly and easily answers the question "to relocate or not to relocate" incumbent microwave links in the 1.9 GHz band. An advanced user interface streamlines and speeds the process of determining which microwave incumbents. PCS Licensees can also use IQ Clear to automatically determine the best channel(s) in which the fewest microwave links need to be relocated in a given market, getting the answers needed in the most timely and efficient manner. IQ Signum is Comsearch's latest RF engineering design and planning tool developed specifically to address the needs of the burgeoning PCS industry. Key elements of IQ Signum include small cell modeling, variable bin size, measurement integration and Comsearch's proprietary terrain database. IQ Link is the first comprehensive domestic 38 GHz interconnection software product.
Comsearch
INFO/CARD #248

Mathematical Reference Software

CRC Press, Inc. of Boca Raton, Florida and Waterloo Maple Inc. of Waterloo, Ontario announced today a new partnership. This partnership with will launch a generation of software products that combines the technical contents of the CRC Handbook series with Waterloo Maple's state-of-the-art mathematical and visualization algorithms in a way that will increase the productivity of engineers, scientists, and technical professionals everywhere.
CRC Press, Inc.
INFO/CARD #249

System Analysis Software Update

Elanix, Inc. today introduced SystemView version 1.8-5. This release of the leading Windows-based development software for Communications, DSP, Signal Processing and Control applications features and enhanced Communications library with new WANs (Wide Area Networks) and LANs (Local Area Networks) and PCS (Personal Communications Systems).
Elanix, Inc.
INFO/CARD #182

Partial Differential Equation Toolbox

The new addition to the MATLAB Technical Computing Environment enables engineers and researchers to model and solve a variety of problems involving partial differential equations over two space dimensions and time. MATLAB PDE Toolbox also features a unique and innovative GUI which includes a toolbar and dialog boxes that step the user through the process of defining the 2D geometry, setting boundary conditions, selecting the type of PDE, solving the PDE and displaying the results.
Mathworks
INFO/CARD #183

Software for RF Communication Test

Hewlett-Packard Company introduced a software package for its HP 8921A RF Communications Test Set that makes optimization and maintenance of Motorola MicroCITE AMPS/NAMPS base stations a fast, simple procedure. Motorola's MicroCITE products are self-contained cellular base stations that measure only 8 feet and provide complete cell-site functionality. HP 11807B Option 070, reduces the time required to optimize the performance of a microcell site and provides and a standard test methodology to ensure that all sites are optimized to the same standards.
Hewlett Packard Company
INFO/CARD #184

Magnetics Designer Package

Magnetics Designer is a new software program for Windows that helps you design all types of transformers and inductors. Typical design applications include high frequency switching regulator transformers and output chokes for off-line full-wave and forward converters, 50 Hz single phase line transformers, AC inductors, planar magnetics and 400 Hz aircraft transformers. Virtually any single phase, layer wound, inductors or transformers from 10 Hz to over 1 MHz can be synthesized with Magnetics Designer.
Intusoft
INFO/CARD #185

RF literature

Crystal Oscillator Catalog

A new catalog from MF Electronics summarizes specifications for more than 200 different units. It describes fixed frequency and voltage controlled (VCXO) types. New generations of extended temperature range oscillators are especially emphasized. Thru-hole and surface mount designs are detailed, including low height SMD units with 5mm x 7mm footprint for Type II PCMCIA use. MF Electronics also offer the ClockChip® family of oscillator-building ASICs which enable users to make, rather than buy crystal oscillator circuits.
MF Electronics
INFO/CARD #237

Applications Notes on Timer/Counter/Analyzers

Fluke Corporation has available two free application notes on its high performance timer/counter/analyzers. The application note, ABCs of Time and Frequency Analysis, addresses the basics of signal analysis, and why a time and frequency analyzer (TFA) is necessary to view frequency noise and frequency modulation. The application note Sources of Error in Time Interval Measurements, explains factors that contribute to inaccuracy in time interval measurements.
Fluke Corporation
INFO/CARD #238

1996 IEEE Standards Catalog

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) announced today the release of its updated printed, and improved electronic versions of the 1996 IEEE Standards Catalog, featuring a complete line of standards products and services. Other new and revised editions are also available, making all related information convenient for users of these standards. The IEEE SPAsystem® World Wide Web is searchable by key word in a standards' title, numeric designation, product order number and ISBN number, at http://stdsbbs.ieee.org/.
The Institute of Electrical and Electronics Engineers, Inc.
INFO/CARD #239

TTP Launches Logistics Newsletter

Transport Technology Publishing has just published its first issue of Logistics Technology News, a new bi-weekly newsletter devoted to reporting on information technology in freight transport. The new publications chronicles the increasing use of advanced technologies in transportation logistics. LTN provides exclusive coverage of the following technologies: Bar coding, Radio Frequency Identification (RFID), Electronic Data Interchange (EDI) Software, applications, Mobile Data Communications, Vehicle Positioning and Imaging.
Transport Technology Publishing
INFO/CARD #241

New Solid State Switch Brochure

K&L Microwave, Inc. introduces a new brochure featuring their Solid State Switch line. The eight page brochure is in full color and includes a capabilities overview. The new literature is divided into three categories including Broadband Microwave, Broadband RF and Communications Band.
K&L Microwave, Inc.
INFO/CARD #240

Electronics Catalog

Jameco Electronics winter '96 edition features over 185 new products, including: ICs from Comlinear and Microchip, BNC connectors, stranded hookup wire, wall transformers, cordless soldering equipment, Windows '95 keyboards and much more. Jameco also has hundreds of items on sale at exceptionally low prices.
Jameco Electronics
INFO/CARD #242

Full Line Connector Catalog

The new Molex 950 full-line catalog, which is also accessible through Molex's web site on the Internet, offers technical information on more than 50,000 Molex products available worldwide. Molex incorporated many suggestions made by the catalog's users, including: a standard page format, standardized 2D and 3D catalog drawings, a trade name index and a glossary. Each product section now includes related application tooling and isometric drawings replace part photographs.
Molex, Inc.
INFO/CARD #243

RF Interconnect Products Catalog

Trompeter Electronics, a leading producer of RF interconnect products, is introduces a new 40-page "Telecommunications Products Catalog." The catalog serves as a complete source and guide to coax connectors, assemblies, patch cords, tools and DSX products. Supported with product drawings, the catalog is a versatile tool.
Trompeter Electronics
INFO/CARD #244

Film Capacitor Catalog

Aerovox Group has published a film capacitor catalog which includes two of its new product lines, the AC rated Blue Mike dry film axial wrap and full capacitors and a new IGBT snubber capacitor line. The new Aerovox film capacitor catalog provides all vital product information including performance testing results.
Aerovox Group
INFO/CARD #245

RF LITERATURE/PRODUCT SHOWCASE

ULTRA BROADBAND AMPLIFIERS

28 ps Risetime
65 kHz-12 GHz
12 dB Gain
Only $500!

Several different models available.
Many other quality products:
pulse generators...bias tees

PICOSECOND PULSE LABS Inc
P.O. Box 44
Boulder, CO
U.S.A. 80306
Phone: (303) 443-1249 Fax: (303) 447-2236

INFO/CARD 121

Free Electronic Hardware Catalog

Broadest selection of quality hardware for electronics assemblies. 350-page catalog in-cludes a full range of standoffs, captive screws and nuts, chassis fasteners, handles, ferrules, spacers and washers. Special sections include: new/unusual products, metric information, and Mil-plating specifications. Full inventory, fast turnaround, samples. ACCURATE SCREW MACHINE CO., *Fairfield, NJ, 1-800-237-0013. Fax: 201-244-9177.*

INFO/CARD 122

Portable Spectrum Analyzers

PS - 2A Series

- 0.1 - 1060MHz range in one scan (0 - 100MHz in 11 span widths)
- Measurement range: -108 dBm to +20 dBm
- Fully portable for field operation
- 5 resolution bandwidths (10 KHz - 1 MHz)
- 50 dB input attenutor in 10 dB steps
- 2 / 10 dB scale display with base line clipper
- Multi-turn tuning
- Built-in AM / FM demodulation with speaker
- Digital controlled center frequency display
- Tracking generator (optional PS-2A TG-01)
- AC / DC / Battery powered (optional +12 V battery pack)
- Compact size (10.3" x 4.0" x 12.3") light weight (approx. 10 lbs)

List Price: $2175 *** $1895 *** Introductory offer

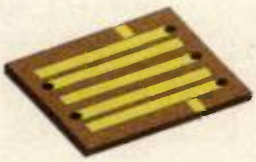
V.TECH Instruments, Inc. Tel (201) 546-7635
171 Burns Ave, Lodi, N J 07644 Fax (201) 546-7651

INFO/CARD 123

Filter Design Software

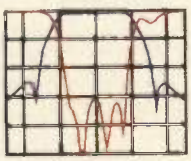
Designs:
Low, High, Band-Pass, Band-Stop
Elliptic & *NEW Cross-Coupled Filters*

Filter Types:
Combline
Interdigital
Half-Wave
Hairpin
Shunt-S



HPCL or DXF File

Structures:
Microstrip
Stripline
Bar & Rod
Suspended SL
Shielded MS



WAVECON
Tel: (619) 747-6922
Fax: (619) 747-5270
P.O. Box 2697 • Escondido, CA 92033

INFO/CARD 124

Get the most from your advertising dollar with RF Design Literature/Product Showcase.

Call Shannon Shuman
at 1-800-443-4969
for more details.

RF design

REPRINTS

Finally. An inexpensive way to promote your products and services.

That's right. Now you can take advantage of a powerful, yet inexpensive way to promote your company. We can reprint any article, ad or section of this magazine
and customize it to your specific needs!

✔ Increase your company's visibility
✔ Enhance your corporate image
✔ Position yourself as an expert in the field

How can you use reprints as a solid marketing tool?

- Direct mail pieces
- Sales presentation aids and leave-behinds
- Promotional material at trade shows
- New product announcements
- Internal/stockholder education

Take advantage of this cost-effective marketing opportunity by calling Ed LaBorwit at (770) 618-0481. Minimum order 100.

RF design

RF marketplace

Classified display ads are available at $125 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 (770) 618-0342.

Career Opportunities

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

I HAVE 30 YEARS EXPERIENCE

As a Nationwide RF Specialist, Microwave, Amplifiers, Transmitters, Receivers, Synthesizers, Filters, NMIC, L-Band, KU-Band, Satellites, Antennas, Audio, Video, Telecomm, CATV, Wireless, VHF, UHF, Radio, Commercial or military Communications.

Call, Fax, Mail Resume to: Bill Elias, Dept. RF
P.O. Box 396, East Brunswick, J.J. 08816
Phone: 908-390-4600 Fax: 908-390-9769

ELIAS ASSOCIATES

Annually A National Award Winning Search Firm

YOUR RECRUITMENT EFFORT SHOULD START HERE

Go with one of the nation's most established search firms, the leader in the Wireless Industry. We have earned the respect of America's Wireless organizations through a reputation built on experience, integrity and results.
Let F-O-R-T-U-N-E work for you.
800.875.2230

F-o-r-t-u-n-e *Communications Group*

Div. of Fortune Personnel Consultants
18552 MacArthur Blvd. #345
Irvine, CA 92715
Fax:714.250.8535
Fax:714.250.8046

CSEM

The high-tech activities of CSEM range from applied research to industrial products, at an international level. The high degree of expertise of our staff is our strength.

Around 350 employees work closely with world renowned companies. Wireless communication is one of our fastest growing activities. To meet this challenge, we are looking for

RF Integrated Circuit Designers

to join our team of integrated circuit and system designers for wireless applications. They will act as:

- Project leaders for custom RF circuit & system development projects
- Internal technical coordinators between design groups
- Primary customer interface on strategic development projects

We are looking for professionals who have experience in the design of low-power RF circuits for wireless communications.

Good interpersonal skills, the drive to succeed in a dynamic technical environment and the capability to work on one's own initiative would be highly appreciated.

If your profile corresponds, please send your application to:
Ph. Widmer, Head of Administration
CSEM Centre Suisse d'Electronique et de Microtechnique SA
Jaquet-Droz 1, CH-2007 Neuchâtel
Phone +41 38 205 111, Fax +41 38 205 700

MIDWEST OPENINGS

RF COMMUNICATIONS EQUIPMENT DESIGN ENGINEERS
BS/MS, 2-8+ yrs. 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. Requires strong analytical skills and experience in RF circuit simulation using RF CAE tools. Reply with assured confidentiality to:

Don C. Gallagher BSME
Gallagher & Associates
418 Baitinger Ct., Sun Prairie, WI 53590
(608)837-5647 Fax(608)837-6096
Now review details of all our engineering openings on the Web at:
http://www.midwestcareers.com

CDI

CDI Telecommunications is part of a large public corporation (NYSE) serving customers nationwide.
We are seeking experienced personnel for the following positions:

CELLULAR & PCS

Program Managers | *Real Estate Specialists*
RF Engineers | *Technicians*
Network Engineers | *Installers*

Call (800) 669 1890 ext. 396

or Fax resume to:
CDI Telecommunications, Inc.
800-875-1904
P.O. Box 4056 Dept. RFD
Scottsdale, AZ 85261-4056
E.O.E.

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

E N G I N E E R I N G

RACAL COMMUNICATIONS, INC. (RCI), growing leader in the design and manufacture of high quality secure tactical communications products, has immedicte openings in Engineering. These positions are highly visible, career opportunities for individuals with the following backgrounds:

SENIOR DIGITAL SOFTWARE DESIGN ENGINEER

The ideal candidate will have a BSEE degree and at least 5 years of experience in digital/software design and development of tactical communication systems with a strong background in digital design and software/firmware development of realtime, embedded microcontroller applications for portable radio products. Experience in developing microcontroller firmware in C and/or Assembly is a must. Hardware and firmware design experience using the Hitachi H* microcontroller families is preferred. Also requires proficiency using the PC for engineering design and administrative tasks.

PRINCIPAL RF DESIGN ENGINEER

The ideal candidate will have a BSEE degree and 10-plus years experience in hands-on RF hardware design and analysis of VHF battery powered transceivers. A strong background designing synthesizer, IF Amplifiers, mixers, low-noise small signal amplifiers, RF filters and power amplifiers up to 10 watts is required. Experience in designing frequency hopping transceivers is preferred. Candidates must have working a knowledge of computer aided analysis tools, good administrative skills with the IBM PC and Windows and proficiency in using standard RF test equipment. Familiarity with MIL-STD test methods is desired.

PRINCIPAL DIGITAL/DSP DESIGN ENGINEER

The ideal candidates will have a BSEE degree and 10+ years experience in hands on digital hardware and software development of DSP and microcontroller based portable VHF radio products. A strong design background using microcontrollers and DSPs, and developing real time software for spread spectrum, Type I secure radios is required. Experience designing SINCGARS compatible frequency hopping digital processing hardware and software is preferred. Software development in both C and assembly is a must. Familiarity with the Analog Devices ADSP-21xx DSP family and Hitachi H8 microcontroller family is a plus. The position also requires proficiency using the PC for engineering design and administrative tasks.

RCI offers our associates the rewards, opportunities and professional environment necessary to promote success. We are located in Rockville a beautiful Maryland suburb minutes from our nation's Capital, Washington, DC. Rockville offers one of our counties best school systems and a wide range of choices in art, entertainment, recreation, and housing to accommodate any lifestyle. For immediate consideration, please forward your resume with salary requirements to:

RACAL COMMUNICATIONS, INC.
5 Research Place • Rockville, Maryland 20850
E.O.E. Attention: Human Resources • Fax #301-948-6015 M/F/D/V

Have Cutting Edge Technology, Will Travel.

If there's progress, M/A-COM's behind it.

M/A-COM PHI is a state-of-the-art designer and manufacturer of RF and Microwave transistors and amplifiers, planning projects that not only exploit technological innovations but also incorporate such development in creating quality, cutting-edge products.

Now M/A-COM can be the force behind your progress. Increased technology, resources and a commitment to research and development continue to take M/A-COM further into the world of wireless — and wired communications. Imagine where you could go as part of the team that's driving the cutting edge in RF/microwave technology. We have the following opportunity available:

SENIOR RF DESIGN ENGINEER

As an innovative, seasoned designer, you possess the creative ability to design around product or process problems - envisioning new approaches that help us push the technological envelope in developing new products. To qualify, you must have a BS, MS or PhD in Electrical Engineering and 5-7 years' related RF design experience.

M/A-COM offers a highly competitive compensation package and attractive benefits. If you are interested in the opportunities at M/A-COM PHI, please forward a resume or letter of interest to: M/A-COM, 1742 Crenshaw Blvd., Torrance, CA 90501. Fax: (310) 618-9191. Email: salomonr@corp.macom.com
Check our Internet home page: www.macom-phi.com
An equal opportunity employer.

STOP BY OUR BOOTH #5
AT THE IWCE CAREER EXPO!
LAS VEGAS, CA
APRIL 24-26

M/A-COM
an AMP company

Paging · PCS · Cellular · SatCom

CNI

Career Networks

Recruiters for the Wireless & Telecom Industries

800-JOB LINK™

Specializing in Sales, Marketing, Technical, Engineering, Operations & Executive Placements

Gables One Tower, Suite 801
1320 S. Dixie Highway
Coral Gables, FL. 33146
joblink@aol.com

Fax Resume to (800) JOB-FAXX

ENGINEERING OPPORTUNITIES

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

FITZPATRICK & ASSOCIATES

16540 East Ashbrook Dr. • Fountain Hills, AZ 85268-2832
E-Mail: FITZPAT@ix.netcom.com
FAX: (602) 956-7644

Microwave RF Engineer
A self starter degreed engineer must have successful design analysis and testing of RF circuitry including Amplifiers Filters. Hands on experience in using modern CAD circuit design and layout.

Resumes To:

AeroAntenna Technology, Inc.
20542 Plummer St., Chatsworth, CA 91311

WESTERN STATES

- California
- Arizona
- Oregon
- Colorado
- Texas
- Washington

RF-Wireless Communication
Digital Cellular, Cordless PCN
DSP: Video, Audio, Multimedia
Custom VLSI Design-CMOS
IC Design: Digital, Analog, Mixed Signal
ASIC/FPGA Ddesign (VHDL, XILINX)

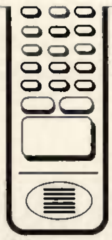
ROBERT MILLER & ASSOCIATES
5850 Oberlin Drive #310 • San Diego, CA 92121
PH: 619-566-4325
FAX: 619-566-4376
email: rmiLleasoc@aol.com

ENGINEERS

RF and MICROWAVE

Design/Production/Mfg.
for
CATV MMDS (Products & Systems)

Live and work in Boca Raton, Florida
Fax Resume: 1-407-998-3712



...YOUR CAREER

RF PA Engineers: Requires 3 + years experience in design, test and manufacturing of high efficiency GaAs MESFET and HBT class A and C power Amplifiers (c2watts) In the frequency range (-2GHz). Experience in both discrete and MMIC design a plus.

Product Marketing Manager: Lead the technical marketing effort for the Wireless Communications Group; develop business/marketing plans, manage customer relationships, perform market analysis, develop sales/marketing material.

Wireless Engineers: RF Design Engineers: Design of Si RF Io's for Wireless Communication applications (AMPS, DAMPS, GSM, DECT, POS). Si RF ixc design experience In the 300-2400 Mhz fast RF PLL sythesizer design experience; RF receiver/transmitter/design experience using Si Bipolar and MOS technologies.

Cellular Engineers: Design/Develop RF and analog circuits for high capacity cellular systems. Requires minimum of 2 years experience In any of the following: DSP, ASIC Design, CAE Development, Digital Modulation, Digital Mobile Communications, Channel Equalizers, Transmitter-Receiver-Synthesizer or Audio Design, Digital Signal Processing.

Regional Field Sales: Aggressive individuals to create and serve new accounts. Positions are located throughout the U.S.A. An engineer who wants to enter sales world is acceptable. Base salary, commission and car. BSEE.

IC Design (RF/Analog): 2+ years' experience with BICMOS/Bipolar processes; design background in AMPS, mixers, VCOs, FM Demode, CpAMPS and basic logic; understanding of specification generation, circuit design, layout, test board generation and testing.

Sr. Project Antenna Design: Lead the conception, design and development of a wide variety of antennas and antenna systems, Including both reflector and array systems using microstrip, stripline and waveguide technologies. BS/MS with 5 years experience.

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

Sr. MMIC Design: Design highly integrated GaAs MMICs for advanced cellular products.Circuits to be designed include power amplifiers, LNAs, mixers, IF amplifiers, buffer amplifiers.RF frequencies are 900 and 1800 Mhz.

Product Line Manager Wireless: Specific responsibilities include product line strategic planning, establishing revenue and price objectives, setting [illegible] cost targets and oversight of internal product realization schedules.

Sr. MMIC Design: Design highly integrated GaAs MMICs for advanced cellular products.Circuits to be designed include power amplifiers, LNAs, mixers, IF amplifiers, buffer amplifiers.RF frequencies are 900 and 1800 Mhz

Sr. Analog IC Designers: Responsible for conceptual circuit design and developing new analog/mixed signal ic's. BS/MS experience in A/D D/A, ASIC's bipolar and BiCMOS.

Rf Systems Engineer PCS: Responsible for developing radio system performance requirements including modulations/demodulations, coding, channel models, deployment models, hardware performance requirements, interference rejection, blocking power control, handover ect . BS/MS

Applications Engineer: 5 years of directly relevant RF/MW engineering applications and measurement techniques.Strong presentation and instructor skills, must be able to communicate effectively with individuals and groups of all levels of technical expertise and experience.

RF Systems Design: RF system design for low cost battery operated systems, battery powered systems, including receiver and transmitrters system planning, analysis and simulation using CAD tools. Experience with CDMA/TDMA. BSEE.

MICRO COMMUNICATIONS EXECUTIVE SEARCH

We specialize in the placement of wireless, RF, microwave communications.

FOR THESE AND OTHER OPENINGS CALL COLLECT: TEL: 508-685-2272
800 Turnpike St. • North Andover, MA 08145
E-mail: micsearch@aol.com
FAX : 508-794-5627

......ACT

Not just another high-tech acronym.

RF, WLAN, PCS, ATM, CDPD, VSAT, SATV, GPS, LEO, CDMA, TDMA, QAM, DSP, MPEG, LPC, ASIC, ITS, PCMCIA...you've heard them all.

We'd like to add a new one to the list: ACT.

ACT keeps you on the cutting edge of technology by providing the information you need to make the best career decisions.

Call us to learn more about exciting opportunities with established industry leaders as well as pioneering start-ups that are developing the technologies for advanced microelectronics and communications systems.

ACT Advanced Communication Technologies

Career Consultants/Search Specialists

25492 Hillsboro Drive ■ Laguna Niguel ■ CA 92677
714/365-9090 **Fax**: 714/365-9191 *Fees paid by employers*
E-mail: weact4u@snni.com *Ask for John Kratz*

CAREER OPPORTUNITIES

RECRUITMENT

DSP Without Tears®

Learn DSP and put your knowledge to work IMMEDIATELY!

To receive an informative brochure on this popular seminar, call Z Domain Technologies, Inc. at **1-800-967-5034**, 770-587-4812. Hours: 9 - 5 EST. Or E-mail dsp@mindspring.com
Also, a 3-day ADVANCED class in DSP is available on a limited basis -- call for more details.

By taking this 3-Day Course, you will really learn DSP. Guaranteed!

Coming to a City Near You:
Ft. Lauderdale FL - Boston MA - San Jose CA

SCTE Sustaining Member

Peter Froehlich & Co.
executive search

RF Communications Positions:

Designers, Engineers, Managers
Wireless/Telecomm/CATV/Video/Voice/Data
RF Equipment and Systems Design: Transmitters, receivers, amplifiers, mixers, filters, synthesizers, modulators, demodulators, PLL's, VCO's. Skills include: PCS, PCN, Spread Spectrum, DSP, CDPD, TDMA, CDMA, QPSK, QAM & others. Digital/Analog, DC to 2 GHz.

Nationwide. 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

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/

TRW ideas from the edge



Communication can be sky high and down to earth

Long an innovative leader in space communication systems, TRW Electronics Systems and Technology Division is expanding frontiers in advanced wireless communication – both system design(the Odyssey program) and technology development (GaAs MMIC).

System Designers

TRW has prime positions for system designers who excel in concept development, performance modeling and design. Apply your strengths in communication theory and DSP to the design of state-of-the-art space communication systems, including satellite payloads, earth terminals, handsets, and more. Requires MSEE or PhDEE, and 3+ years of applicable experience.

In addition to competitive salaries and generous benefits, expect to work side-by-side with some of the industry's brightest minds. You'll also have plenty of opportunity to soak up the sun and fun of Southern California, thanks to TRW's enviable location in Manhattan Beach and Redondo Beach. Relocation assistance is available.

Please send your resume to: **TRW ES&TD, Dept RF, Recruiting Office, M5/1426, One Space Park, Redondo Beach, CA 90278. FAX: (310) 814-8022.** U.S. citizenship may be required. EOE.

Visit us on the World Wide Web at http://www.trw.com

TRW
TRW Electronics Systems and Technology Division

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:

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
Vacuum
Surcom Associates, Inc., 2215 Faraday Ave., Suite A, Carlsbad, CA 92008 ....(619) 438-4420

CRYSTALS/RESONATORS
Jan Crystals, P.O. Box 60017, Fort Myers, FL 33906-6017 ....(800)JAN-XTAL

Quartz

Oak Frequency Control Group,
100 Watts St., PO Box B, Mt. Holly Springs, PA 17065 ....(717) 486-3411

DIODES
Loral Semiconductor Division, 75 Technology Dr., Lowell, MA 01851 ...(508) 256-4113 ext.3311
Varactor
Knox Semiconductor, Inc.
13 Quarry Rd., P.O. Box 609, Rockport, ME 04856.................(207) 236-6076 Fax(207) 236-9558

HIGH POWER DIODE SWITCHES
Hill Engineering, 461 Boston Rd., Topsfield, MA 01983 .... (508)887-5754 Fax 887-7244

INTEGRATED CIRCUITS/MCM
California Eastern Laboratories,
4590 Patrick Henry Dr., Santa Clara, CA 95054-1817.......(408) 988-3500 Fax (408) 988-0279
Micro Hybrids, Inc., 2864 Route 112, Medford, NY 11763...(516) 732-3448

MODULAR COMPONENTS

AMPLIFIERS
Broadband
Dressler HF Technik Gmbit,
Werther Str. 14-16, D-52224, Stolberg, Germany ....+49-2402-71091 Fax: (-71095)

AMPLIFIERS
RF Power
Silicon Valley Power Amplifiers, 529 Forman Dr. # B, Campbell, CA 95008 ....(800) 986-9700

FILTERS
Delta Microwave Inc., 840 Vira Alondra, Camarillo, CA 93012 ....(805)987-6892
Crystal
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013...............................(717) 243-5929
RF Microwave
Microwave Circuits, Inc., 6856 Eastern Ave., NW, Washington, D.C. 20012........ (800)642-2587
Saw
Phonon Corp., 7 Herman Dr., PO Box 549, Simsbury, CT 06070 ....(203) 651-0211
SAW Components & Subsystems ....Fax (203) 651-8618

OSCILLATORS
Crystal
Oak Frequency Control Group,
100 Watts St., PO Box B, Mt. Holly Springs, PA 17065 ....(717) 486-3411
Saronix, 151 Laura Ln., Palo Alto, CA 94303 ....(415) 856-6900 (800) 227-8974
Wenzel Associates, Inc., 1005 La Posada Dr., Austin, TX 78752 ....(512) 450-1400
Phase Locked
Mode Space Digital
235 Circle Drive, State College, PA 16801 ....(814)466-3327 FAX:(814)466-6577

SYSTEM SUBASSEMBLIES

PRINTED CIRCUIT BOARDS
Harmon Electronics, Inc., 601 N. Main, Warrensburg, MO 64093 ....(816) 747-2236

RF Design Yellow Pages continued from page 119

RF TRANSMISSION COMPONENTS

ANTENNAS
Sinclair Technologies, Inc Oriskang Dr Tonawanda NY 14150 ....(800)288-2763
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

Custom & Specialty
Myers Engineering International, Inc.
P.O. Box 15908, Ft. Lauderdale, FL 33318 ....(954) 345-5000 Fax: (954) 345-5005

Site
Dapa, Deleware Park Centre, Suite 6, Olean, NY 14760 ....(800) 325-DAPA

ATTENUATORS
Coaxial
SV Microwave, 3301 Electronics Way, West Palm Beach, FL(407) 840-1800 Fax (407) 844-8551

CABLE ASSEMBLIES
SRC Cables, 5590 Skylane Blvd., Santa Rosa, CA 95403 .... (707)573-1900
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

FILTER ASSEMBLIES
Low Pass

Coil Specialty Co., 2730 Carolean Ind. Dr., PO Box 978, State College, PA 16801 .. (814)234-7044

INDUCTORS AND CHOKES
Kintronic Labs, 144 Pleasant Grove Rd., Bluff City, TN 37618 ...(615)878-3141 Fax (615)878-4224

ISOLATORS/CIRCULATORS

Airtron Corp., 200 E. Hanover Ave., Morris Plains, NJ 07950 ....(201)539-5500

MICROWAVE CONNECTORS
Applied Engineering Products, P.O. Box 510, New Haven, CT 06513 ....(203)776-2813
Coaxial Connectors, Inc., 1500 N.W. 62nd St.,Ste.501, Ft. Lauderdale, FL 33309 .... (305)772-2664
Southwest Microwave, Inc., 2922 S. Roosevelt St., Tempe, AZ 85282 ....(800) 587-5995

PRECISION

RF CONNECTORS
Molex, Inc., 2222 Wellington Ct., Lisle, IL 60532 ....800-MOLEX78
Specialty Connector Company,
2100 Earlywood, Franklin, IN 46131 ....(317) 738-2800 Fax: (317) 738-2858

SURGE & TRANSIENT PROTECTORS

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

RF TRANSMISSION COMPONENTS

TELEMETRY

TEST SOCKETS & TEST FIXTURES
Condel Microwave Technology, 19925 Stevens Creek Blvd., Cupertino, CA 95014 .... (408)253-1811

VACUUM TUBES

WATTMETERS & LOADS

WAVEGUIDES & COMPONENTS
Electromechanical
MBF Microwave, Inc., Rt. 2, Box 252A, Hardy, AR 72542 .... (501) 856-2685

MATERIALS AND HARDWARE

CRYSTAL BLANKS
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013 ....(717) 243-5929

MOBILE DATA TERMINALS
Dinet, Inc. (AVL/GPS) ....(619(724-5355 Fax: (619) 724-6209

PACKAGING/CRYSTAL HOLDERS
Crystal Holders
United Glass to Metal Sealing, Inc. 11A Executive Park Dr., North Billerica, MA 01862... (508)670-6494

Components/Hybrid Packages
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

Racal Instruments, 4 Goodyear St., Irvine, CA 92718 .... (800) 722-2528

ANTENNA TEST & RF INSTRUMENTATION
Anritsu Wiltron Co., 490 Jarvis Dr., Morgan Hill, CA 95037 ....(408) 776-8300 Fax (408) 776-1744

RF TEST & MEASUREMENT EQUIPMENT
COAXIAL DYNAMICS, INC.,
15210 Ind. Pkwy., Cleveland, OH 44135 ....(216) 267-2233 Fax (216) 267-3142
Grayson Electronics, 306 Enterprise Dr., Forest, VA 24551....(800) 800-746 3 Fax (804) 385-7692

SERVICES

ANTENNA DESIGN & MEASUREMENT
Kintronic Labs, 144 Pleasant Grove Rd., Bluff City, TN 37618..(615) 878-3141 Fax (615) 878-4224

EMC/EMI TESTING
TUV Rheinland of North America, Inc.,
12 Commerce Road, Newtown, CT 06470 ....(203) 426-0888 Fax (203) 270-8883

OEM PRODUCTS
Locus, Inc., 1842 Hoffman St., Madison WI 53704 ....(608) 244-0500

RECRUITMENT
Technical Employment Consultants, 52 East St. Rd., Suite C-1 Feasterville, PA 19053
Refer to advertisement on page 94 ....(215) 396-1840 Fax (215) 396-1501

TELEMETRY SYSTEMS & ENGINEERING
Telemetry Technologies, Inc., 3307 West St., Rosenberg, TX 77471 ....(713) 344-9000

RF Design Yellow Pages continued from page 120

SOFTWARE & SYSTEMS CAD/CAE

SOFTWARE

Circuit Simulation

Design Automation, Inc., 4 Tyler Rd., Lexington, MA 02173........(617) 862-8998 Fax (617) 862-3769

ingSoft Ltd. – the providers of the RF Designer® Solution........(416) 730-9611
213 Dunview Ave., North York, ON M2N-4H9, Canada;........Fax:(416) 226-0861

SOFTWARE & SYSTEMS, CAD/CAE

Waypoint Software,
5540 Manor Court, Woodland Park, CO 80863-9084..........(719) 687-5458 (Waypointsw@aol.com)

SYSTEM SIMULATION

RHR Laboratories, 207 Harding Blvd. W., Richmond Hill, Ontario,CN L4C 8x6......(905) 884-2392

Tesoft, Inc., 205 Crossing Creek Ct., Roswell, GA 30076........(800) 631-1113
Makers of TESLA Com Simulator........Fax (770) 664-5817 Intl (770) 751-9785

EMC TEST & DESIGN Products & Services Directory

The Products & Services Directory is a convenient guide to suppliers of products and services for the EMC/ESD industry. Products & Services Directory listings are sold on an annual basis.

For information on rates, closing dates and details on a special Introductory Offer, call **1-800-443-4969**. Ask for your yellow page representative.

EMI SUPPRESSION COMPONENTS

EMI/RFI Filters

RtroN Corp., P.O. Box 743 Skokie, IL 60076........(708) 679-7180

Ferrite Beads, Rods, Forms

Fair-Rite Products Corp., P.O. Box J, Wallkil, NY 12589........(800) 836-0427

ESD AND SURGE CONTROL COMPONENTS

Lightning Arrestors

Fischer Custom Communications, 2905 W. Lomita Blvd, Torrance, CA 90505........(310) 891-0635

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
Microsorb Technologies, Inc., 14A Airport Dr. Hopedale, MA 01747........(508)634-1900
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
Rantec, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

Antennas

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

Antennas Above 30 MHz

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

Antennas Masts

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888

Current Probes

Fischer Custom Communications, 2905 W. Lomita Blvd, Torrance, CA 90505........(310) 891-0635
Ion Physics Corp., 11 Industrial Way, Atkinson NH 03811........(603) 893-6687

Ferrite Absorber Tiles

Rantec, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

GTEM Cells

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888

Line Impedance

EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

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
Rantec, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

Near Field Probes

EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

Shielding Effectiveness Testers

EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

EMC TEST EQUIPMENT - SUSCEPTIBILITY

Antennas

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888
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

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888
EMCO, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

ELECTRONIC COMPONENTS AND EQUIPMENT

EMC TEST EQUIPMENT - SUSCEPTIBILITY

Power Amplifiers

Applied Systems Engineering Inc., 8623 Hwy. 377 S., Fort Worth, TX 76126........(817) 249-4180

Pulse Generators

EMCO, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

Sheilded Fiber Optic Links

Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705.......(301) 937-8888

ESD TEST EQUIPMENT

ESD Event Detectors

TREK INC., 3932 Salt Works Rd., P.O. Box 728, Medina, NY. 14103........(800) FOR-TREK

Surface & Volume Resistivity Meters

TREK INC., 3932 Salt Works Rd., P.O. Box 728 Medina, NY. 14103........(800) FOR-TREK

MATERIALS, HARDWARE AND PACKAGING

SHIELDING MATERIALS

Antenna Towers

EMCO, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

Conductive Adhesives

Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370........(800) 343-1076 Fax: (617) 871-0065

Conductive Fiber/Fabric

Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370........(800) 343-1076 Fax: (617) 871-0065

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........(800) 343-1076 Fax: (617) 871-0065

Laminates

Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370........(800) 343-1076 Fax: (617) 871-0065

Positioning Controls

EMCO, P.O. Box 1546, Austin, TX 78767........(512) 835-4684

Sheilding Foils and Tapes

Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370........(800) 343-1076 Fax: (617) 871-0065

Tripods

EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

Turntables

EMCO, P.O. Box 1546, Austin, TX. 78767........(512) 835-4684

ESD PACKAGING

Antistatic and Conductive Polyurethanes

Pad-Tastics, Inc., P.O. Box 50479, Cicero, IL 60650........(708) 780-8402 FAX (708) 780-1636

ESD ENVIRONMENTAL CONTROL

Antistatic or Conductive Flooring

nora®
ESD Safe Rubber Flooring for Work Areas
1-800-332-NORA
Nora Rubber Flooring
Freudenberg

TEST LABORATORIES AND CONSULTANTS

LABORATORIES

TUV Product Service, Inc., 1775 Old Hwy. 8, New Brighton, MN 55112........(800) 472-7999

CONSULTANTS

Kimmel Gerke Assoc. Ltd., 1544 N. Pascal, St. Paul, MN 55108........(612) 330-3728
EMC Design/Troubleshooting-Medical, Industrial, ITE, Vehicles & More-50+ years exp.

RF guide to editorial coverage

RF advertising index

RF DESIGN (ISSN:0163-321X USPS 453-490) is published monthly and semi-monthly in October. April 1996. Vol.19, No. 4. *RF Design* is a registered trademark of Intertec Publishing Corp. Copyright 1996 by Intertec Publishing Corporation, 9800 Metcalf, Overland Park, KS 66212-2215. 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 Overland Park, KS and at additional mailing offices. Subscription office: *RF Design*, P.O. Box 1077, Skokie, IL 60076. Subscriptions are $48 per year ($82 for two years) in the United States; $68 (surface mail) or $108 (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/96/$3.00. For those seeking 100 or more more copies, please contact the magazine at (303) 220-0600.

SUBSCRIPTION INQUIRIES: (847) 647-0756.

POSTMASTER & SUBSCRIBERS: Please send address changes to RF Design, P.O. Box 1077, Skokie, IL 60076.

25 to 1025MHz VCO's only $119.95 (1-9)

load insensitive (+9dBm output)

From Mini-Circuits...here's the ZOS solution! A winning lineup of low cost, connectorized voltage controlled oscillators that typically provide wide octave band linear tuning, low phase noise, and excellent 25dB harmonic suppression. The dual output provides well isolated ports (47dB typ), and frequency settings are virtually independent of the load. Applications include frequency monitoring, PLL circuitry, laboratory use, and as a frequency source for burn-in, power test, and other production testing. So, turn to the ZOS solution for reliable, high performance VCO's with the " Mini-Circuits" stamp of value.

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

Model No.	Freq. Range (MHz) Min.-Max.	Phase Noise (dBc/Hz) SSB@10kHz Typ.	Pulling, Typ. (MHz)pk-pk @ 0 dBr	Harmonics (dBc) Typ.
ZOS-50	25-50	-107	0.012	-22
ZOS-75	37.5-75	-110	0.016	-26
ZOS-100	50-100	-111	0.026	-29
ZOS-150	75-150	-107	0.017	-26
ZOS-200	100-200	-106	0.015	-25
ZOS-300	150-280	-103	0.017	-27
ZOS-400	200-380	-100	0.021	-24
ZOS-535	300-525	-96	0.018	-27
ZOS-765	485-765	-96	0.033	-27
ZOS-1025	685-1025	-92	0.051	-25

Notes: Tuning voltage 1 to 16V required to cover freq. range. Power output +9dBm Typ. (Main). Power 12V DC, +130mA (MAX.). Operating temperature range: -55°C to +85°C.

Mini-Circuits®

US 87 INT'L 88
CIRCLE READER SERVICE CARD

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 INTERNET http://www. minicircuits. com

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

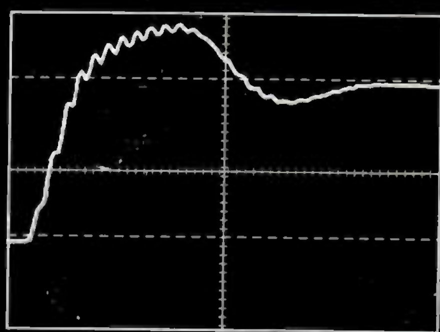
CUSTOM PRODUCT NEEDS...*Let Our Experience Work For You.*

F 218 Rev Orig

Fast Lock Times *go* PLLatinum.

PLLatinum™: the industry's highest performing PLLs.

We could spend hours talking about our amazing single and dual PLLs, but we'll make this quick—our FastLock™ technology enables improved lock times with no added noise or changes in loop feed. The PLLatinum product family performs over the widest frequency range in the industry (510MHz to 2500MHz). And very low power consumption extends battery life. So call **1-800-324-4443, Ext. 605*** for a free sample and a product selection guide. Because isn't it time you went PLLatinum?



LMX2332A switching from 865MHz to 915MHz (the GSM band) in less than 350μs

	LMX1501A	LMX1511	LMX2314/15	LMX2320	LMX2325	LMX2330A	LMX2331A	LMX2332A	LMX2335	LMX2336	LMX2337
RF Input-Main PLL	1.1GHz	1.1GHz	1.2GHz	2.0GHz	2.5GHz	2.5GHz	2.0GHz	1.2GHz	1.1GHz	2.0GHz	550MHz
RF Input-Aux PLL						510MHz	510MHz	510MHz	1.1GHz	1.1GHz	550MHz
I_{cc} (typ) @3V	6mA	6mA	6mA	10mA	11mA	15mA	14mA	8mA	9mA	11mA	9mA
Powerdown (typ)	N/A	N/A	30μA	30μA	30μA	1μA	1μA	1μA	1μA	1μA	1μA

National Semiconductor

In Europe call +49 (0) 180 532 78 32 (English) or +49 (0) 180 530 85 85 (German); in Japan call 81-43-299-2300; in Southeast Asia call 852-2737-1600.

INFO/CARD 89