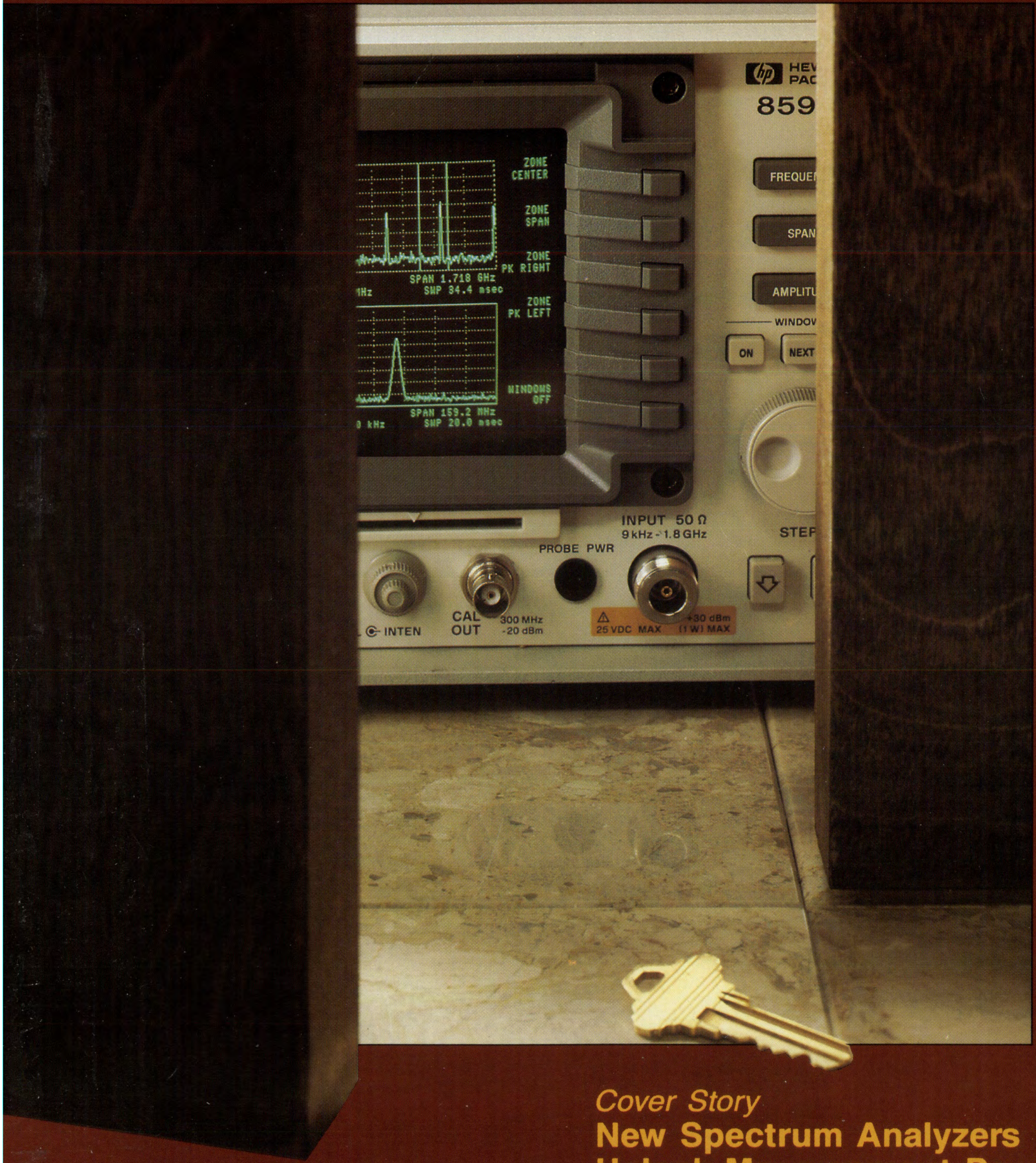
RF design

engineering principles and practices

May 1992



Cover Story

New Spectrum Analyzers Unlock Measurement Power

Featured Technology

Frequency Control: Oscillators, Filters and Synthesizers

GaAstronomical Choice.

Announcing a New Line of GaAs MMICs from DAICO.

DAICO now ships GaAs MMIC Amplifiers, Attenuators and Switches, which are available as chips or already packaged, and we can deliver from stock in as little as 24 hours!

If price, quality, delivery and performance are your objectives, then call DAICO, at 310/631-1143, Ext. 240 for more information.

DAICO INDUSTRIES, INC.
2453 East Del Amo Boulevard,
Rancho Dominguez, CA 90220
Telephone 310/631-1143
FAX 310/631-8078

DAICO GaAs MMIC Switches

Type	Configuration	Max Freq./GHz	Typ Loss/dB	Typ Iso/dB	Package Style	Comments
P35-4211-0	SPDT-R	2	0.5	26	Chip	Low Cost
P35-4215-0	SPDT-RT	4	0.9	28	Chip	On Chip Term
P35-4226-0	SPDT-RT	6	1.7	30	Chip	
P35-4230-0	SPST-R	12	2.2	23	Chip	
P35-4245-0	DPDT-R	6	0.8	32	Chip	
P35-4250-0	SP4T-R	4	1.1	28	Chip	0.67mm Squared
P35-4252-0	SP4T-T	3	1.0	24	Chip	

DAICO GaAs MMIC Amplifiers

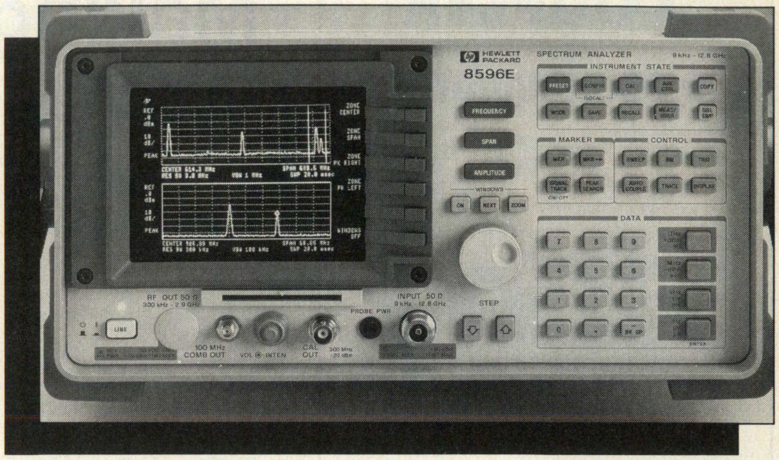
Type	Frequency Range/GHz	Typ Gain/dB	Typ Noise Figure	Typ Power/dBm	Package Style	Comments
P35-4100-0	0.05-3.5	10	6.0	22	Chip	
P35-4101-0	0.5-3.5	9	4.5	22	Chip	Self-Biased
P35-4104-0	0.05-3.0	18	6.0	13	Chip	Low VSWRs
P35-4105-0	0.8-1.8	21	3.5	8	Chip	
P35-4110-0	1-6	7.5	4.6	20	Chip	
P35-4140-0	6-18	5.5	5.5	15	Chip	Pos. Gain Slope
P35-4150-0	2-18	6.0	7.5	15	Chip	AGC
P35-4160-0	3-6	20	2.8	14	Chip	Low VSWRs

This product is manufactured by GEC-Marconi Materials, UK and distributed by Daico Industries Inc.

RF design

contents

May 1992



featured technology

cover story

tutorial

design awards

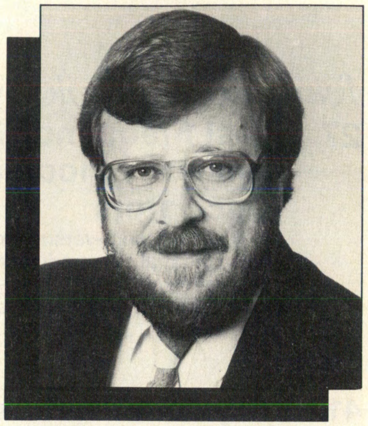
departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in summer. May 1992. Vol. 15, No. 5. Copyright 1992 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111 (303) 220-0600. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: *RF Design*, P.O. Box 1077, Skokie, IL 60076. Subscriptions are: $39 per year in the United States; $49 per year in Canada and Mexico; $54 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $5.00 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.

SUBSCRIPTION INQUIRIES: (708) 647-0756.

POSTMASTER & SUBSCRIBERS: Please send address changes to R.F. Design, P.O. Box 1077, Skokie, IL 60076.

Making Waves



By Gary A. Breed
Editor

The title above isn't about civil disobedience; I mean "making waves" in the literal sense — oscillators, frequency synthesizers, and the specialized components that are used in them. These circuits and devices are among the most universal elements in electronics, filling needs in both digital and analog applications. This issue features this technology, a good time for me to underscore the close relationship between *RF Design* and an important segment of the RF industry.

This issue of *RF Design* is being distributed at the Frequency Control Symposium later this month, and will again be handed out to those attending the Piezoelectric Devices Conference in September. These two conferences assemble the country's most influential engineers, managers and executives to deal with issues in design, technical standards, manufacturing and markets.

Each conference fulfills a different need. Under IEEE and U.S. Army LABCOM sponsorship, the Frequency Control Symposium has become the premier technical forum for presentation and exchange of ideas in high performance circuits, systems and components. With the recent addition of tutorial sessions, this conference serves an even broader range of engineers. The EIA's Piezoelectric Devices Conference (PDC) covers many of these same subjects, but from the perspective of companies manufacturing products using crystal, SAW and ceramic technologies. The PDC targets competitive manufacturing and marketing topics, and has recently expanded its coverage to include more material of interest to end-users of piezoelectric products.

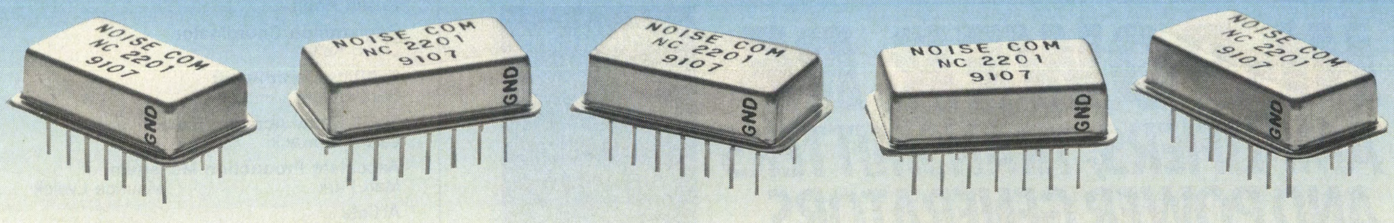
As evidence of our support of this important part of RF business, I will not only be attending both conferences, I'll be chairing the end-user sessions at September's PDC. These sessions are intended to provide users of piezoelectric products with information on applications, performance specifications, product options and circuit design.

If you will be at either of these gatherings, please take a moment to say hello. I'll be asking for your comments on important technology developments, practical engineering concerns, and how *RF Design* can help get you the right information. See you there!

We've Added to Our Staff

Andy Kellett has joined *RF Design* as our new Technical Editor, to help us handle the growing need for information in the RF industry. He is a recent graduate, receiving a degree in Engineering Physics from the Colorado School of Mines, where his studies included research in high temperature superconductors. He also brings a personal interest in RF to the job, as an experimenter and newly-licensed amateur radio operator. You will be hearing from Andy as he prepares some of our industry reports, the New Products, Literature and Software columns, and many of our articles.

Up to 1000 MHz
Up to +5 dBm
14-pin DIP



Noise Com introduces high-power drop-in noise sources...from stock.

When you need the finest high-output noise sources in a 14-pin package for PC board mounting – and you need them fast – look to Noise Com, the leader in noise source technology.

Our NC 2000 amplified noise sources deliver up to +5 dBm output from 1 to 100 MHz. They're available in +15 VDC or +12 VDC models, as well as with TTL control, MIL-E-5400T performance, and with other custom features.

And if you need them fast, we'll ship them to you the same day. Just give Noise Com a call at (201) 261-8797, and ask for Gary Simonyan.

NC 2000 Series Specifications

	NC 2201	NC2301	NC2401	NC2501
Frequency range (MHz)	1 to 100	1.5 to 300	1 to 500	1 to 1000
Output power (dBm)	+5	0	0	–5
Flatness (dB)	+/–1			
Load impedance (ohms)	50			
Operating voltage (VDC)	12 or 15			
Operating temperature (°C)	–0 to +85			
Temperature coefficient	0.025 dB/°C			
Package	14 pin DIP			

NOISE/COM

Number One in Noise Sources.

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

Noise Com now offers noise source calibration traceable to NIST too!

INFO/CARD 5

RF design

a Cardiff publication — Established 1978

Main Office:
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111 • (303) 220-0600
Fax: (303) 773-9716

Vice President — Group Publisher
Kathryn Walsh

Editor
Gary A. Breed

Associate Editor
Liane Pomfret

Technical Editor
Andrew M. Kellett

Consulting Editor
Andy Przedpelski

Associate Sales Manager
Bill Pettit

Account Executive
Maryanne Averill
Main Office

Account Executive
Cindy Wieland
Main Office

Editorial Review Board
Alex Burwasser
Doug DeMaw
Dave Krautheimer
James W. Mize, Jr.
Robert J. Zavrel, Jr.
Ed Oxner
Andy Przedpelski
Jeff Schoenwald
Raymond Sicotte

Advertising Services
Tisha Boberschmidt Hill

Reprints Manager
Mike Martin

Secretary
Theresa Maier

Secretarial Assistant
Lynette Jackson

Convention Manager
Kristin Hohn

Registration Coordinator
Dawn Keith

Exhibits Coordinator
Barb Binge

Trade Show Account Executive
LeAnn Nowacki

Associate Production Managers
Matt Park
Maurice Lydick

Artists
Kim Austin
Joyce Fields
Brad Fuller
Paul Rivera
Sheri Culmer

Composition
Mike C. Moore
Marcie Tichenor

Creative Director
Bob Stewart

Published by

CARDIFF PUBLISHING COMPANY, INC.

BPA

President
Robert A. Searle

Vice President — Production
Cherryl Greenman

Vice President — Convention Management
Kathy Kriner

Vice President — Finance
Jennifer Burger

Vice President — Circulation
Patricia Shapiro

Credit Manager
Tim Gleason

Please address subscription inquiries to:
RF Design
P.O. Box 1077, Skokie, IL 60076-9931
Postmaster: send form 3579
to the above address.

EEsof®

The Key Building Block in High-Frequency EDA Applications

From cellular and satellite communications to radar and electronic defense, EEsof's electronic design automation (EDA) software suite is the key building block in today's rapidly growing RF and microwave applications. In fact, EEsof is the world leader in EDA software tools for high-frequency analog circuit and system design.

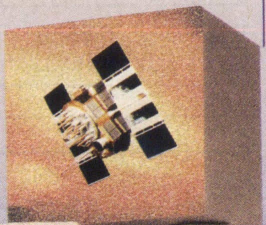
Top electronic engineering firms like AT&T, General Electric, IBM, Motorola, Raytheon and Texas Instruments use EEsof's powerful design-for-manufacturing software to increase design efficiency, reliability and yields while reducing time-to-market.

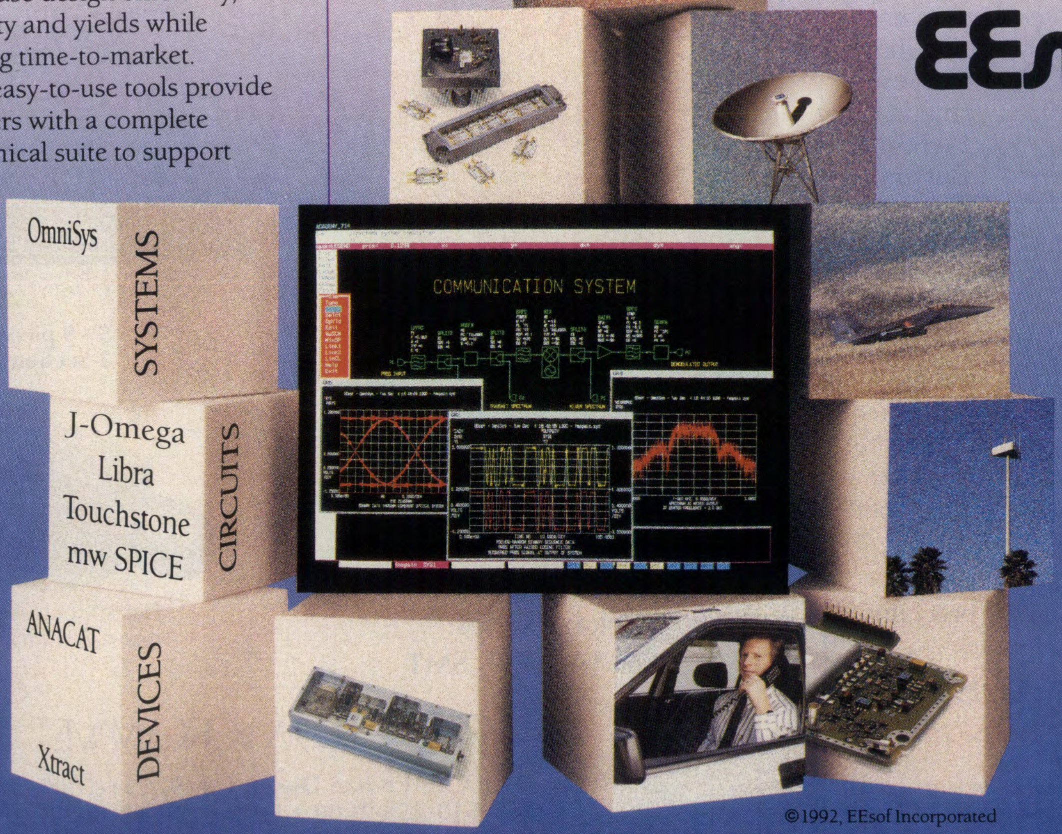
Our easy-to-use tools provide engineers with a complete hierarchical suite to support advanced circuit design... from top-down design of high-frequency systems, to bottom-up development of detailed electrical models. EEsof provides the most complete line of high-frequency simulators, along with libraries of circuit and system models. We support industry manufacturing standards like Gerber,™ GDSII,™ and IGES,™ and interfaces to Cadence, Mentor Graphics and other top EDA vendors.

Make EEsof the key building block in your applications. Call, FAX or write EEsof for more information on the complete suite of integrated high-frequency analog simulation software.

5601 Lindero Canyon Road
Westlake Village, CA 91362 USA
Phone: 1-800-34-EESOF
FAX: 1-818-879-6467.

EEsof®





Come By Our Booth #405 at MTT-S.

INFO/CARD 7

RF letters

Letters should be addressed to: Editor, *RF Design*, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111.

Cable Correction

Editor:

The QMI ad which appeared in the April 1992 issue of *RF Design* contained typographical errors regarding the specifications of the advertised SEMI-FLEX cables. I would like to submit the correct specifications and thank you for alerting your readers to the published errors.

The correct information is:

Specifications @ 18 GHz		
6 inch assembly	601 Series (0.141 dia.)	600 Series (0.086 dia.)
VSWR	Typ. 1.2:1 Max. 1.3:1	Typ. 1.2:1 Max. 1.3:1
Loss	0.55dB (Max.)	0.75dB (Max.)

Paul Tusini
Quality Microwave Inc.

RF Design *regrets any published errors regarding the specifications of the SEMI-FLEX cable in the April 1992 QMI advertisement.* — Editor

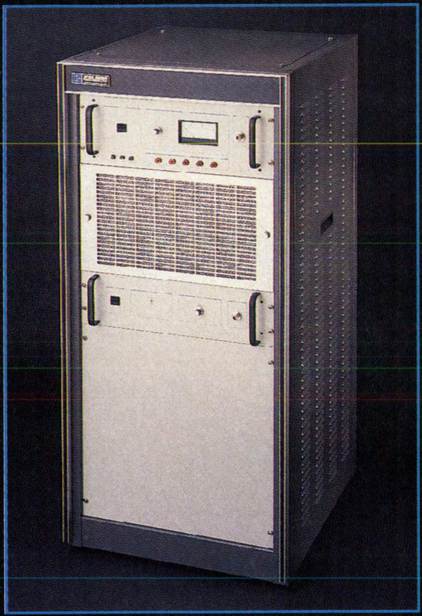
Copyright Credit

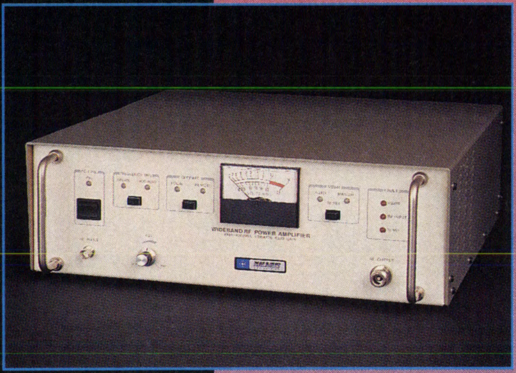
The Smith® charts reproduced in the article "The Smith Chart and its Usage in RF Design" in the April 1992 issue should have included the following credit line:

"The Smith® chart shown is reproduced by permission from Analog Instruments Co., P.O. Box 808, New Providence, NJ 07974."

Readers are reminded that the Smith chart is copyrighted, and its use in publication must reference that fact.


We Just Rewrote The Book
On Performance
...and it's 360
Pages Big!
New In M-92
40 Extra Pages
60 New SMD's
77 New Product Series
Merrimac
RF & MICROWAVE PROCESSING M-92
I & Q Networks
Phase Shifters and Comparators
0°, 90° and 180° Power Dividers / Combiners
2, 3, 4, 8 and 12 Way Power Dividers
Single Sideband Modulators
Image Reject Mixers
Directional Couplers
Surface Mount Devices
Attenuators
Balanced Switches
Active Isolators
Complex Phasing Components
QPL Qualified Devices
Merrimac
Merrimac
Merrimac
Merrimac
Merrimac
CALL OR WRITE
FOR YOUR FREE COPY TODAY
Merrimac
41 Fairfield Place, West Caldwell, NJ 07006
Tel: (201) 575-1300 • FAX: (201) 575-0531
INFO/CARD 10





RF calendar

May

12-14 **Electro '92**
Boston, MA
Information: Electro '92, 8110 Airport Boulevard, Los Angeles, CA 90045. Tel: (800) 877-2668. Fax: (310) 641-5117.

12-14 **IEEE Instrumentation and Measurement Technology Conference**
Meadowlands Hilton, NJ
Information: Robert Myers, 3685 Motor Avenue, Ste. 240, Los Angeles, CA 90034. Tel: (310) 287-1463. Fax: (310) 287-1851.

18-20 **42nd Electronic Components and Technology Conference**
San Diego, CA
Information: EIA, 2001 Pennsylvania Avenue, NW, Washington, DC 20006-1813. Tel: (202) 457-4900. Fax: (202) 457-4985.

27-29 **46th Annual Symposium on Frequency Control**
Hershey, Pennsylvania
Information: Mr. Michael Mirarchi or Ms. Barbara McGivney, Synergistic Management Inc., 3100 Route 138, Wall Township, NJ 07719. Tel: (908) 280-2024.

June

2-4 **MTTS**
Albuquerque, NM
Information: Joyce Long, Horizon House. Tel: (617) 769 -9750.

9-12 **Conference of Precision Electromagnetic Measurement**
CNIT Paris la Defense, Paris, France
Information: Ginette Bonami, SEE, 48, Rue de la Procession, 75724 Paris, Cedex 15, France. Tel: (33) 1 4567 0770. Fax: (33) 1 4065 9229.

10-13 **NAB/Montreux International Radio Symposium and Exhibition**
Montreux, Switzerland
Information: NAB, 1771 N Street, N.W., Washington, DC 20036-2891. Tel: (202) 429-5350.

17-19 **Virginia Tech Symposium on Wireless Personal Communications**
Blacksburg, VA
Information: Ted Rappaport, MPRG, Bradley Department of Electrical Engineering, Virginia Tech, Blacksburg, VA 24061-0111. Tel: (703) 231-5182.

July

1-2 **JEMIMA Measurement Technology Exhibition**
Nagoya, Japan
Information: Japan Electric Measuring Instruments Manufacturers' Association, 1-9-10 Toranomon, Minato-ku, Tokyo, 105, Japan. Tel: (03) 3502-0601. Fax: (03) 3502-0600.

3-7 **International Broadcasting Convention**
Amsterdam, Holland
Information: Secretary, IBC Convention Office, IEE, Savoy Place, London WC2R 0BL, United Kingdom. Tel: (44) 071 240 1871. Fax: (44) 071 497-3633.

Satellite Communication Systems
July 26-31, 1992, Guildford, UK
Information: IEE, Savoy Place, London WC2R 0BL, United Kingdom. Tel: (44)071-240 1871.

Time and Frequency Seminar
June 23-25, 1992, Boulder, CO
Information: Patsy Tomingas, Division 847, NIST, Boulder, CO 80303. Tel: (303) 497-3276.

Frequency Hopping Signals and Systems
May 18-20, 1992, Washington, DC
Satellite Communications Engineering Principles
May 20-22, 1992, Washington, DC
Introduction to Modern Radar Technology
May 27-29, 1992, Washington, DC
Electromagnetic Interference and Control
June 1-5, 1992, Washington, DC
Grounding, Bonding Shielding and Transient Protection
June 8-11, 1992, Orlando, FL
Spread Spectrum Communications Systems
June 15-19, 1992, Washington, DC
Radio Frequency Spectrum Management
June 15-19, 1992, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Merril A. Ferber. Tel: (202) 994-8522 or (800) 424-9773.

Computational Methods in Electromagnetics
June 15-18, 1992, San Diego, CA
Numerical Techniques for RCS Computation and Scattering Center Approach to RCS Modeling
June 15-18, 1992, San Diego, CA
Finite Element and Finite Difference Time Domain Methods for Solving Electromagnetic Engineering Problems
July 28-30, 1992, Champaign, IL
Information: Kelly Brown, Southeastern Center for Electrical Engineering Education. Tel: (407) 892-6146.

Principles of Target Tracking and Data Fusion
June 2-5, 1992, San Diego, CA
Antenna Design
June 9-12, 1992, Silver Spring, MD
Radomes
June 9-12, 1992, Bethesda, MD
Antenna Measurement Techniques
June 16-19, 1992, Rockville, MD
Near-Field Antenna Measurement Techniques
July 7-10, 1992, Boulder, CO
Modern Antennas
July 14-17, 1992, Boulder, CO
Information: Technology Service Corporation, Lynda S. Epstein, Training Coordinator. Tel: (301) 565-2970. Fax: (301) 565-0673.

The EC Directive on EMC
May 15, 1992, Boston, MA
June 4, 1992, Washington, DC
Information: Technology International, Inc. Tel: (804) 644-7735 or (800) 242-8399.

RF and Microwave Circuit Design: Linear and Non-Linear
May 18-22, 1992 Garmisch-Partenkirchen, Germany
RF and Microwave Component Modeling
May 20-22, 1992, Garmisch-Partenkirchen, Germany
Satellite Communications and Broadcasting
June 1-5, 1992, Garmisch-Partenkirchen, Germany
Modern Microwave Techniques: Measurements, Signal and Network Analysis, Microwave Products and Systems Characterization
July 13-17, 1992, Singapore
Aspects of Modern Military and Commercial Radar
July 13-17, 1992, Singapore
Maintaining Signal Quality in High-Speed Digital Systems
July 13-17, 1992, Singapore
Information: CEI-Europe/Elsevier, Mrs. Tina Persson. Tel: (46) 122-175-70. Fax: (46) 122-143-47.

ISO 9000 Introduction and Company Registration
June 2-3, 1992, Danbury, CT
ISO 9000 Internal Auditor Course
June 4-5, 1992, Danbury, CT
Information: TUV Rheinland. Tel: (313) 464-8881.

RF Exposure at Cellular Frequencies: Effects, Evaluation & Guidelines
May 13, 1992, Washington, DC
Spread Spectrum Technologies
May 14-15, 1992, Washington, DC
Information: Cellular Institute, KK Arora. Tel: (703) 516-7630. Fax: (703) 516-4950.

Pulsed EMI
June 25-26, 1992, Minneapolis, MN
Information: Keytek. Tel: (508) 658-0880.

Advanced Linear Design Seminar
May 19, 1992, Saddlebrook, NJ
May 19, 1992, Atlanta, GA
May 20, 1992, Smithtown, NY
May 20, 1992, Tampa, FL
May 21, 1992, Trumbull, CT
May 21, 1992, Orlando, FL
May 27, 1992, Santa Clara, CA
May 27, 1992, Rochester, NY
May 28, 1992, Beaverton, OR
May 28, 1992, Toronto, Canada
May 29, 1992, Montreal, Canada
May 29, 1992, Bellevue, WA
Information: Analog Devices. Tel: (800) 262-5643 or (617) 937-1430.

Modern Power Conversion Design Techniques
July 13-17, 1992, Chicago, IL
Information: e/j Bloom Associates, Joy Bloom. Tel: (415) 492-8443.

RF Shield Effectiveness Test Standards/Specifications for EMI & Tempest: An In-Depth Review
May 18-20, 1992, San Diego, CA

How to Meet EMI/Tempest Shielding Requirements for Rooms and Facilities
June 8-11, 1992, San Diego, CA

Electromagnetic Test Facilities: Design Principles, Applications and Examples
June 8-10, 1992, San Diego, CA

Physical Security Standards for Sensitive Compartmented Information Facilities (SCIF)
June 12, 1992, San Diego, CA

High Power Microwaves: Sources, Systems and Effects
June 15-17, 1992, San Diego, CA

Information: Praxis International. Tel: (215) 524-0304.

DSP Without Tears
May 13-15, 1992, Arlington, VA
June 17-19, 1992, San Jose, CA
June 24-26, 1992, Richardson, TX
June 29-July 1, 1992, Chicago, IL

Information: Z-Domain Technologies. Tel: (800) 967-5034. Fax: (404) 442-1210.

Antenna Theory Simplified
May 14, 1992, Boulder, CO

Information: Henry Ott Consultants, 48 Baker Road, Livingston, NJ 07039. Tel: (201) 992-1793. Fax: (201) 533-1442.

Worst Case Circuit Analysis
May 18-19, 1992, Washington, DC

Information: Design and Evaluation, Inc. Tel: (609) 228-3800.

EC/Design Seminar Series
June 9-11, 1992, Brea, CA
July 14-16, 1992, Tillamook, OR

Advanced HIRF Testing Seminar
April 7-10, 1992, Mariposa, CA

Basic HIRF Seminar
May 27-29, 1992, Mariposa, CA

Information: CKC Laboratories, 5473A Clouds Rest, Mariposa, CA 95338. Tel: (209) 966-5240. Fax: (209) 742-6133.

RF Component Modeling
July 15-17, 1992, Oxford, United Kingdom
August 24-26, 1992, Los Angeles, CA

RF/Microwave Circuit Design Linear and Nonlinear Circuits
July 13-17, 1992, Oxford, United Kingdom

Information: Besser Associates, Eva Koltai. Tel: (415) 949-3300. Fax: (415) 949-4400.

RF Expo West A Hit in San Diego

RF Expo West 1992, held in San Diego during March 18-20, topped the numbers of any previous Southern California RF Expo. Nearly 1700 engineers came to the San Diego Convention Center for classes, technical papers, product exhibits and the opportunity to meet and share ideas with other engineers in this exciting part of the electronics industry.

The opening of exhibits on the first day of RF Expo was kicked off with an intriguing keynote address by CNN and former NBC correspondent Robert Mayer Evans. Mr. Evans has been handling European political and economic reporting for CNN, and was on the scene in Moscow during the attempted coup to overthrow the Presidency of Mikhail Gorbachev. Stressing the theme of global markets and global economic dependency, he found a receptive audience with many RF marketers who are already finding international markets to be a prime opportunity.

Personnel from more than 160 companies were on hand to show attendees the latest RF hardware and software, from test equipment to sophisticated design software; from passive components to advanced semiconductors. Among the products unveiled for the first time at RF Expo West were Sciteq's Arithmetically Locked Loop with fractional division up to 2.4 GHz; Signetics' improved FM and data receiver IC family, the NE624/5/7, with high-speed RSSI; as well as the many products listed in the special RF Expo Products section in the March issue.

Full-day courses have been a major attraction at all RF Expos, with no letup in interest this year. Well over 300 engineers refined their skills in RF Fundamentals, Filters and Matching Networks, and Oscillator Design. Instructors Randy Rhea and Les Besser found many new faces from San Diego and nearby locations.

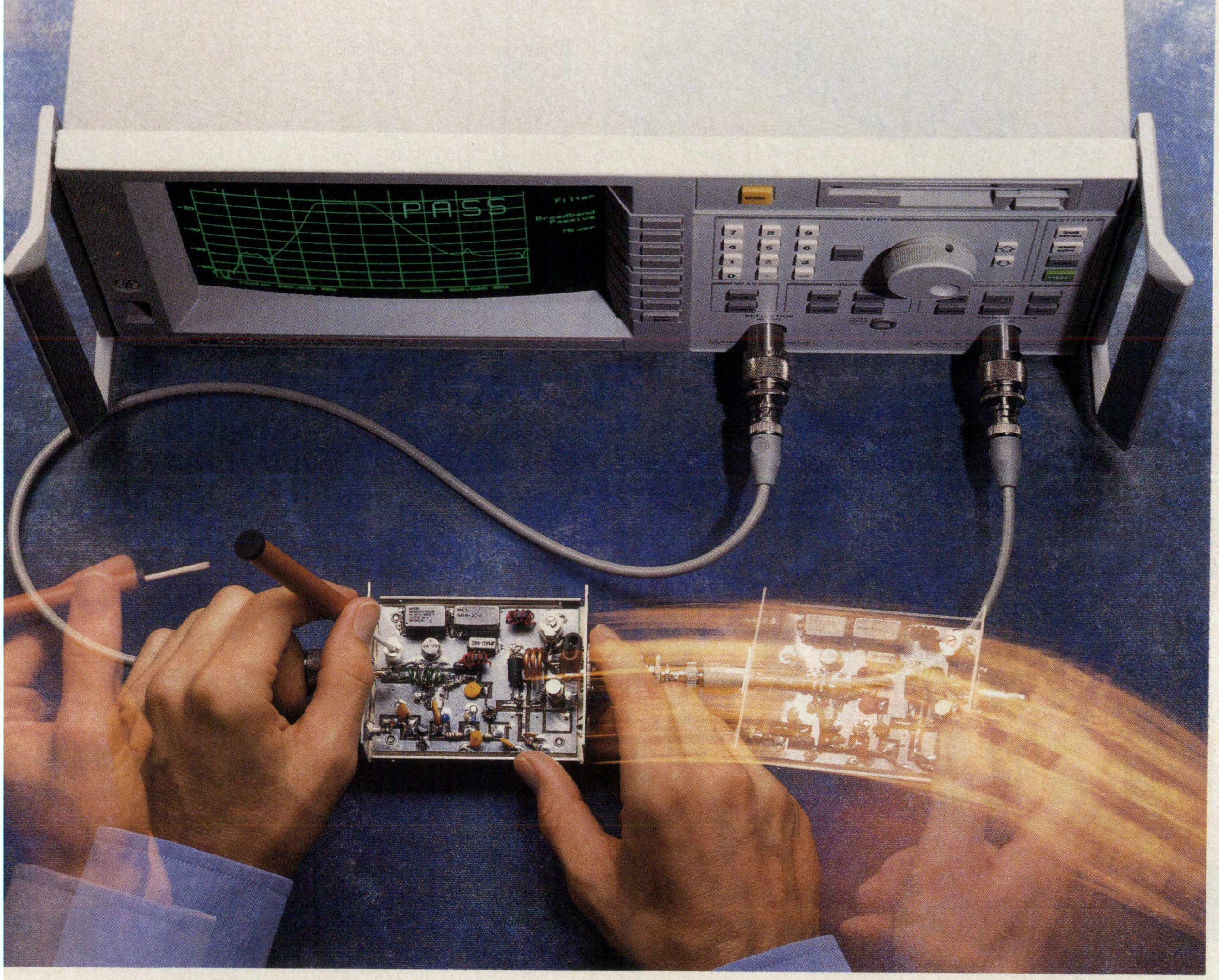
Technical papers were offered on many topics from basic to advanced, including several on full-system design methodology. Prior to Mr. Evans address, two very general sessions were held. One covered the basics of the Smith chart, a universal technical RF subject. The other opening session provided an introduction to modern competitive design principles, such as development teams, shortened design cycles, computer-aided design, and lowest cost component selection and manufacturing methods.

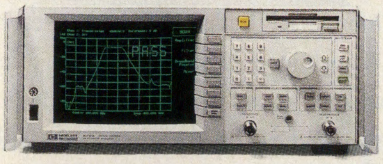
Other papers of high interest included several papers on components for low cost design from Avantek, Siemens and Hewlett-Packard. As has been the case for the past two years, papers on digital modulation, cellular applications, power amplifiers and frequency synthesis drew some of the largest audiences.

The next RF Expo will be held in Tampa, Florida, September 22-24, 1992. For more information, call (800) 525-9154.

New EIA Standards and Publications Catalog — The Electronic Industries Association and affiliated groups have published a catalog containing all their standards, speci-

Break the RF testing speed limit without paying a penalty.





The new HP 8711A makes faster RF testing affordable.

To beat the competition in RF manufacturing, you have to get products tested and out the door faster, while keeping costs down. And with the new HP 8711A network analyzer you can do just that.

The HP 8711A brings fast trace update and synthesized accuracy together for the first time. So you can tune in "real-time" from 300 kHz to 1300 MHz—without frequency drift.

Selectable broadband/narrow-band measurement modes let you test conversion loss of frequency translators and mixers. And make high dynamic range (90dB) measurements on filters and switches. All with the same instrument. You don't even need a computer. Built-in automation lets you race through tests without one.

As for cost control, the HP 8711A is priced so that the only penalty is not having one.

So, move fast. If you'd like more information on the HP 8711A, call your local HP sales office (check the numbers listed below), and find out how you can afford to go a lot faster.

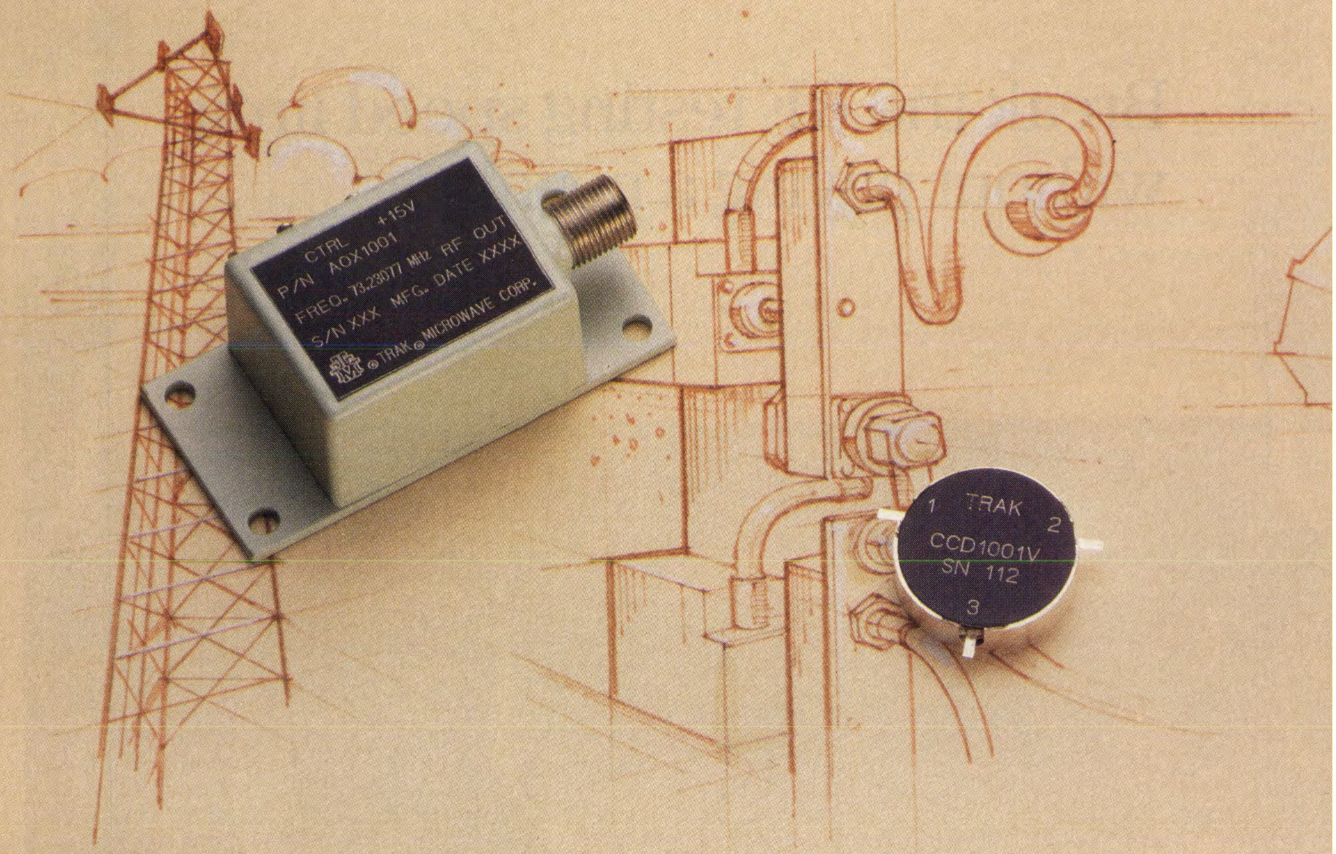
There is a better way.

HEWLETT PACKARD

INFO/CARD 16

United Kingdom (0344) 369 369 • Germany (06172) 16 0 • France (1-69) 82-65-00 • Italy (02) 95.300.134
Singapore (65) 291 8554 • Taiwan (886-2) 714 8740 • Hong Kong (852) 848 7070 • Korea (82-2) 784 2666

See the HP 8711A at MTT-S.



TRAK Commerc

Designed For Quality. Built For Per

Unbeatable Quality

For many years engineers designing circuits over the VHF to microwave spectrum have recognized TRAK as a supplier of top quality components and subsystems.

These products have been used in many applications from the earliest space programs to fighter aircraft to missiles to communication systems.

Leading Edge Engineering

TRAK is recognized for its innovations in RF and microwave product design. Our engineers have shrunk sizes while maintaining high performance and have introduced innovative packaging techniques now emulated by others.

Cellular Radio Circulator

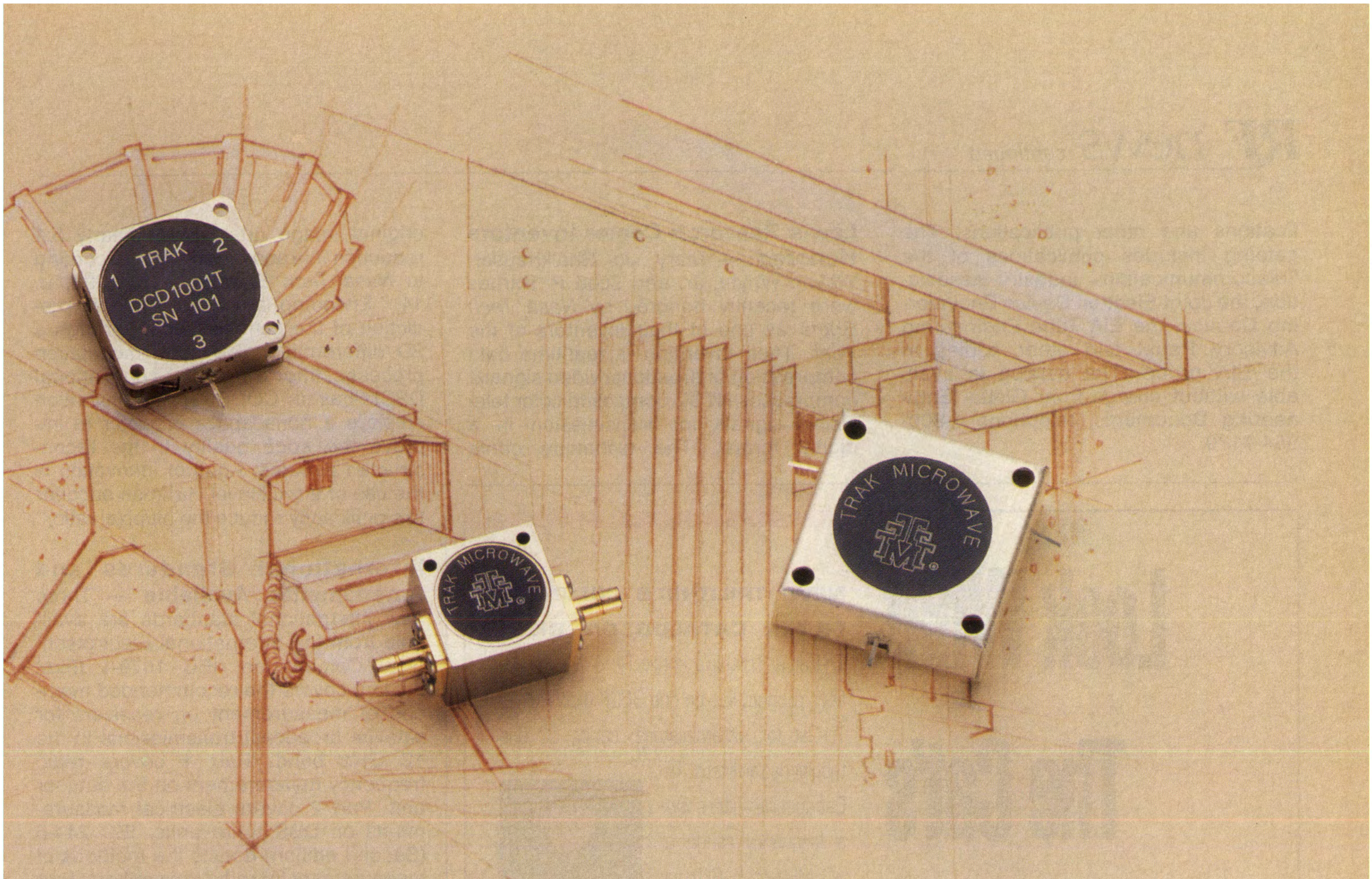
Parameter	Performance
Frequency	860-900 MHz
Isolation	25 dB Minimum
Insertion Loss	0.3 dB Maximum
VSWR	1.19:1
Operating Temp.	0-40°C
Average Power	300 Watts
Peak Power	1 KW
Size	.960 Diameter x .250 High

Enter the Commercial Products Division

Now TRAK's Commercial Products Division offers these well-known TRAK qualities at highly competitive prices for commercial applications. If you don't require the high overhead expense that comes with MI Q-9858A or BS5750 you don't have to pay for it — but you get the same high quality!

Products

TRAK is producing circulators, isolators, crystal controlled oscillators and phase locked oscillators for *Cellul Radio, Wireless Telephone, Microwave Links,* and *Test Equipment.* TRAK Commercial Products Division also



ial Components:

formance. Priced For Competition.

offers frequency multipliers, comb generators, IF amplifiers and synthesizers.

American and European Manufacturing

Our plants in Tampa, Florida and Dundee, Scotland give you a choice. Get the same high quality at commercial prices.

TRAK COMMERCIAL PRODUCTS DIVISION

Call or write:

Jim Riddle
TRAK Microwave Corp.
4726 Eisenhower Blvd.
Tampa, FL 33634
Tel: 813-884-1411
FAX: 813-886-2794

Ken Allstaff
TRAK Microwave Ltd.
4 Lindsay Court
Dundee, Scotland DD2 1TY
Tel: (0382) 561509
FAX: (0382) 562643

TRAK® MICROWAVE CORPORATION

THINK TRAK

TOTAL QUALITY LEADERSHIP

INFO/CARD 17

fications and other publications. The catalog includes publications of the Telecommunications Industry Association, the Joint Electron Device Engineering Council, the EIA Tube Engineering Advisory Panel and other bodies in the EIA group. The catalog is available without charge from Global Engineering Documents, telephone 1-800-854-7179.

Lewis Research Center Inventors Honored — Mary Jo Shalkhauser, Wayne Whyte, Jr. and Scott P. Barnes were recently honored by *Nasa Tech Briefs* as one of their Inventors of the Year. Their invention, a real-time data compression of broadcast video signals, compresses NTSC composite color television signals for transmission in a digital format. The technique offers original image quality with nearly 5:1 reduction in transmitted data. According to *Nasa Tech Briefs* March, 1992, p. 14, "Encoding is accomplished by prediction of the sampled video through a 2D differential pulse code modulation process. Improving on conventional DPCM-based CODECs, the invention employs a nonadaptive predictor to improve the edge quality in the reconstructed pictures. Another innovation is the use of a multilevel Huffman encoder to significantly reduce the bit/pixel ratio."

International Standards and Amendments Available — Three new international standards are available from the International Electrotechnical Commission. IEC 1079-1 (First edition) covers the recommended methods of measurement on receivers for satellite broadcast transmissions in the 12 GHz band. Part 1 covers radio frequency measurement on the outdoor unit. Part 2 covers electrical measurements on DBS tuner units. IEC 244-5 (Second edition) details the methods of measurement for radio transmitters. Part 5: Performance characteristics for television transmitters. Prices for these standards are available from the Sales Department at the IEC Central Office, 3, rue de Varembe, 1211 Geneva 20, Switzerland. Tel: (41 22) 7340150. Fax: (41 22) 7333843.

Hybrid Circuits Conference Call for Papers — The 1992 Microwave Hybrid Circuits Conference to be held October 25-28 in Wickenburg, Arizona has issued a call for papers. The theme of this year's conference is: A New Era: Adapting to the Realities of Today's Microwave Industry. Suggested subject areas include: new applications for microwave, innovative designs, processing and quality, advancements in materials, materials testing, packaging techniques, unsolved problems in design or implementation, software tools and high volume manufacturing methods. Abstracts are due by May 15 and may be sent to the General Chairman, Rick Jansen, Rogers Corporation, 100 S. Roosevelt Avenue, Chandler, AZ 85226. Tel: (602) 961-1382. Fax: (602) 961-4533.

NJIT Opens New Laboratory — The New Jersey Institute of Technology and the New Jersey RF and Microwave Industries Association have opened the Center for Microwave and Lightwave Engineering and the Microwave and Lightwave Engineering Laboratory. The new facility, which houses state-of-the-art measurement equipment and simulation tools, was funded by local and non-local RF, microwave and optical companies.

Telecommunications Test Market Continues to Grow — The market for test instruments used with telecommunications services and equipment was valued at $975 million in 1991. This figure is expected to grow 15 percent annually to reach $1,931 million by 1996 according to a newly published report, "Telecommunications Test Equipment - U.S. Markets and Opportunities: 1991-1996 Analysis." The study provides statistical information and analysis on the markets for analog line test equipment, digital line test equipment, protocol analyzers, optical test sets, automatic test systems, end-user requirements, market trends during the next five years and supplier market shares. The price for the report is $1900 and is available from World Information Technologies Inc., 24 Woodbine Avenue, Northport, NY 11768. Tel: (516) 754-5700. Fax: (516) 754-5746.

New Company Formed to Market New Class of Antenna — Wang-Tripp Corporation has received an exclusive license from Georgia Tech Research Corporation to market a spiral-mode antenna. The antenna, developed by the founders of the new company, combines the broadband frequency performance typical of cavity-backed spiral and sinuous antennas with the surface mount capabilities, size and efficiency of flat microstrip patch antennas. The antenna can be manufactured using conventional printed circuit board technology, thereby keeping costs low. The antenna can be used for applications such as personal communications systems, inter and intra-office communications, wireless local-area networks (LANs), cellular telephones and other mobile systems, global positioning system receivers, intelligent highway systems, direct broadcast satellite systems and many other applications. Because of the antenna's broadband capabilities, a single antenna could serve several systems operating on the same vehicle. That would allow an automobile radio, cellular telephone or other communications equipment to share a single antenna. For more information contact the Wang-Tripp Corporation, 1710 Cumberland Point Drive, Suite 17, Marietta, GA 30067. Tel: (404) 955-9311.

TRAK Forms Commercial Products Division — TRAK Microwave Corporation has announced the formation of a Commercial Products Division to supply RF and microwave components for commercial applications. They will produce crystal controlled oscillators, isolators and circulators for various non-defense systems such as L and S-band communication VSAT, medical equipment and cellular radio.

Comlinear Announces Merger — Comlinear Corporation and Electronic Decisions recently announced a corporate merger. The merger was accomplished with the participation and support of Hughes Aircraft Company. The merger brings together Electronic

Decisions' staff of 55 with Comlinear's of over 150. The company will focus on the application of Acoustic Charge Transport technology, a new gallium-arsenide signal processing technology that is faster and consumes less power than conventional analog or digital approaches. The new Comlinear will consist of several divisions, each focusing on a different aspect of the business.

Two Cellular Operators to Implement Motorola's NAMPS — Motorola recently announced that two major international cellular operators plan to implement their Narrowband Advanced Mobile Phone Service by fourth quarter 1992. Thailand's Total Access Communications and Israel's MTCCL have selected NAMPS for use on their expanding systems.

Radian Corporation Awarded Contract — Radian Corporation has been awarded a contract for the design and fabrication of a 915 MHz Wind Profiler and Radio Acoustic Sounding System (RASS) for the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) program. The experimental objective of the ARM Program is to characterize the radiative process in the earth's atmosphere with improved resolution and accuracy. As part of this contract Radian will deliver and test an improved version of the LAP™-3000 Lower Atmospheric Profiler built under a license agreement with the National Oceanic and Atmospheric Administration. Terms of the contract were not announced.

Synchronous Demodulators Developed — Two new types of synchronous demodulators have been developed by researchers at the Goddard Space Flight Center. The first is an improved analog synchronous demodulator where output ripple is suppressed without an output filter. Low-pass filtering at the input and synchronized switching eliminate the need for the output filter. The second demodulator, a digital synchronous demodulator, offers greater speed, precision and reliability as compared to the analog version. Precise matching of the active and passive components is not necessary in the digital demodulator. Large numbers of samples can be accumulated thereby reducing the amount of error contributed by the analog-to-digital converter and results in higher precision measurement. This work was reported in the March 1992 edition of *Nasa Tech Briefs*. Both inventions have had patent applications filed for and inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Donald S. Friedman, Goddard Space Flight Center, Mail Code 702.1, Greenbelt, MD 20771. Tel: (301) 286-6242.

Ball and Rockwell International Sign Agreement — Ball Corporation has recently signed a non-exclusive general terms agreement with Rockwell International. Under the terms of the contract Rockwell has guaranteed the purchase of 10,000 Ball GPS antennas. The contract potential value is several million dollars over the next three years. Ball's GPS antennas will be offered by Rockwell to original equipment manufacturers for configuration into a variety of GPS receiver products which include Rockwell's GPS NavCore V receiver.

Watkins-Johnson Wins Contract — Watkins-Johnson Company has announced that it has been awarded a contract valued in excess of $15.6 million by Hughes Aircraft Company, Missile Systems Group. Under the contract, W-J will continue production of radio frequency data-link processors for Lot V of the AIM-120 Advanced Medium-Range Air-to-Air Missile. The contract also calls for the production of an improved microwave assembly and radio frequency head component for the missile.

Joint Venture Team Awarded Contract — AEL Defense Corporation and their joint venture partner, Lockheed Sanders have received incremental funding of $23.9 million of a $47.8 million contract to produce seven engineering development models of the TACJAM-A mobile tactical Electronic Surveillance Measures (ESM) system from the U.S. Army Communications and Electronics Command. The TACJAM-A program will provide the next generation communications jamming technology designed into a multi-platform, modular signal intercept and jamming system.

The RF Job Market: How to Compete

By Gary A. Breed
Editor

After several years of intense observation and analysis of the career opportunities for RF engineers, it can be said with certainty that the job market is stagnant right now. There are many jobs open, but not enough for the many engineers who are looking for work.

In general, military contractors are laying off engineers of all sorts, including those working on RF design and communications systems. In locations where military contractors are major employers, this has upset the job market for commercial RF engineering positions.

Also, commercial hiring is very uneven. A few positions are open in specialized applications like Part 15 spread spectrum, high speed data transmission, and high reliability medical equipment. A few companies are hiring aggressively; Motorola reports openings for entry-level engineers, Ford Motor Company was recruiting at the recent RF Expo West, and several cellular operating companies are looking for engineers to do system planning. Most companies are either maintaining steady levels of staffing, or reducing staff as engineers leave for retirement or other positions.

A good example is the Colorado Front Range, a substantial high-tech region with strong military operations, space technology, large commercial equipment companies and many small and mid-sized entrepreneurial firms. The Department of Labor says that Colorado has one of the lowest unemployment rates in the country, but those statistics do not fit the engineering job market, especially RF.

In the past several months, *RF Design* magazine and some of its sister publications have hired technical editors, most positions requiring a BSEE. A few observations can be made from the number and types of applicants for these technical positions. First, the unemployment situation for engineers is substantial, despite the overall low unemployment rate. Much of this excess labor pool is due to layoffs at defense contractors; these engineers are saddled with secrecy requirements and can't fully explain their experience or past duties! Also, unfortunately, those laid off engineers do not always represent the best talent, as companies reassign their best people to other projects.

Another observation is that the overall economy is the main force behind current job market difficulties. Engineers of all disciplines and specialties are looking for work. Some are willing to explore new career paths, and are seeking the same RF positions for which a new or junior engineer would normally be considered. This confuses the job market even more.

Recommendations for Job-Seekers

Despite the overall employment situation, there are a good number of RF engineering jobs waiting to be filled. To help get those jobs, we have collected a few suggestions from engineering managers who are either directly responsible for hiring, or who work closely with their personnel departments.

Two factors require attention — First, most jobs (certainly the best ones) have specific requirements for experience and expertise. Companies do not want to take the time for retraining, even for a brilliant engineer. Also, your application will be competing with a huge number of others, so it must stand out in a positive way.

Often, an engineer with the right experience is not available for an open position. As a result, important engineering positions remain unfilled, even when hundreds of applications are received. Currently, companies are looking for a fast start on designs involving digital modulation and demodulation, for low cost systems operating in the 800 MHz to 2.4 GHz range requiring specific experience with cellular, GPS, data communications, automated assembly or offshore manufacturing. Of course, there are relatively few engineers with this kind of experience, and they already have good jobs!

When the position can no longer remain open, someone must be selected from the collection of resumes and referrals. This is where you can help your own cause:

Write a new resume for each job. Managers are looking for a specific set of qualifications. Make sure all your relevant study and experience is brought out; relate them to the job you are seeking. Don't dwell on other skills unless they demonstrate exceptional ability. Don't try to be fancy, just offer a clear presentation of your abilities. Don't over-sell yourself; the person interviewing you will know it — guaranteed!

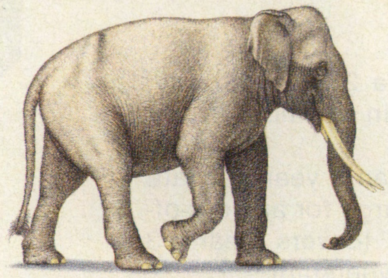
Learn new skills; brush up on old ones. Although specific experience is ideal, employers can't always find it. Your chances to stand out from the crowd improve if you can demonstrate significant knowledge of the desired subject, even if you have little actual experience. For example, you can experiment with DSP for about $500 using kits from major chip manufacturers. Short courses and extension classes can build your knowledge on current "hot" subjects like spread spectrum. Read everything you can to gain knowledge of the technology and marketplace your prospective employer is in.

Be professional. No one should have to remind you, but engineering managers say that basic grooming, professional appearance and presentation are still problems with many engineers. Modern RF engineers are no longer isolated tinkerers. Interaction with customers and suppliers, attending meetings, and exchanging information within a development team require better "people skills" than past engineers needed.

Finally, the good news is that many new RF applications are waiting for development. As the economy improves, and as regulatory hurdles are cleared, there will be new products for RF engineers to create as companies move from advanced development into actual product design. **RF**

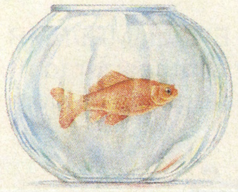
For reprints of this report, contact Cardiff Publishing Company at (303) 220-0600. Ask for the Circulation Department.

A New Breed Of TCXOs That Combine Some Very Important Features.



Stable

Compact



Affordable

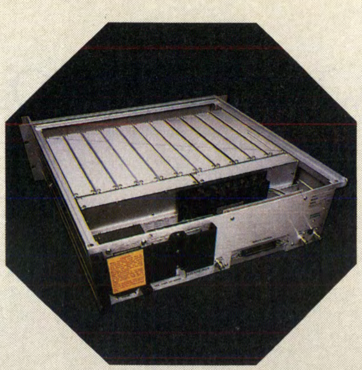
From avionics and instrumentation to communications and medicine, the new TCXOs from Oak Frequency Control Group combine stability and affordability. In extremely compact sizes. For more information about TCXOs from Oak, call 717-486-3411, fax 717-486-5920, or circle number 127 on your reader service card.

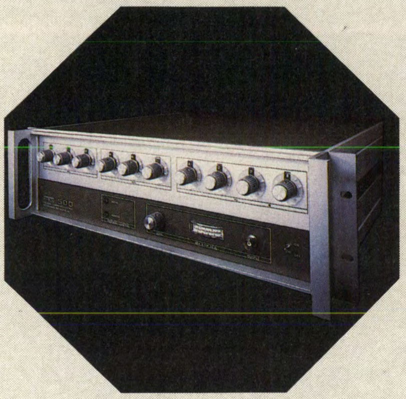
Series	Freq. Range	Output	Stability	Size	Features
185	3 - 150 MHz	Sine	+/- 1.0 to +/- 5.0 PPM	2" X 2" X .55"	wide frequency range, military and commercial applications
934	10 -20 MHz	TTL	+/- 3.0 to +/- 5.0 PPM	.820" X .525" X .395"	4-Pin DIP replacement for clock oscillator, low cost
103M	10 - 50 MHz	TTL	+/- 1.0 to +/- 5.0 PPM	.970" X .795" X ..375"	16-Pin DIP, hybrid construction Class B-Military
544	3 - 25 MHz	TTL or HCMOS	+/- 0.5 to +/- 5.0 PPM	1.00" X 1.00" X .500"	1" square metal package, low phase noise, +5 VDC
100	.2 - 25 MHz	TTL or HCMOS	+/- 1.0 to +/- 5.0 PPM	1.40" X .8" X .375"	24-Pin DIP, low power, hermetically sealed
355	3 - 20 MHz	TTL, Sine, HCMOS	+/- 0.5 to +/- 2.0 PPM	1" X 1.5" X .5"	non-hermetic package, low cost, commercial applications

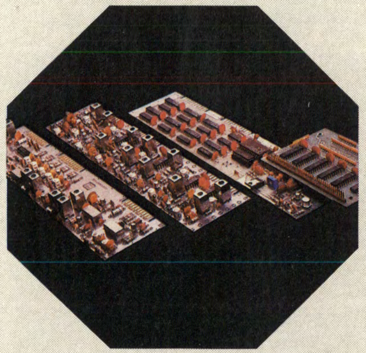
McCoy · Ovenaire · Croven

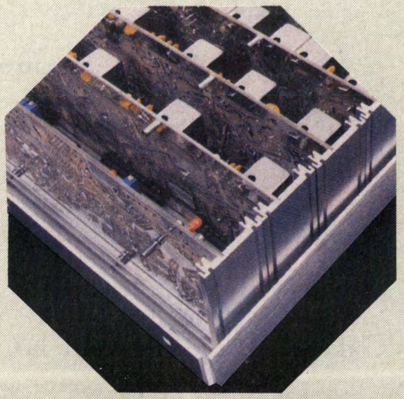
an Oak Industries Group of Companies

INFO/CARD 127









PTS 310

Fast Frequency Measurement Analyzes Modulation and Oscillators

By Douglas Barker
Philips Test and Measurement Group
John Fluke Mfg. Co., Inc.

The oscilloscope and spectrum analyzer are standard equipment on any RF designer's bench. Oscilloscopes are time domain instruments. Both analog oscilloscopes and digital storage oscilloscopes perform the same basic function of displaying signal voltage versus time. Spectrum analyzers operate in the frequency domain, measuring the spectral components of signals in amplitude versus frequency form, typically using a swept narrow band receiver technique. Both the oscilloscope and the spectrum analyzer continue to serve us well for most applications. However, another measurement technology, based in the modulation domain, may soon take its place beside these two.

In Figure 1, the axes of time, frequency, and amplitude illustrate the close relationship between the time domain, frequency domain, and the modulation domain. The signal shown is the output of a 50 MHz oscillator which can be looked at in any of the three domains. The significance of choosing one domain over another is really a matter of choosing the best measurement technology for your task. Suppose our task is to analyze the performance of this 50 MHz oscillator. The oscilloscope is the ideal general purpose tool that can provide amplitude, frequency, and time information for the signal. The oscilloscope, using cursor functions to measure a few periods of the waveform, tells us the frequency is 50.0 MHz, its amplitude is 1 Vpp, and that, visually, the wave-shape looks like a "pretty good" sine wave. For detailed spectral information on the signal, such as its harmonic distortion, the spectrum analyzer is the right choice. The spectrum analyzer can also tell us that the frequency is 50.0 MHz, the amplitude of the fundamental carrier is +4 dBm, and that the second harmonic is −45 dBc, a more precise indicator of the sine wave purity. The spectrum analyzer may not be able to provide a real-time picture of rapidly changing signals because of limitations in sweep speed and resolution bandwidth. To more clearly understand the frequency behavior of the oscillator, either in terms of short-term jitter or long term stability, the frequency counter is the right choice. What has made the frequency counter a more powerful option is the vastly increased measurement speed, resolution and analysis power unavailable in a cost-effective product until recently.

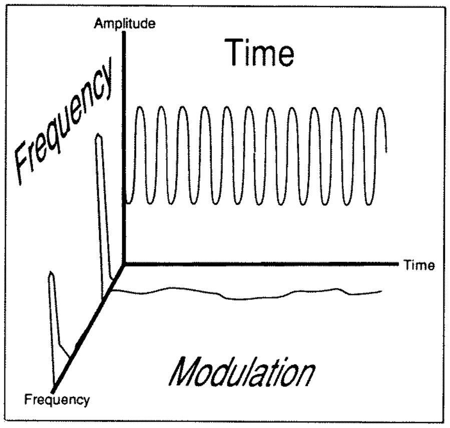


Figure 1. Time, frequency, and modulation domains.

Frequency counters have gotten a lot faster and more capable, creating a whole new range of measurement possibilities for the traditional frequency counter. Measurement speeds in thousands or even millions of readings per second are now possible. Equally important is improved frequency resolution, now at 10 digits of resolution per second of measuring time. New analysis tools, either built into the instrument or in software, provide quick access to frequency versus time plots, histogram plots, and mean, standard deviation, and min/max calculations.

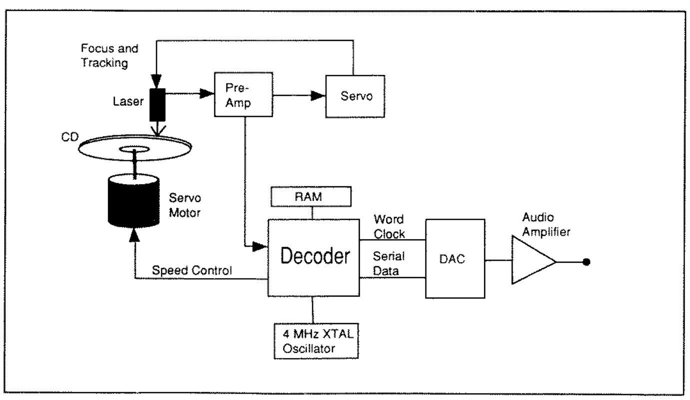


Figure 2. Block diagram of a typical compact disk player.

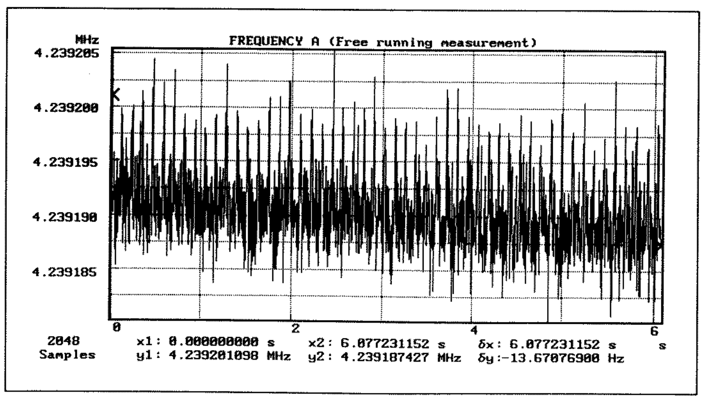


Figure 3. Frequency versus time plot of CD player oscillator.

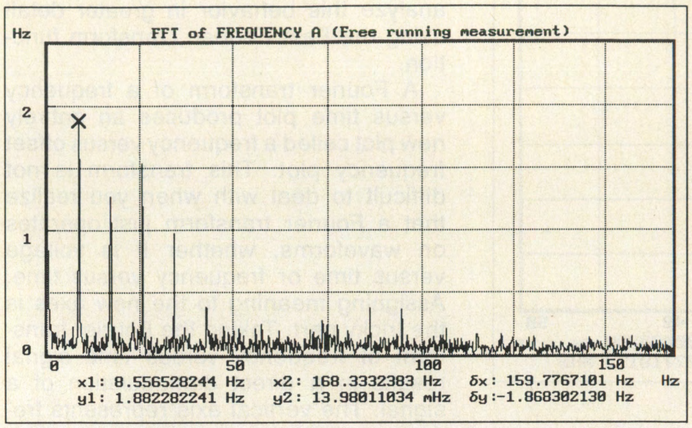


Figure 4. Frequency versus offset frequency of 4.239 MHz oscillator.

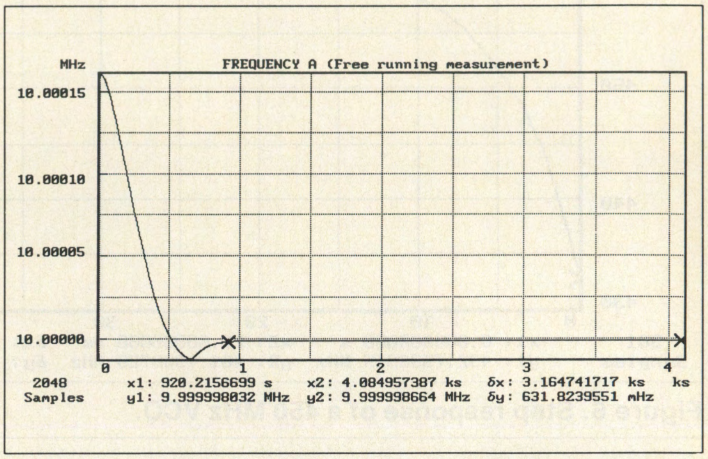


Figure 5. Oven oscillator warm up curve.

This new class of measurements has been dubbed the modulation domain. Modulation domain analysis was previously available only in analyzers costing $20,000 and over. The Philips PM 6680 frequency counter/timer and TimeView software now provide this capability for less than $3,000. TimeView is a PC-based software package for analyzing time and frequency data from the PM 6680. The best way to illustrate the power of modulation domain analysis is with some real measurement examples.

Analyzing Clock Jitter in a CD Player

Compact disk players are complex systems containing electro-mechanical servo loops to rotate the disk and position the laser, digital filters and decoders to handle the digital data, and an analog audio chain down-stream from the D/A convertor for the right/left audio channels. Figure 2 shows a typical block diagram of a CD player.

CD players depend on crystal oscillators, typically using low-cost AT crystal strip resonators to maintain system stability. All major clock functions and sampling rates are derived from this 4 MHz clock.

Looking at only a few samples of the 4 MHz crystal oscillator output with an oscilloscope showed a visible amount of jitter on the signal. Other than knowing that short term stability does not look good, there is no further analysis we can do with the oscilloscope. A fast frequency counter is just the right tool.

The frequency counter was set up for 2.5 ms measuring time per point and 2048 samples (about 5 seconds of data) were collected and displayed (Figure 3) using the TimeView software package and the Philips PM 6680 counter. Although this plot may look a lot like a conventional oscilloscope plot, the information being displayed is quite different. Instead of sampled voltages, this plot displays calculated frequencies, which are averaged over the measuring time between successive points. Measuring times and sample intervals can be independently set.

From the data in Figure 3, the oscillator appears to be frequency modulated at a periodic rate by an impulse waveform. The average height of the spikes is approximately 6 Hz off the main carrier of 4.239 MHz. We can

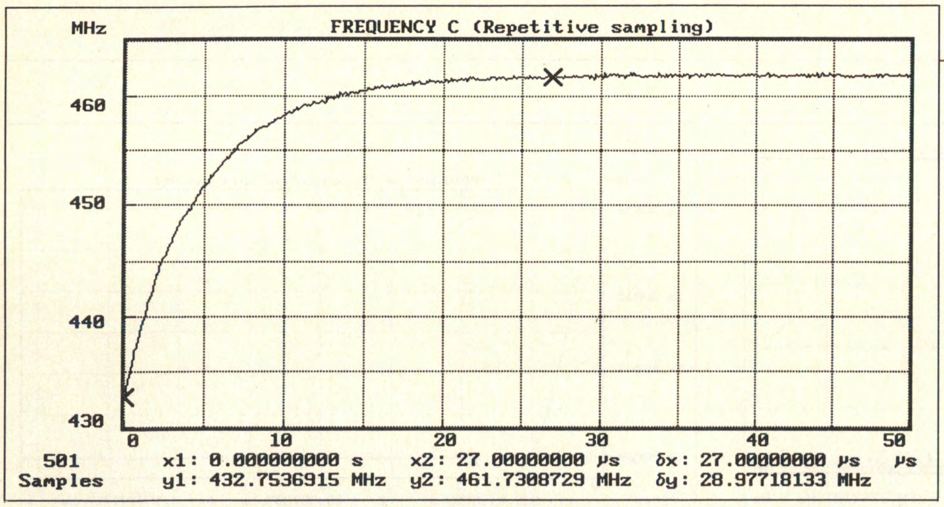


Figure 6. Step response of a 450 MHz VCO.

analyze this behavior in greater detail using the Fast Fourier Transform function.

A Fourier transform of a frequency versus time plot produces an entirely new plot called a frequency versus offset frequency plot. This transform is not difficult to deal with when you realize that a Fourier transform just operates on waveforms, whether it is voltage versus time or frequency versus time. Assigning meaning to the new axes is the tricky part. Taking the Fourier transform of frequency versus time signal results in a direct demodulation of a signal. The vertical axis represents fre-

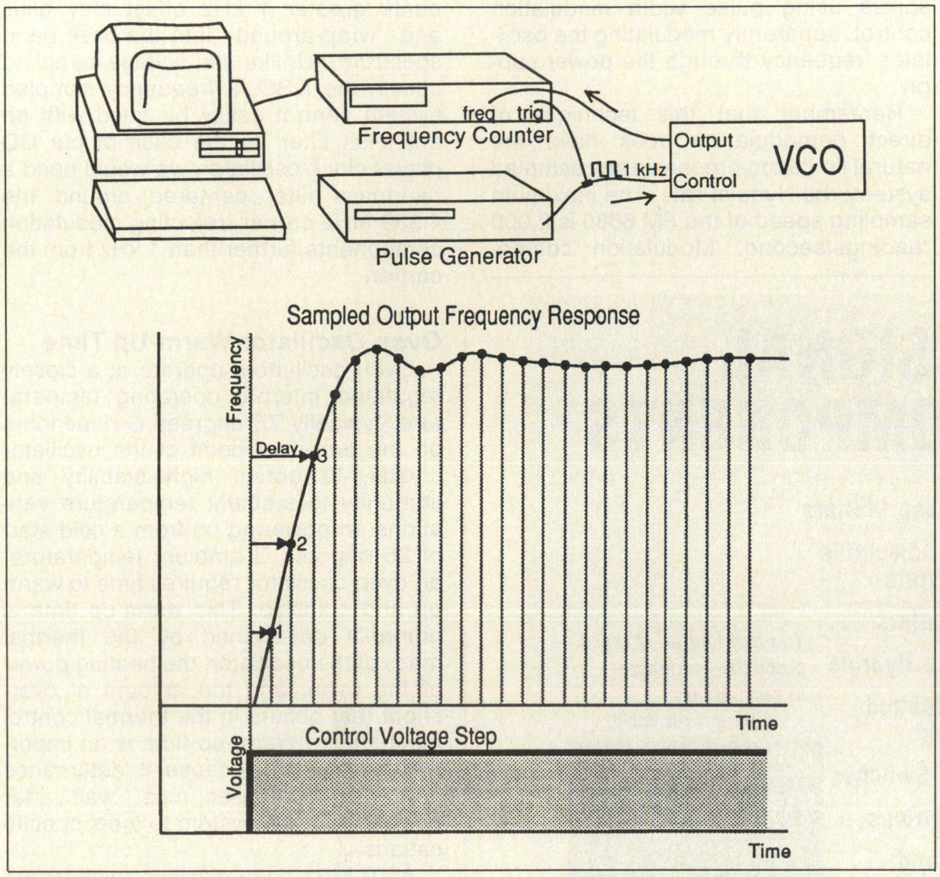


Figure 7. VCO step response test set-up.

quency deviation in Hz. The horizontal axis is the frequency offset from 0 Hz. There is no need to convert the signal down to baseband in order to see the modulation products.

In Figure 4, the carrier component, at 0 Hz offset with 4.239 MHz "deviation", is clipped in order to zoom in on the modulation components which happen to be down in the Hz range. The modulation is highly periodic over the 5 second time record, since there is very little spreading in the sidebands. The fundamental frequency is 8.56 Hz. The modulation waveform is mainly an impulse as we can see that it is rich in both even and odd harmonics.

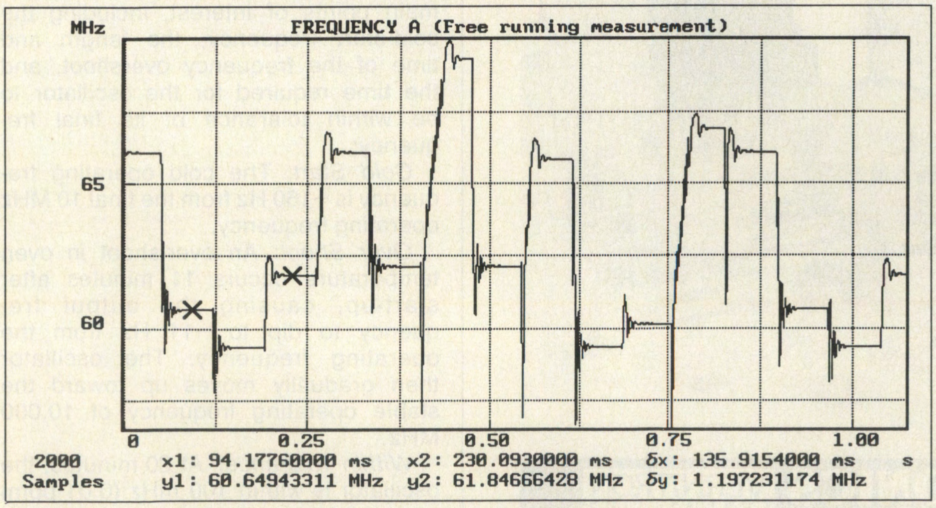


Figure 8. Frequency versus time plot of frequency agile local oscillator.

Checking this frequency against other system elements in the CD player to find the source of the modulation, the 8.56 Hz frequency exactly matched the rotation frequency of the compact disk (513 rpm). Note that a CD player is a constant-velocity mechanism and the disk rotation speed can vary between 400 and 800 rpm depending on the track. The drive motor draws current in spikes using pulse width modulation control, apparently modulating the oscillator frequency through the power supply.

Remember that this technique of direct demodulation does have the natural limitation present in any sampled system: the Nyquist rate. The maximum sampling speed of the PM 6680 is 2,000 readings/second. Modulation components greater 1 kHz offset may alias and "wrap-around" into the base band spectrum. Unlike its voltage-sampling cousin the DSO, a frequency sampled system cannot easily be fitted with an anti-alias filter. In the case of our CD player clock oscillator, we would need a bandpass filter centered around the 4.239 MHz carrier, rejecting modulation components further than 1 kHz from the carrier.

INFO/CARD 29

Oven Oscillator Warm-Up Time

Oven oscillators operate at a closely regulated internal operating temperature, typically 75 degrees C depending on the turn-over point of the oscillator crystal, to obtain high stability and immunity to ambient temperature variations. In powering up from a cold start of 25 degrees C ambient temperature, an oven oscillator requires time to warm up and stabilize. This warm-up time is primarily determined by the thermal mass of the oscillator, the heating power of the oven, and the amount of overshoot that occurs in the thermal control mechanism. Warm-up time is an important parameter because it determines how long the user must wait after power-up for his system to meet specifications.

A 10 MHz oven oscillator was tested for warm-up time by powering it up from cold start and measuring its output frequency over 2 second intervals.

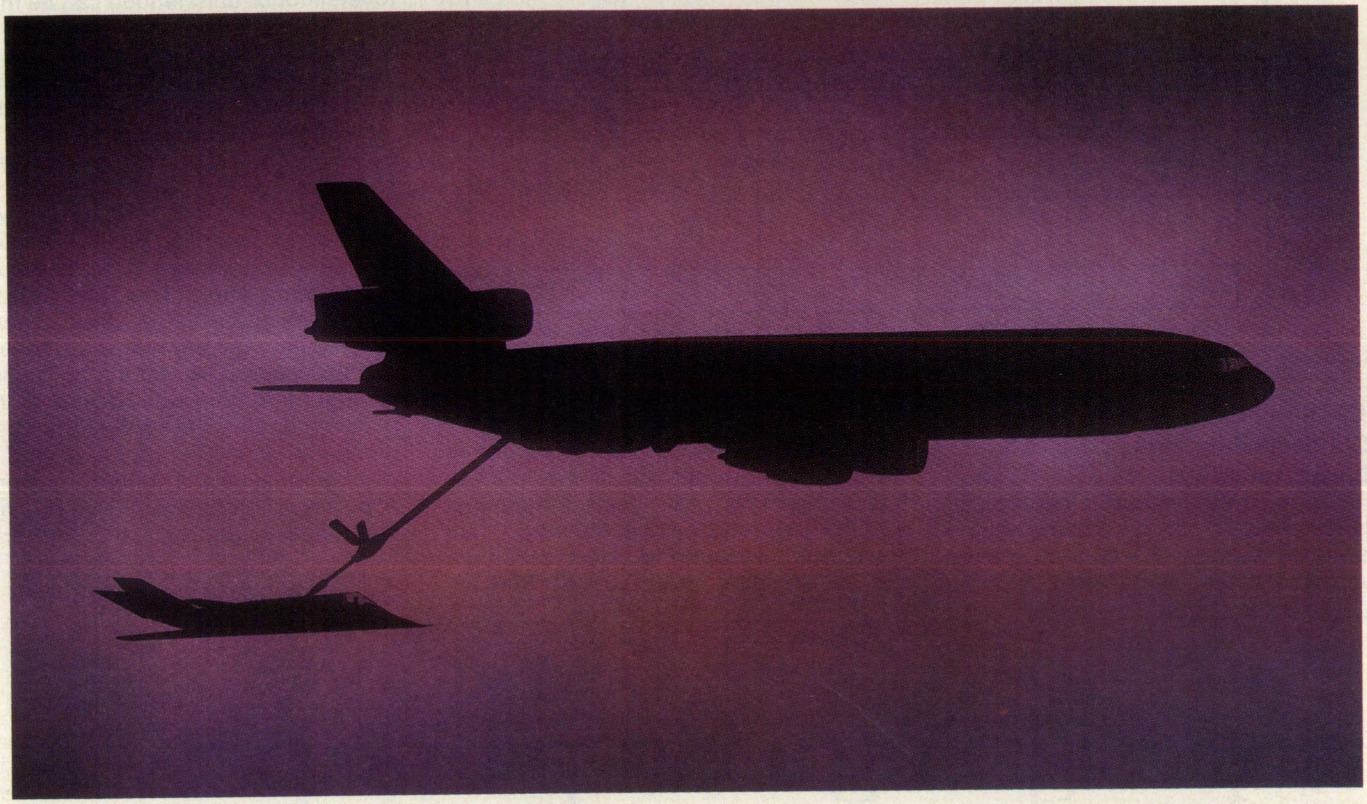
The data in Figure 5 was gathered over a time period of 4000 seconds beginning at oscillator cold-start. The oven warms up very rapidly in the beginning, over-shoots the final operating temperature, and slowly ramps back in. The warm up curve has three main points of interest, including the cold-start frequency, the length and time of the frequency overshoot, and the time required for the oscillator to be within tolerance of its final frequency:

Cold Start: The cold operating frequency is +160 Hz from the final 10 MHz operating frequency.

Over Shoot: An over-shoot in oven temperature occurs 11 minutes after start-up, causing the output frequency to dip to −11 Hz from the operating frequency. The oscillator then gradually moves up toward the stable operating frequency of 10.000 MHz.

Within Tolerance: At 20 minutes, the oscillator is within 100 mHz (0.01 ppm) of the 10 MHz operating frequency.

FUELING THE NEXT GENERATION IN DEFENSE ELECTRONICS



The Commitment of HP, the Technology of Avantek.

Avantek, the innovative and reliable MIL SPEC RF/microwave component manufacturer you've trusted for the past quarter century now has the backing and resources of Hewlett-Packard. And a new commitment to meet your defense/aerospace program requirements far into the next century.

We're proud to have played a part in many of your EW, ECM, C^3I, and guidance programs, such as:

ASPJ, APG-68, MIMIC, ALQ-142, LANTIRN, ALR-67, EA6B/ADVCAP... AN/APR-50, SSMIS, ALQ-162, HARPOON, ALQ-161, ICS-B1B... TPQ-37, TORNADO-ELS, ALR-85, DESM, ALQ-184, ESM... GD53, ALQ-94/137, GPS, ALQ-99, AMRAAM, ALQ-117/172, S3B... TPQ-36, PAVEMINT, ALQ-119, RAPPORT, ALR-56C/M... SUPER-CVR, APR-50, AQUILA, SLQ-32, ERINT, APG-65, SM-2, APG-164... MILSTAR, ALQ-126B, HARM, ORC-80, RAPIER, ALQ-131, JAS-RADAR... ALR-62(I), ALARM, APG-66, ZEUS, ALQ-135, ADVANCED(PAT)... ALR-64, PATRIOT, ALQ-137, DCSC, ALR-66, MANPACK...

And, we're taking this opportunity to tell our customers we will offer a renewed dedication to design, develop and deliver the highest performance RF/microwave ICs, components, and sub-assemblies available *anywhere.*

We've geared up to meet your requirements. With the vanguard technology of Avantek, combined with HP's tradition of reliability, competitive pricing and customer service, we're just what you'll need in the next generation of defense electronics.

The Next Generation in Defense Electronics is Here.

As you begin making the critical choices for platform retrofits and next generation programs, from conformal/steerable array radar, to anti-stealth platforms, to microexpendables, advanced countermeasures, and communications systems, call Avantek. We're poised for the long run—thanks to HP—and we're looking to bring our new team to your new team.

For additional information call:

USA:	1 (800) 752-0900 ext. 3203
Canada:	1 (800) 387-3867 dept. 3203
Europe:	44-276-685753

AVANTEK
A Subsidiary of Hewlett-Packard

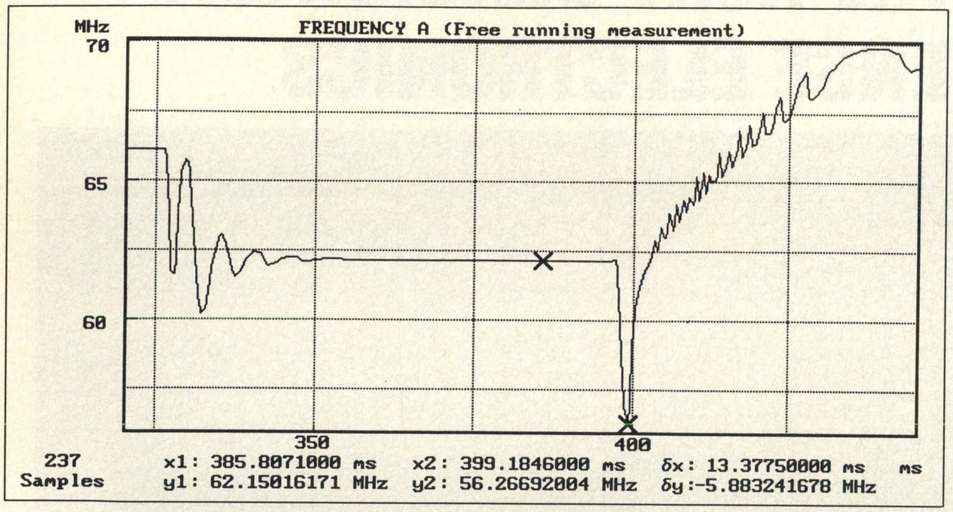


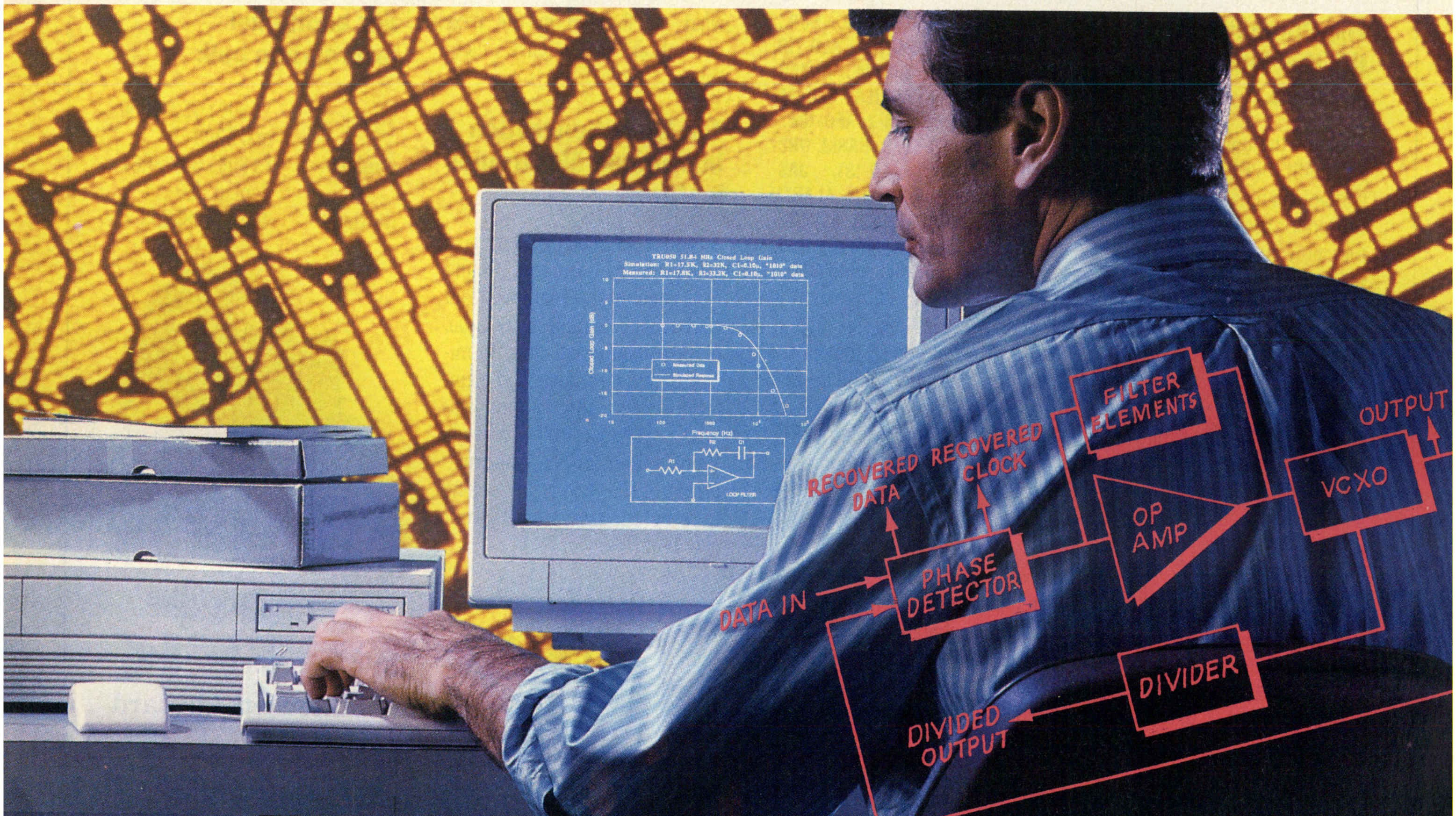
Figure 9. Zoom-in view of oscillator "drop-out."

VCO Step Response Characterization

Voltage controlled oscillators are usually characterized by plotting output frequency versus DC control voltage. Such plots are useful and easy to do. Often overlooked, however, is the dynamic response of the VCO to fast-changing AC control voltages which are often encountered in real systems. Measuring step response is a standard measure of the dynamic behavior of the VCO. From the step response, parameters such as frequency slew rate (how fast the VCO can change frequency) and damping (overshoot or undershoot) can be measured.

From the curve in Figure 6, we can see that the VCO is under-damped and requires approximately 27 us to slew from 432.7 MHz to 461.7 MHz. This curve was created with an equivalent sampling rate of 10 MS/s using the Philips PM 6680 and TimeView software in repetitive sampling mode. Measuring this step response at 10 MS/s requires a little extra effort. The TimeView software package has a repetitive sampling mode that automates the measurement process. The test set up is shown in Figure 7. As with digital storage oscilloscopes, the waveform being measured must be repetitive and the counter must have a stable trigger point. A pulse generator, with 2 ns rise time, was used to generate the step waveform.

The step waveform created by the



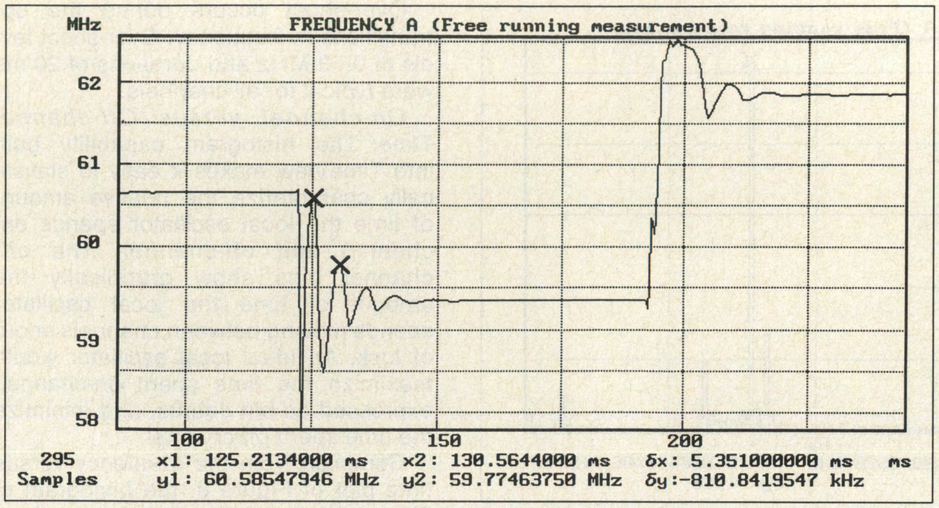


Figure 10. Close-up view of the overshoot and ringing.

pulse generator is actually a 1 kHz square wave. The frequency counter triggers off the positive edge of the pulse and measures the instantaneous frequency of the VCO at varying delays off that edge. By successively delaying the measuring further and further from the trigger point, the step response is reconstructed from the repetitive series of measurements. The maximum resolution of this programmable time delay is 100 ns, which gives a maximum equivalent sampling rate of 10 MS/s.

Frequency-Agile Local Oscillator Performance

The local oscillator is one of the key subsystems in a frequency agile receiver. Such a subsystem might consist of a programmable frequency synthesizer phased locked to a voltage controlled oscillator. As new frequencies are sent to the synthesizer, the VCO must follow and maintain phase lock. By rapidly sampling the output of the VCO using a frequency counter, the real performance of the local oscillator subsystem can be determined.

The receiver being tested had a local oscillator that ranged between 56 and 70 MHz. Figure 8 shows a 1 second time record of the local oscillator as it switches from channel to channel. From this plot, we can make a number of observations regarding its performance:

Slew Rate: The slew rate of the local

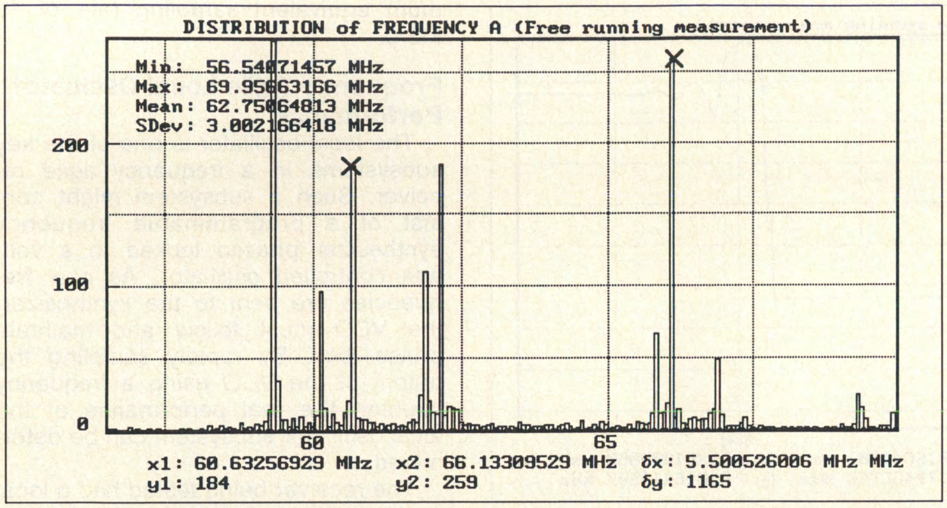


Figure 11. Histogram of frequency counts.

oscillator is significant in that it can significantly reduce the amount of time the receiver spends on channel if the VCO has to move a long way to get there. During small frequency transitions with negligible slew time, on-channel time is around 60 ms. During large frequency transitions involving a significant amount of slew time, on-channel time drops to 27 ms. The upward slew rate of the oscillator is 227 MHz/ms. The worst case slew time is from the lowest channel (59.35 MHz) to the highest channel (69.35 MHz) is 44 ms. The down-ward slew rate of the VCO is nearly 10 times faster.

Drop-Outs: The plot also shows several frequency "drop-outs" as indicated by the sharp down-ward spikes where the local oscillator appears to lose its loop error voltage. A quick zoom-in shows these spikes are real, with 5 - 10 frequency samples that give a shape to the drop-out. The oscillator appears to lose the loop error signal altogether, regaining it after about 4 ms. The depth of the drop-out is around 5 MHz. The reason for these drop-outs is unclear but may be related to delays in setting up the divider chain during a frequency change.

Ringing and Overshoot: There is a significant amount of overshoot (moving up toward phase lock) and ringing (moving down toward phase lock). Using the Zoom feature of TimeView, we can take a closer look at the over-shoot and ringing.

The ringing occurs during the down-transitions in frequency from one channel to another. In our picture, the ringing has a period of 5.3 ms, as shown by the cursors on the crests of the waveform, a ringing frequency of about 190 Hz. The ringing dies out after 25 ms, leaving 47 ms of usable on-channel time.

Over-shoot occurs during the up-transitions in frequency. Over-shoot levels of 0.53 MHz and durations of 20 ms were typical for all channels.

On-channel versus Off-channel Time: The histogram capability built into TimeView makes it easy to statistically characterize the relative amount of time the local oscillator spends on-channel and off-channel. The off-channel bins show graphically the amount of time the local oscillator spends moving between channels or out of lock. An ideal local oscillator would maximize the time spent on-channel, expressed as bin counts, and minimize the time spent off-channel.

Compiled from the frequency versus time plot of Figure 8, the histogram of Figure 11 shows the relative amount of time the local oscillator spends at each frequency, recorded as bin counts. The tallest 9 bins are the on-channel bins. The off-channel bins show the results of ringing and overshoot in the bins surrounding the on-channel bins. Slew-rate limitations increase the counts between widely spaced channels. The highest channel, at 69.35 MHz, clearly suffers from oscillator slew rate and overshoot deficiencies which significantly reduce the ratio of on-channel to off-channel counts.

Conclusion

The examples covered illustrate the wide variety of measurements that cannot otherwise be done with conventional oscilloscopes and spectrum analyzers. Better analysis tools help create better designs and minimize design cycles. The modulation domain, thanks to faster, higher resolution counters like the Philips PM 6680 and TimeView software, is a powerful and affordable new tool for understanding the frequency behavior of signals. ***RF***

About the Author
Doug Barker is a product manager with the John Fluke Manufacturing Company, Philips Test and Measurement Group. Before joining Fluke, Doug worked for 5 years as a manufacturing development engineer with the Hewlett-Packard Company. He holds BSEE and MSEE degrees from The University of Michigan and an MBA from The University of Washington. He can be reached at John Fluke Mfg. Co., Inc., PO Box 9090, M/S 213A, Everett, WA 98206-9090. Tel: (206) 347-6100.

Crystal Filters Without Inductors

By William Lurie
Consultant

This article describes a method for designing narrow-band filters with quartz crystals almost identical in motional parameters (spot diameter, for AT-cut crystals), totally without wound inductors or transformers, and yet having frequencies of infinite attenuation both above and below the passband. Such filters have the steepest shape-factor for the number of resonators used, yet are economical to manufacture because of the similarity between all resonators, and do not suffer the cost and loss of performance usually associated with wound coils.

A review of the various types of narrowband crystal filters is in order, leading to the new technique. First of all, what is a crystal filter, and why is it of value? A crystal filter is nothing more than an L-C filter in which a quartz (or other piezoelectric) resonator has replaced a group of discrete electrical components. Any filter in which an array of three reactive components appears (such as Figure 1) can be made with those three components replaced by a crystal, subject to certain limitations on the electrical values. Why is this of value? Because in most cases the losses in the crystal are dramatically less than in the L-C (higher Q), and the frequency stability of the crystal is orders of magnitude better.

Lattice sections, with one or more resonators in the branches of each section, have the most flexibility in the design of crystal filters (1). These may be all-pole, with no attenuation peaks at real frequencies, or they may be pole-zero, having peaks at real frequencies to improve the "shape factor." Also available are all-pole ladder filters, sometimes realized as monolithic structures with more than one resonator on a single quartz slab or disc. In general, although theoretical methods exist for creating exact monolithic designs incorporating attenuation peaks, these are seldom produced in practice.

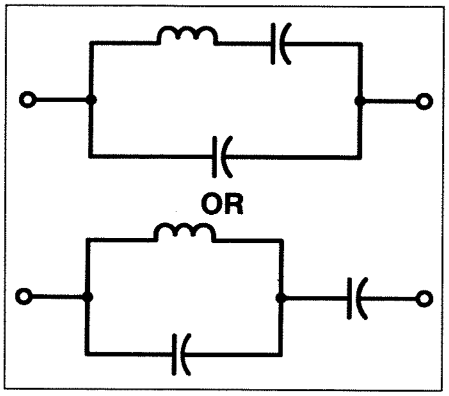


Figure 1. Electrical schematics for quartz crystal.

Another method is available for creating ladder-type designs using only crystals and capacitors. As described and tabulated by Humpherys (2) and Zverev (3), attenuation peaks are forced to appear, all at one frequency in the stopband of the filter above the passband, giving rise to a highly asymmetrical response. Uses for this type of design rarely exist in practice. The corresponding designs, with all peaks below the passband, appear to be possible, but highly impractical.

It would be ideal to be able to design such filters as a cascade of crystals, alternately in series and shunt, in a ladder structure, and indeed it is possible to do so, using modern synthesis techniques (4). Reference 4, although quite extensive, could use some expansion which is one of the basic purposes of this article.

Using whatever techniques are available, a transfer function is arrived at, representing compliance with the filter's performance requirements. Then it is synthesized in ladder form, using appropriate calculations, usually implemented in a computer program. In an example created, the filter is synthesized in "zig-zag" form. It should be pointed out that there is some flexibility in the order of pole removals in synthesizing, so there are actually four (or more) basic schematics for this test case, all meeting the requirements. All four can be synthesized and studied to provide a choice for the final design.

The specifications for this filter are as follows:

Center Frequency 10 MHz
1 dB bandwidth, 4 kHz minimum
Ripple 0.1 dB
59 dB bandwidth and returns ... 12 kHz maximum

Of the four available, the schematic of Figure 2 was selected. As synthesized,

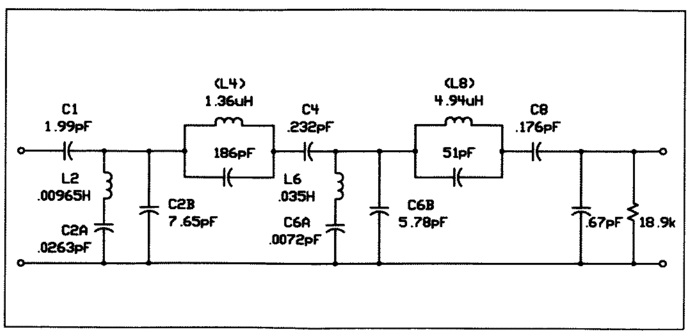


Figure 2. Bandpass filter as synthesized.

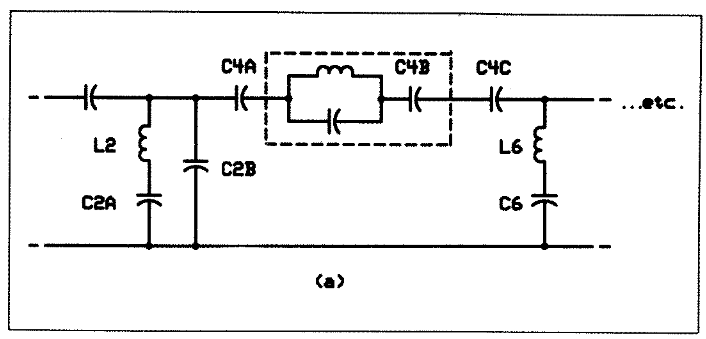


Figure 3a. Figure 2 with C4 split.

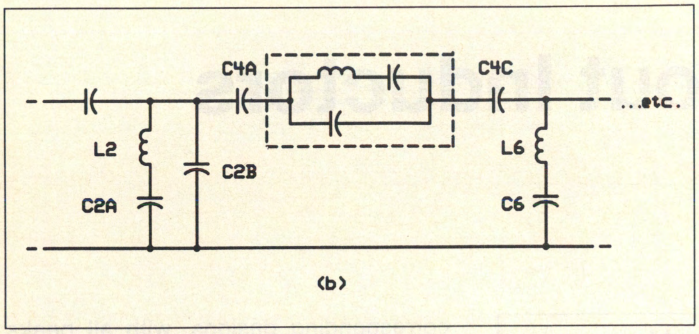


Figure 3b. Figure 3a with crystal schematic.

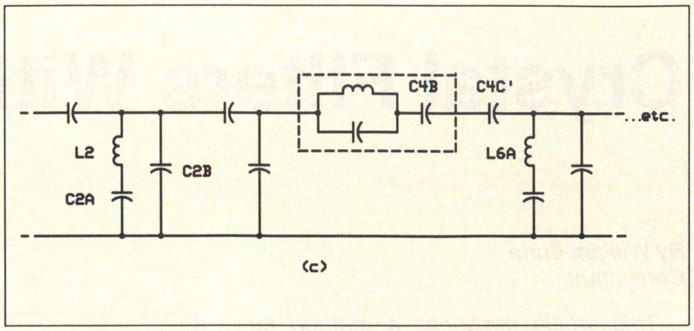


Figure 3c. Figure 3b with Norton transformation.

two of the three-element branches already have the correct schematic to be crystals, and the other two could be converted to exact crystal equivalents. This would not be a satisfactory result, however, as the crystals would have widely disparate motional parameters. Observe the sequence in Figures 3a, 3b, and 3c. Capacitor C4 is split into three capacitors in series, C4A, C4B and C4C, and they are arranged in the sequence shown in Figure 3a. Now the central parallel L-C and C4B are transformed to the canonic equivalent (in Figure 3b). Now a Norton transformation is performed on C4A to make the motional inductance of the crystal following it the same as in the three-element branch L2-C2A-C2B, yielding the schematic of Figure 3c.

The next step is another Norton transformation, to make the motional inductance of the next shunt crystal, L6A, the same as the preceding two crystals. Then capacitor C8 is split into three capacitors in series, C8A, C8B, C8C, and the process used to transform the second crystal is repeated, yielding Figure 4. Finally, if desired, a Norton transformation might be done at the input end to reduce the source impedance. Analysis of the final network shows it to be exactly equivalent to the initial network, which is as it should be, since no approximations or narrow-band equivalences have been used in the process.

Not mentioned above was any rationale for splitting the series capacitors.

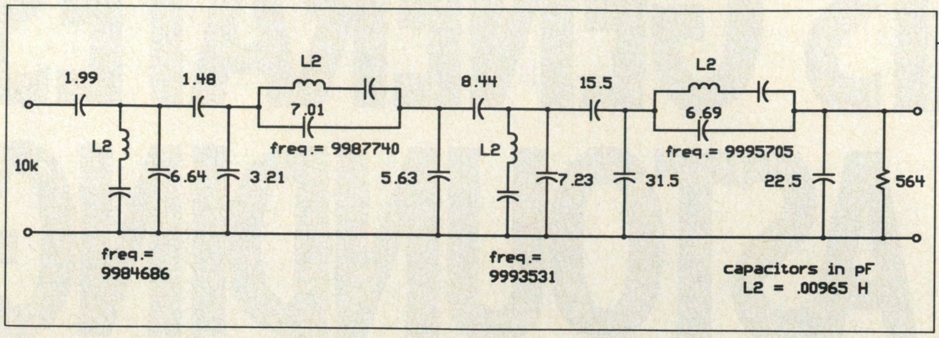


Figure 4. Final schematic with equal motion inductances.

About the Author

William Lurie has worked as a mathematician, physicist and electronics engineer in a variety of fields, including magnetic compasses, X-ray tubes and measuring equipment, airborne Doppler radar, and filters. He currently works as an independent consultant and can be reached at 8503 Heather Place, Boynton Beach, FL 33437. Tel: (407) 369-3218.

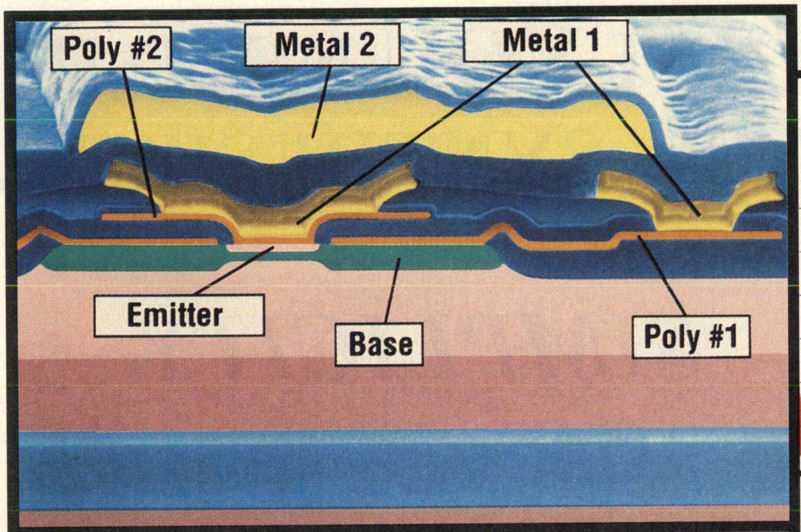
An interactive program has been written by the author in which a few values are selected, really by experience and intuition, and the steps are allowed to proceed and the results viewed. Results in this case are a tabulation of L, C, and Co for the four crystals, their capacitance ratios and series resonant frequencies, and the output capacitor and new load resistor. It proceeds quickly, and the goal is to have all element values positive (naturally), and have the capacitance ratios reasonably equal as well as practical. In the example, the range of ratios is 252 to 275.

The program has been mechanized to run interactively for 4-, 6- or 8-crystal designs, the larger ones taking longer for a number of reasons, not the least of which is that it is a trial-and-error proposition. And there is no guarantee that another sequence will not yield better values, nor that a sequence with all positive values will be found. Many factors influence the practicability of the end result. For example, it has been found empirically that the minimum capacitance ratio achievable is almost directly proportional to the center frequency divided by the displacement of the furthest infinite rejection from the center frequency. With some loss of generality, and perhaps performance far removed from the passband, these frequencies can be placed closer to the passband, improving the capacitance ratio achievable. *RF*

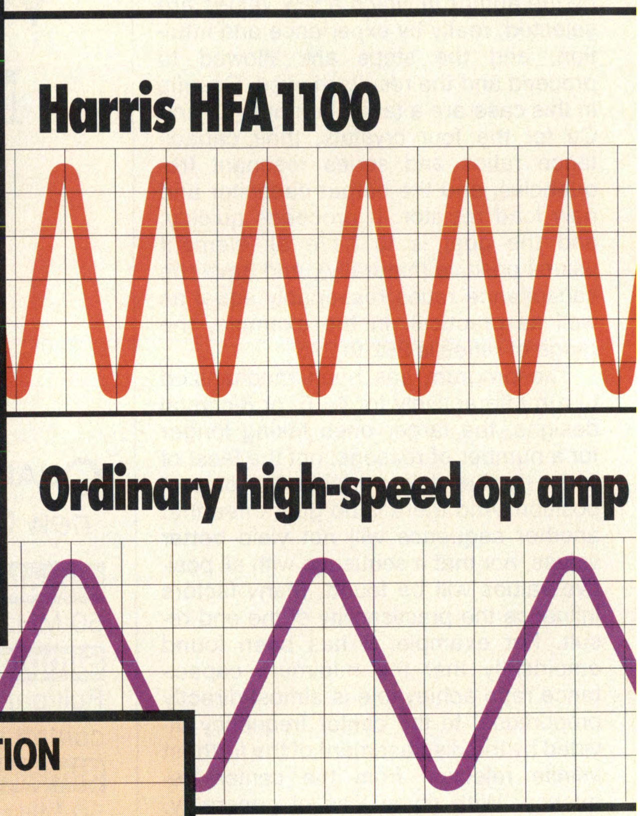
References

1. G. Szentirmai, Chapter 4 in *Modern Filter Design and Theory*, Edited by G. Temes and S. Mitra, John Wiley & Sons, 1973. The author credits Dr. Szentirmai for theoretical and practical achievements in synthesis of filters of this type.
2. D.S. Humpherys, *The Analysis, Design and Synthesis of Electrical Filters*, Prentice-Hall, 1970, pp. 489 ff.
3. A.I. Zverev, *Handbook of Filter Synthesis*, John Wiley & Sons, Inc., 1967, pp. 461 ff.
4. See Reference 1, pp. 124-129.

HARRIS GENERATES ASTOUNDING



This HFA1100 family's fast performance is made possible by Harris' unique UHF-1 process. The shallow structure of UHF-1 transistors is the result of bonded wafer technology.

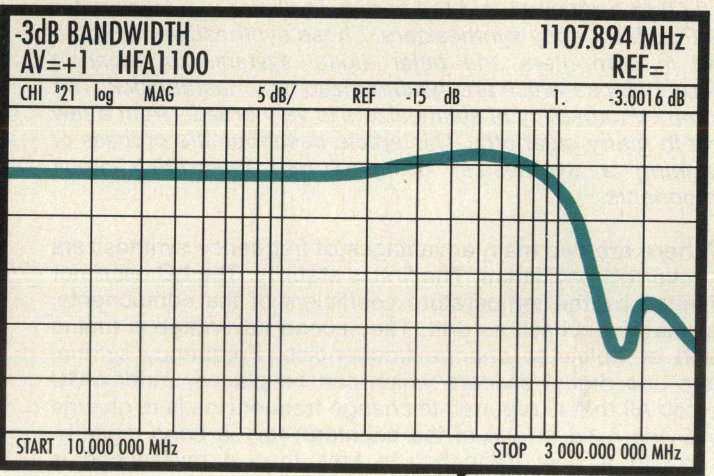


PRODUCT	CONFIGURATION
HFA1100 op amp	Standard pinout
HFA1120 op amp	Output offset adjust
HFA1130 clamped op amp	User-defined output clamp
HFA1110 buffer	Standard buffer pinout
HFA1112 buffer	Standard op amp pinout

Once again, the latest breakthrough in ultra-high-speed op amps comes to you from Harris.

This time, it's the HFA1100. Three times as fast as the old record holder. And just what fast-thinking engineers like you have been waiting for. Quickly imagine what you can do with a bandwidth so huge. Providing excellent phase linearity and a remarkable gain flatness of 0.14 dB to 100 MHz. And your creativity

INNOVATIONS WITH FREQUENCY.



APPLICATIONS

- High-Resolution Displays
- RF Transmitters/Receivers
- Medical Imaging Systems
- Radar Systems
- Flash A/D Drivers
- Video Switching and Routing/Line Drivers
- Fiber Optics

	HFA1100/20/30	HFA1110/12
-3dB Bandwidth	870 MHz	700MHz
Slew Rate	2500V/μsec	2500V/μsec
Settling Time (0.1%)	11 ns	7 ns
High Current Output	60 mA	60 mA
Temperature Range	-40°C to 85°C	-40°C to 85°C
Packages	8-pin PDIP, CerDIP, SOIC	8-pin PDIP, CerDIP, SOIC
Prices (100s)	$9.95	$5.95

needn't stop with standard products. Because the UHF-1 process is available in semicustom, as part of Harris' industry-leading FASTRACK™ design system.

So rev up your oscilloscopes. And get your hands on some HFA1100s today. Just call 1-800-4-HARRIS, ext. 1173.

HARRIS SEMICONDUCTOR

INFO/CARD 37

HF and VHF Oscillator Basics Using Frequency Synthesis

By David Babin and Mark Clark
Motorola

Phase-locked loop (PLL) frequency synthesizers are used in most communication gear today. Commonly, the local oscillator (LO) in a receiver and the carrier oscillator in a transmitter use PLL frequency synthesizers. These synthesizers are also used in computers and other digital systems to generate different clocks which are synchronized to a master clock. The frequency capability of synthesizers is very broad - from a few hertz to many gigahertz. This article describes the process of designing a synthesizer using current integrated circuit components.

There are two main advantages of frequency synthesizers over LC oscillators. The first is stability. The LC oscillator is limited by the temperature coefficient of the components. This manifests itself as drift. The second advantage is tuning speed or ability to change frequencies. Frequency synthesizers use digital dividers which can be placed under MCU control. All that is required to change frequencies is to change the divide ratio of one of the counters; this is done digitally. Tuning to a new frequency in less than a millisecond is achievable.

The main advantage synthesizers have over crystal oscillators is simplicity. For example, to tune 20 frequencies with a crystal oscillator requires 20 crystals. With frequency synthesis, only one reference oscillator source is required.

PLL frequency synthesizers can generate many frequencies based on the accuracy of a single reference source. For example, the reference can be a low-cost basic crystal oscillator or a temperature-compensated crystal oscillator (TCXO). Therefore, tuning accuracies down to a few PPM can be achieved. When "synthesizing" the desired frequency, the reference frequency may be boosted up to 100x or more.

Elements in the Loop

Referring to Figure 1, the components used in PLL frequency synthesizers are the PLL chip, low-pass filter, and voltage-controlled oscillator (VCO). Occasionally, a voltage-controlled multivibrator (VCM) is used in place of the VCO. The output of a VCM resembles a square wave and usually must be integrated before being fed to other sections of the radio. A VCM output can be used directly in computers and digital equipment. The output of a VCO is usually buffered, as shown.

Per Figure 2, the PLL chip contains a reference counter, VCO/VCM counter, and phase detector. The chip accepts input from a reference oscillator source or may have the active circuitry for the oscillator on board.

Referring to Figures 1 and 2, when the two inputs to the phase detector are equal in frequency and phase, the output of the phase detector is in the rest condition. For a single-ended detector, this is usually the high-impedance state. As the phase and frequencies differ, an error voltage appears at the detector output. The error voltage, which is pulse-width modulated, is integrated by the low-pass filter and fed to the VCO or VCM. This causes an adjustment of the VCO/VCM's frequency. The frequency is then divided down and fed back to the phase detector where it is compared to the reference frequency, f_R. This is a closed loop where any difference in f_R and f_V results in a change in the error voltage. This subsequently changes the VCO/VCM frequency until f_R and f_V are equal in frequency and phase.

In Figure 2, the reference counter is provided for convenience. f_R is usually in the kHz range while the oscillator is in the MHz range. Therefore, a counter is needed to divide down the reference oscillator frequency and generate the reference frequency at the phase detector input.

The N Counter causes f_R to be multiplied up to the desired frequency, which is generated by the VCO/VCM. Therefore, the N Counter value is changed to tune the system.

HF Synthesizer

The basic information required for designing a stable HF PLL frequency synthesizer is the frequencies required, tuning resolution, lock time, and overshoot. The goal is to have a stable loop which meets the design requirements. The techniques employed are from closed-loop design practices in control theory.

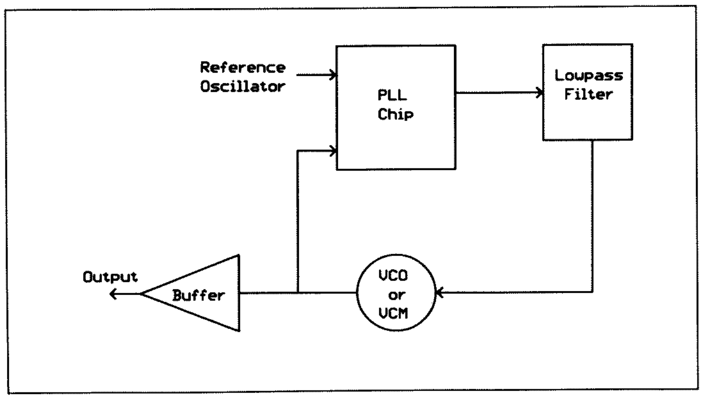


Figure 1. PLL frequency synthesizer.

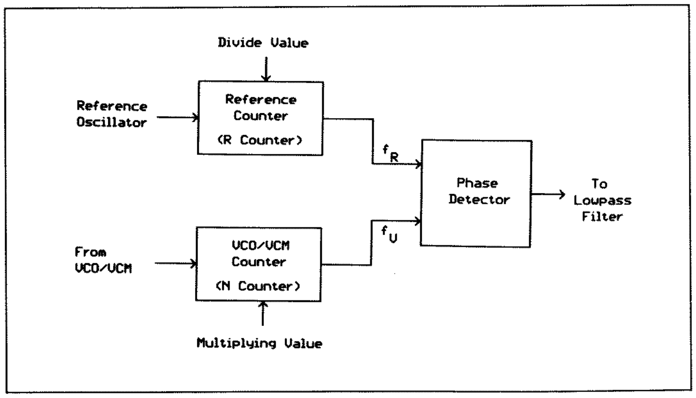


Figure 2. Detail of PLL chip.

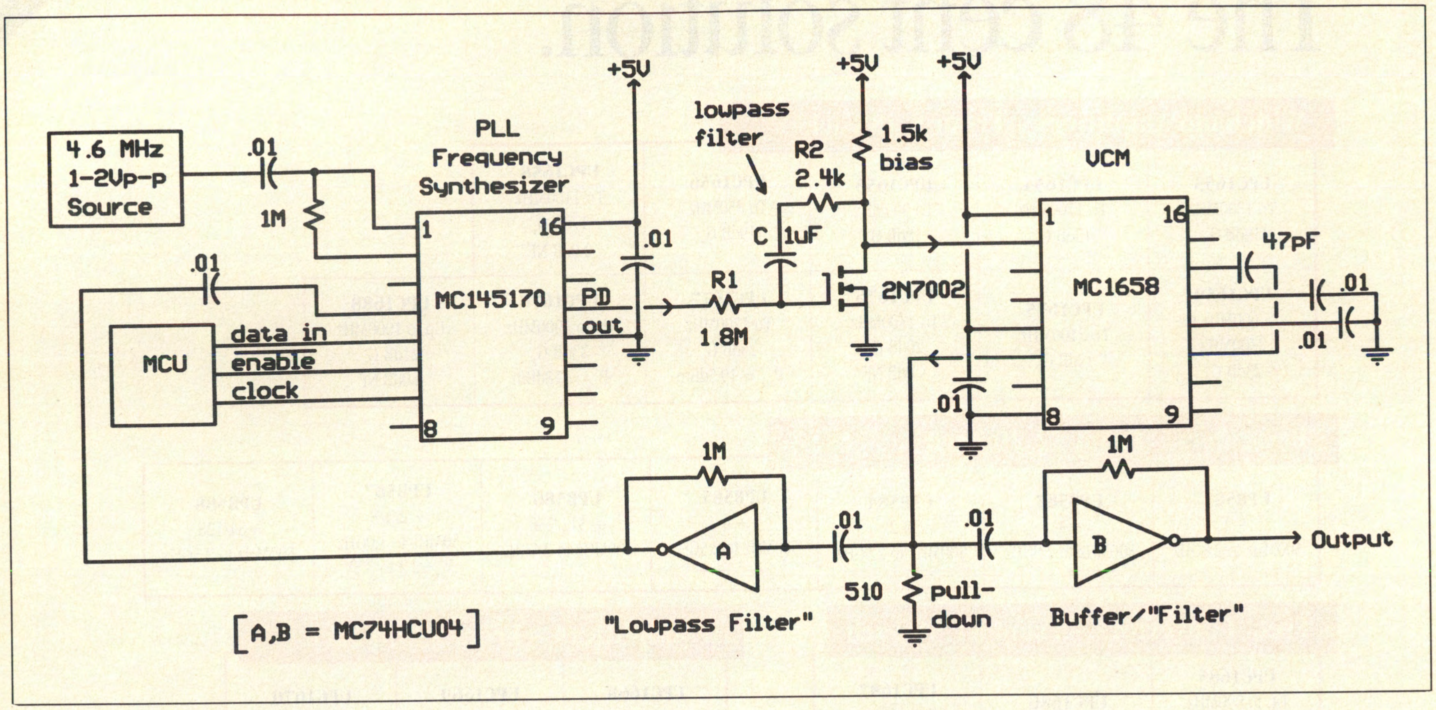


Figure 3. HF synthesizer.

For this example, the frequencies needed are 9.20 MHz to 12.19 MHz. The resolution (usually the same as the channel spacing or frequency steps) is 230 kHz. The lock time is 8 ms with an average overshoot of about 15 percent allowable. For the purposes of this example, lock is considered to be when the frequency reaches within 1 percent of its final value.

The maximum frequency is the main factor in determining the PLL chip to be used. For a maximum requirement of 12.19 MHz, Motorola's MC145170 may be used as shown in Figure 3.

HF Synthesizer Low-Pass Filter

For this example, a square wave output is acceptable. Therefore, to facilitate the design, the MC1658 VCM chip is chosen (1). The MC1658's transfer function K_{VCM} is calculated

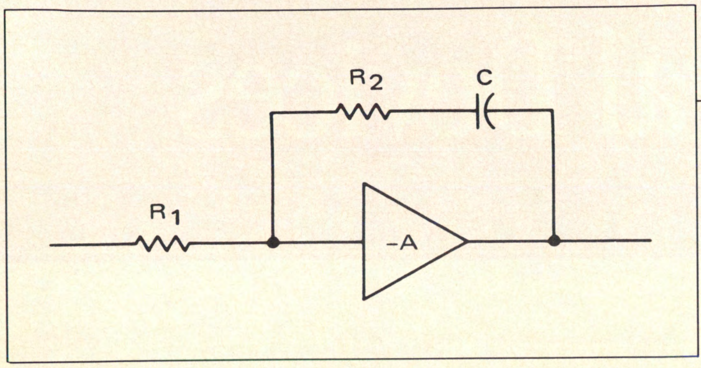


Figure 4. Active filter design.

by dividing the change in radians per second by the associated change in voltage on the VCM's control input. Per the data sheet, this is approximately $[(29 - 13 \text{ MHz}) 2\pi]/(1 - 0 \text{ V}) = 1.0 \times 10^8$ radians/second/volt. The loading presented by the MC1658 control input is heavy, requiring a maximum current of 350 uA. Therefore, an active instead of a passive low-pass filter is used so that the filter's response is more immune to loading. See Figure 3. The 2N7002 FET (6) is a good active element for the filter because of its low input leakage (100 nA maximum) and very-high transconductance (80 mmhos).

The average divide value used to divide down the VCM frequency to the resolution is calculated as follows. First, determine the average frequency; this is $(12.19 + 9.2)/2 = 10.695$ MHz or about 10.7 MHz. Then divide this frequency by the resolution; this is 10.7 MHz/230 kHz = about 47 which is referred to as the average N value.

Next, application note AN535 is referenced (3). The active filter chosen takes the form shown in Figure 4 (3). This filter is used in conjunction with the single-ended phase detector output of the MC145170, PD_{out}. From the data sheet, the phase detector associated with PD_{out} has a gain $K_\phi = V_{DD}/4\pi$. For a 5 V supply, this is $5/4\pi = 0.398$ V/rad. The step response for this system is shown in Figure 6 of the application note. To achieve an average of about 15 percent overshoot, a damping factor of 0.8 is used. This causes the frequency to settle to within 1 percent at $\omega_n t$ of approximately 5.5 per Figure 5 (3).

A summary of information at this point is as follows:

$f_{ref} = 230$ kHz
$f_{VCM} = 9.2$ to 12.19 MHz, the average is 10.7 MHz
average N = 47
power supply = 5 V for the phase detector
$K_{VCM} = 1 \times 10^8$ rad/s/V
overshoot = about 15 percent, yields a damping factor = 0.8
lock time t = 8 ms settling to within 1 percent, $\omega_n t = 5.5$
K_ϕ or $K_p = 0.398$ V/rad.

Taking the form of the equation from Reference 3, equation 61 (using 5.5),

$$\omega_n = \frac{5.5}{t} = \frac{5.5}{0.008} = 687.5 \text{ rad/s} \qquad (1)$$

Next, solving for R_1C yields:

$$R_1C = \frac{(K_pK_v)}{\omega_n{}^2N} = \frac{(0.398 \times 1 \times 10^8)}{(687.5^2 \times 47)} = 1.79 \qquad (2)$$

This equation, taken from Reference 3, equation 59, is used because of the high-gain FET.

Next, the capacitor C is picked to be 1 uF. Therefore, $R_1 = 1.79/C$ which is 1.79 Mohms. The standard value of 1.8 Mohms

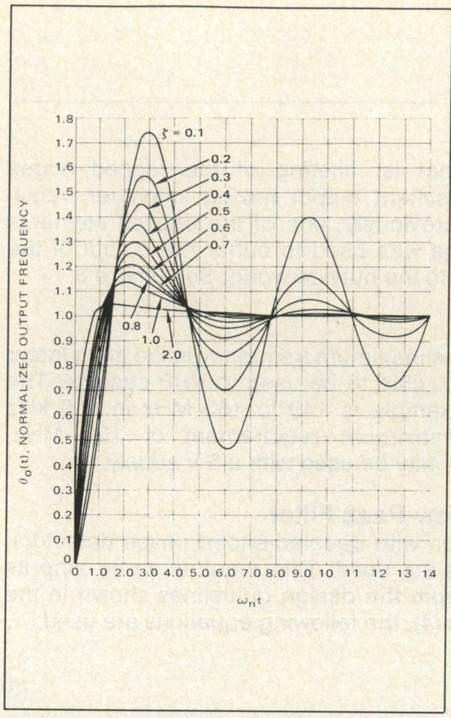


Figure 5. Type 2 second order step response.

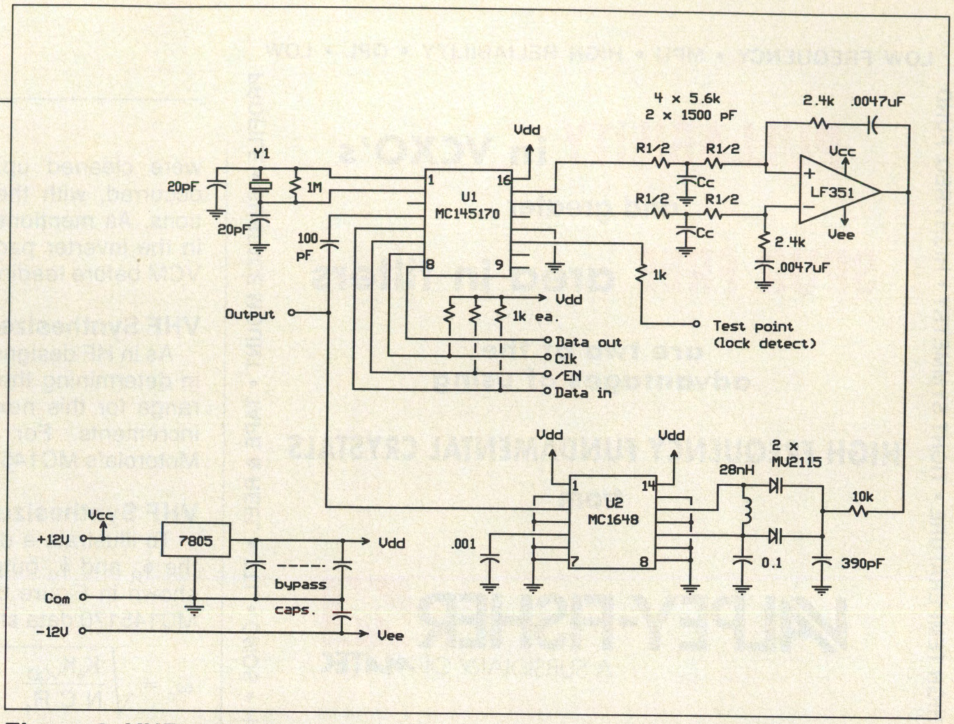


Figure 6. VHF synthesizer.

is utilized for R_1.

Solving for R_2 (Reference 3, equation 63) = 2.33 kohms.

A standard value of 2.4 kohms is utilized for R2.

HF Synthesizer Programming

Programming the MC145170 is straightforward. There are 3 registers and each may be programmed in a byte-oriented fashion. The registers retain their values as long as power is applied. Therefore, usually both the C and R Register are programmed just once.

The C Register configures the device and is programmed with a hexadecimal value of $C0 (1 byte). This sets the phase detector to the correct polarity and activates PD_{out} while turning off the other outputs. The phase detector polarity is determined by the filter and the VCO/VCM. In this example, the VCM data sheet shows that a higher voltage level is needed if speed is to be increased. However, the low-pass filter inverts the phase detector's signal (due to the active element configuration). Thus, the programming of the polarity for the phase detector dictates that the POL bit must be a "one."

The R Register is programmed for a divide value which delivers the proper frequency at the phase detector reference input. In this case, 230 kHz is needed. Therefore, if a 4.6 MHz source is utilized (feeding OSC_{in}), the R Register needs a value of $000014 (3 bytes, 20 in decimal).

The N Register determines the frequency tuned. To tune 9.2 MHz, the value required for N to multiply up the reference of 230 kHz to 9.2 MHz is 40 decimal. For 12.19 MHz, the value is 53 decimal. To tune over the range, simply change the value in the N Register with a 2-byte transfer.

HF Extra Filtering

When the HF oscillator was built, the unit did not output the correct frequencies. The output of the MC1658 was examined with an oscilloscope and the switching edges were discovered to be ragged. That is, the output did not appear to be a good square wave with clean transitions.

The f_{in} input of the MC145170 is sensitive (down to 500 mV_{p-p}), and the ragged edges were getting amplified and counted down by the N Counter. Therefore, some way to clean up the edges was required. One method would have been to add a low-pass filter between the MC1658 and MC145170. However, because an additional buffer was needed elsewhere in the circuit, a MC74HCU04 inverter was used in place of the filter. This inverter's frequency response is such that the edges were cleaned up. That is, filtering of the ragged edges occurred, with the resultant output having smoother transitions. As mentioned previously, one of the unused elements in the inverter package was used to buffer the output of the VCM before feeding it to the outside world. See Figure 3.

VHF Synthesizer

As in HF designs, the maximum frequency is the main factor in determining the PLL chip to be used in VHF designs. The range for this next example is 140 to 160 MHz in 100 kHz increments. For a maximum requirement of 160 MHz, Motorola's MC145170 may be used with a 5 V supply.

VHF Synthesizer Low-Pass Filter

To illustrate a design with doubled-ended phase detectors, the ϕ_R and ϕ_V outputs are used. This requires an op amp as shown in Figure 6. From the design guidelines shown in the MC145170 data sheet (4), the following equations are used:

$$\omega_n = \sqrt{\frac{K_\phi K_{VCO}}{N\,C\,R_1}} \quad (3)$$

$$\text{damping factor } \zeta = \frac{\omega_n R_2 C}{2} \quad (4)$$

Where, from the data sheet, the equation for the ϕ_R & ϕ_V phase detector,

$$K_\phi = \frac{V_{DD}}{2\pi} = \frac{5}{2\pi} = 0.796 \text{ V/rad} \quad (5)$$

$\zeta = 0.707$,

$$\omega_n = \frac{2\pi f_R}{50} = \frac{2\pi \times 100 \text{ kHz}}{50} = 12{,}566 \text{ radians per second} \quad (6)$$

and

$$K_{VCO} = \frac{2\pi\,\Delta f_{VCO}}{\Delta V_{VCO}} = \frac{2\pi \times (160 - 140 \text{ MHz})}{10 - 2} = 1.57 \times 10^7 \text{rad/s/V} \quad (7)$$

(The control voltage range on the input to the VCO is picked to be 2 to 10 V.

The average frequency = (140 + 160)/2 = 150 MHz. Therefore, the average N = 1500.

The above choices for ζ and ω_n are rules of thumb that are a good design starting point. A larger ω_n value results in faster loop lock times and higher reference frequency VCO sidebands for similar sideband filtering. (See Advanced Considerations section.)

Choosing C_1 to be 4700 pF, R_1 is calculated from the rearranged expression for ω_n as:

$$R_1 = \frac{K_\phi K_{VCO}}{C_1 \omega_n^2 N} = \frac{(0.796 \text{ V/rad})(1.57 \times 10^7 \text{ rad/s/V})}{(4700\text{pF})(12566 \text{ rad/s})^2\,(1500)} = 11.23 \text{ k}\Omega \quad (8)$$

Therefore, chose a 11 kΩ standard value resistor. R_2 is determined from:

$$R_2 = \frac{2\zeta}{\omega_n C_1} = \frac{(2)(0.707)}{(12{,}566)(4700\text{pF})} = 23.94 \text{ k}\Omega \text{ or } 2.4 \text{ k}\Omega \text{ (standard value)} \quad (9)$$

VHF Synthesizer Extra Filtering

For the more demanding applications, extra filtering is sometimes added. This reduces the VCO sidebands caused by a certain amount of the reference frequency feeding through the filter. One form of this filtering consists of spitting R_1 into 2 resistors; each resistor is half the value of R_1 as indicated by $R_1/2$ in Figure 6. Capacitors C_C are added from the midpoints to ground to further filter the reference sidebands. The value of C_C is chosen such that the corner frequency of this added network does not affect the loop bandwidth ω_B in a significant manner.

The rule of thumb for an initial value is $C_C = 4/(R_1\ \omega_{RC})$ where ω_{RC} is the filter cutoff frequency. A good value is to choose ω_{RC} to be $10 \times \omega_B$, so as to not significantly impact the original filter.

The Varactor

The MV2115 was selected for its tuning ratio of 2.6 to 1. The capacitance can be changed from 49.1 pF to 127.7 pF over a reverse bias swing of 2 to 30 Volts. Refer to the Motorola RF Device Data Volume III manual for information regarding the MV2115 varactor diode.

For example, three parameters are considered.

Ct = Nominal capacitance
CR = Capacitance ratio
FR = Frequency ratio

$$C_R = \frac{C_{vmin}}{C_{vmax}} = \left(\frac{V_{max}}{V_{min}}\right)^{\varrho} \qquad (1a)$$

where ϱ = the capacitance exponent

Therefore,

$$C_R = 2.6 \left(\frac{30}{2}\right)^{\varrho} \qquad (2a)$$

$$\log(2.6) = \varrho\log(15) \qquad (3a)$$

$$\varrho = \log(2.6)/\log(15) = 0.3528 \qquad (4a)$$

Using the nominal capacitance of 100 pF at 4 Volts;

$$\frac{100\text{pF}}{C_{vmax}} = \left(\frac{10}{4V}\right)^{0.3528}$$

$$\frac{100\text{pF}}{C_{vmax}} = 1.382 \qquad (5a)$$

Solving for C_{vmax},

$$\frac{100\text{pF}}{1.382} = 72.4\text{pF}$$

Solving for C_{vmin},

$$2.6 = \frac{C_{vmin}}{49.1\text{pF}} \qquad (6a)$$

$$C_{vmin} = (2.6)(49.1\text{pF})$$

$$C_{vmin} = 127.7\text{pF}$$

$$\omega_B = \omega_n\sqrt{1 + 2\xi^2 + \sqrt{2 + 4\xi^2 + 4\xi^4}}$$
$$= 12{,}566\sqrt{1 + (2)(.707)^2 + \sqrt{2 + (4)(.707)^2 + (4)(.707)^4}} \qquad (10)$$
$$= 25{,}760 \text{ rad/s}$$

$$\omega_{RC} = 10\omega_B = (10)(25{,}760) = 257{,}600 \text{ rad/s} \qquad (11)$$

$$C_c = \frac{4}{R_1\omega_{RC}} = \frac{4}{(11.23\text{ k}\Omega)(257{,}600\text{ rad/s})}$$
$$= 1383\text{pF} \approx 1500\text{pF} \qquad (12)$$

There is also a filter formed at the input to the VCO. This should be selected to insure that it does not significantly affect the loop bandwidth. For this example, the filter is dominated by R_{14} with C_5. The capacitance of the varactors (in series with the rest of the circuit) are much smaller than C_5 and can therefore be considered to be zero for this application.

As above, let ω_{RC} = 257,600 rad/s be the cut off of this filter. R_{14} is chosen to be 10 kohms. Therefore,

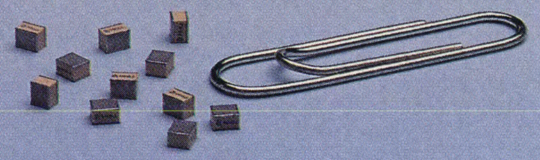
$$C_5 = \frac{1}{\omega_{RC}R_{14}} = \frac{1}{(257{,}600)(10\text{ k}\Omega)}$$
$$= 388\text{pF} \approx 390\text{pF} \qquad (13)$$

ATC 180 Series Capacitors

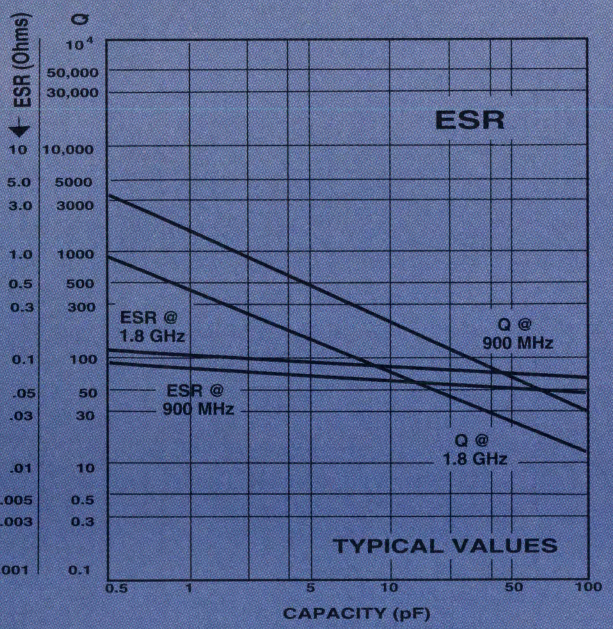
Custom Designed for 1.8 GHz Mobile Telephone and the Higher Frequency, Higher Power Applications of Today.

FEATURES:

- LOW ESR - 1/3 TO 1/5 THAT OF CONVENTIONAL MLCS
- LOW POWER DISSIPATION
- HIGH POWER
- PARALLEL RESONANT-FREE THROUGH 2.0 GHZ
- T.C. 0 ±30 PPM/°C
- IR - 10^6 Megohms min. at 25°C and rated WVDC
- 500 WVDC



ATC's 180 Series 1.8 GHz Capacitors, custom designed for mobile telephone applications, offer the lowest ESRs and the highest current handling properties in the industry. Parallel resonant-free through 2.0 GHz, these self-encapsulated porcelain MLCs have a zero T.C. (0 ± 30 PPM/°C). Operating temperature range is -55°C to 125°C. Their unique, rugged hermetic construction ensures predictable, stable operation. 180 Series capacity value range is 0.5 to 100 pF. Available in case size R in two termination styles: nickel barrier, solder coated (.079"L x .105"W x .090"T) and nickel barrier, solder plate (.065"L x .100"W x .090"T).



LOWER ESR MEANS LOWER LOSS - WHICH MEANS HIGHER POWER FROM YOUR SYSTEM.

For Complete Information and Catalog

Call our **APPLICATIONS HOTLINE**

(516) 547-5708

and ask for free samples and pricing today!

american technical ceramics CORP.
one norden lane, huntington station, n.y. 11746-2102
516-547-5700 • telex 825707 • facsimile 516-547-5748

INFO/CARD 45

See us at MTT-S '92, Booth #525.

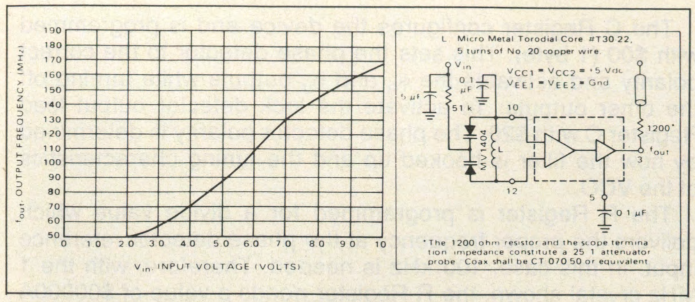


Figure 7. Transfer characteristics in the voltage controlled mode using external varactor diode and coil. TA= 25 degrees C.

The VCO

For convenience, the MC1648 VCO is selected. The tuning range of the VCO may be calculated as

$$\frac{F_{max}}{F_{min}} = \frac{(C_d max + C_s)^{0.5}}{(C_d min + C_s)^{0.5}} \qquad (14)$$

Where

$$F_{min} = \frac{1}{2\pi[L(C_d max + C_s)]^{0.5}} \qquad (15)$$

As shown in Figure 7 (Reference 2, Figure 8), the VCO tank circuit is comprised of two varactors and an inductor. Typically, a single varactor might be used in either a series or parallel configuration. However, the second varactor has a two-fold purpose. First, if the 10k isolating impedance is left in place, the varactors add in series for a smaller capacitance. Second, the added varactor acts to eliminate distortion due to the tank voltage changing.

Therefore, with the two varactors in series, $C_d max' = C_d max/2$. The shunt capacitance (input plus external capacitance) is symbolized by C_s. Therefore, solving for the inductance:

$$L = \frac{1}{(2\pi F_{min})^2(C_d max' + C_s)} = 19.9 \text{ nH} \qquad (16)$$

The Q of the inductor should be more than 100 for best performance.

$$F_{min} = \frac{1}{2\pi[(19.9 \text{ nH})(69.85\text{pF})]^{0.5}} = 135 \text{ MHz} \qquad (17)$$

$$F_{max} = \frac{1}{2\pi[(19.9 \text{ nH})(42.2\text{pF})]^{0.5}} = 173 \text{ MHz} \qquad (18)$$

The frequency ratio is 1.5 to 1 and is impacted by the tuning range of the MV2115 varactor diode (5) used in the tank circuit (See sidebar for further discussion of diode selection). Therefore, the target range of 140 to 160 MHz is not limited by this VCO design.

A pc board should be used to obtain favorable results with this VHF circuit. The lead lengths in the tank circuit should be kept short to minimize parasitic inductance. The length of the trace from the VCO output to the PLL input should be kept as short as possible. In addition, use of surface-mount components is recommended to help minimize strays.

VHF Synthesizer Programming

As in the HF oscillator, programming the 3 registers of the MC145170 is straightforward. Also, usually both the C and R Register are programmed just once.

The C Register configures the device and is programmed with $00 (1 byte). This sets the phase detector to the correct polarity and activates the ϕ_R and ϕ_V outputs while turning off the other outputs. To activate the lock detector output load Register C with $20. The phase detector polarity is determined by how the filter is hooked up and the tuning characteristics of the VCO.

The R Register is programmed for a divide value which delivers the proper frequency at the phase detector reference input. In this case, 100 kHz is needed. Therefore, with the 1 MHz crystal shown, the R Register needs a value of $00000A (3 bytes, 10 in decimal).

The N Register determines the frequency tuned. To tune 140 MHz, the value required for N to multiply up the reference of 100 kHz to 140 MHz is 1400 decimal. For 160 MHz, the value is 1600 decimal. To tune over the range, simply change the value in the N Register with a 2-byte transfer.

Advanced Considerations

Op amps are usually too noisy for critical applications. Therefore, if an active element is required in the integrator, one or more discrete transistors are utilized. These may be FETs or bipolar devices. However, active filter elements are not needed if the VCO loading is not severe such as is encountered with most discrete VCO designs. Because active elements add noise, some performance parameters are improved if they are not used. On the other hand, an active filter can be used to scale up the VCO control voltage. For example, to tune a wide range, the control voltage may have to range up to 10 V. For a 5 V PLL output, this would be scaled by 2x via use of active elements.

Some applications have requirements which must be met in the areas of phase noise and reference suppression. These parameters are in conflict with fast lock times. That is, as lock times are reduced, reference suppression becomes more difficult. Both reference suppression and phase noise are advanced areas which are covered in several publications. As an example, consider that the VCO input voltage range for the above VHF loop was merely picked to be 16 V. Advanced techniques demand a trade off between this voltage range and the spectral purity of the VCO output. This is because the lower the control voltage range, the more sensitive the VCO is to noise coming into its control input.

A VCO IC may not offer enough performance for some applications. Therefore, the VCO may have to be designed from discrete components. *RF*

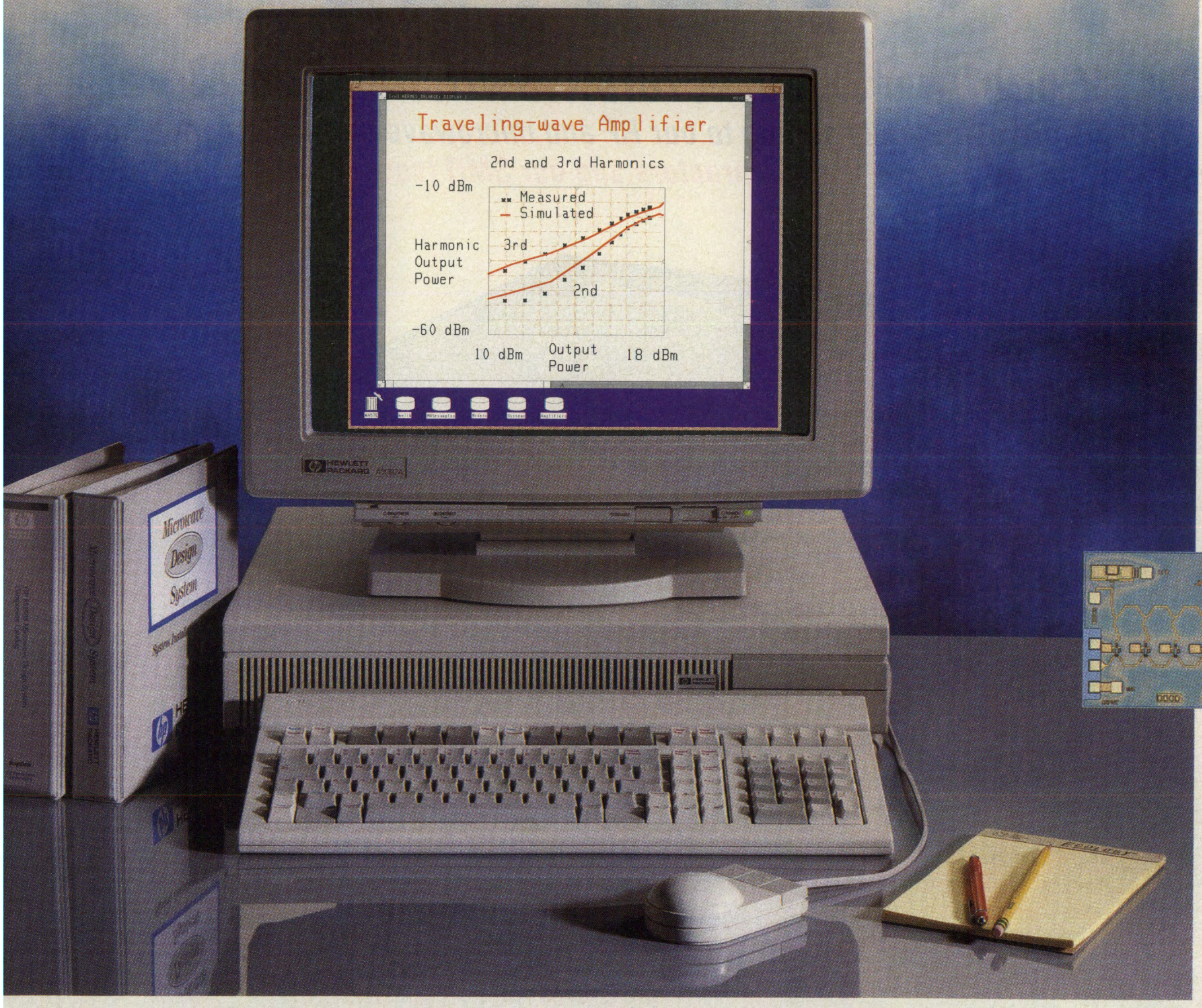
References

1. MECL Device Data, book DL122, Motorola, 1989, MC1658 data sheet.
2. MECL Device Data, book DL122, Motorola, 1989, MC1648 data sheet.
3. AN535, *Phase-Locked Loop Design Fundamentals*, Motorola Semiconductor Products, Inc., 1970. See Reference 4.
4. CMOS Application-Specific Standard ICs, book DL130, Motorola, 1990, MC145170 data sheet.
5. RF Device Data (Vol. 2), book DL110, Motorola, 1988, MV2115 data sheet.
6. Small Signal Transistors, FETs and Diodes, Book DL126 Rev. 2, Motorola, 1989.

About the Authors

David Babin is a Patent Liaison with the MOS Digital-Analog L.C. Division. He can be reached at (512) 322-8850. Mark Clark currently works in the high end microprocessor division as a member of the research and development staff. He can be reached at (512) 891-3572.

HP's software shows you exactly what your GaAs FET circuits will do. Even when they go nonlinear.



Now nonlinear GaAs FET circuits like this 0.5-50 GHz amplifier can be accurately simulated using the new HP Root Model.

HP's Microwave Design System produces accurate nonlinear simulations.

The only way to get an accurate nonlinear simulation of a GaAs circuit is to use an accurate model. Now there is one—the HP Root Model. And it's part of the HP Microwave Design System (MDS).

Not only does the HP Root Model accurately simulate nonlinear GaAs FET circuit behavior, it accurately calculates linear behavior over bias as well.

To help you get started, popular GaAs FET devices characterized using the HP Root Model are already included in the HP MDS nonlinear libraries—ready to go.

It doesn't require optimization or specialized modeling expertise to add your own, either. Because the HP Root Model computes device parameters directly from measured data.

And the HP MDS software runs on HP, Apollo, Sun, DEC or 386-based platforms.

So if you'd like to see what will happen when your GaAs circuits go nonlinear, call your local HP sales office or one of the numbers listed below. And find out exactly what HP's Microwave Design System software can do.

There is a better way.

HEWLETT PACKARD

United Kingdom (0344) 369 369 • Germany (06172) 16 0 France (1-69) 82-65-00 • Italy (02) 95.300.134 • Singapore (65) 291 8554 • Taiwan (886-2) 714 8740 • Hong Kong (852) 848 7070 • Korea (82-2) 784 2666

INFO/CARD 48

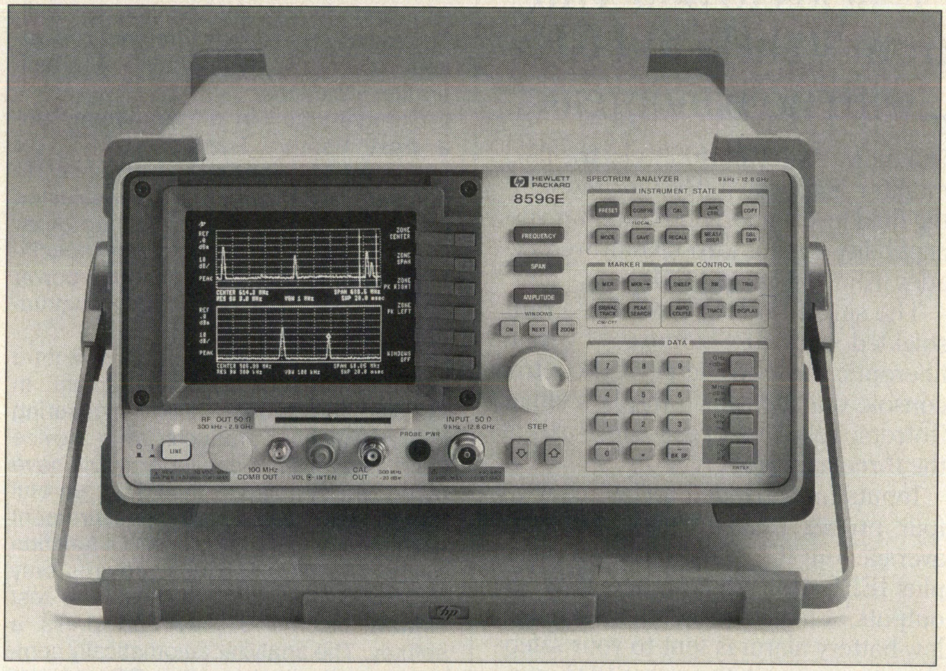
See the HP Root Model in Action at MTT-S.

New Portable Spectrum Analyzers Are Keys to Innovative Testing

By Mary Jane Pahls
Hewlett-Packard Company

Portable spectrum analyzers are indispensable tools for engineers and technicians who must install, test, or service equipment. A new generation of these instruments from Hewlett-Packard Company now offers the measurement power and versatility needed for a wide range of RF, microwave, and digital applications — from the most basic to the very challenging. In manufacturing, they provide repeatable test solutions that are economical and easy to use. In communications, they allow companies to test and maintain increasingly complex radio, telephone, and cable television systems with minimal interruption to customers. The new HP 8590 E-series combines high quality spectrum analysis, advanced operation functions, and built-in "one-button" measurements with an architecture that permits many optional hardware and software configurations. Five models offer a choice of RF and microwave frequency coverage extending from 9 kHz to 1.8, 2.9, 6.5, 12.8, or 26.5 GHz.

Performance specifications have been improved. Phase noise is a low −105 dBc/Hz at 30 kHz offset, which allows close-in, low level signals to be identified. Frequency synthesized accuracy is 7.6 kHz at 1 GHz, or 240 Hz with an optional precision frequency reference. Second and third order dynamic ranges are at least 77 dB and 88 dB, respectively. A circuit card option, which can be added at any time, adds narrow resolution bandwidths of 30 Hz, 100 Hz, 200 Hz (EMI), and 300 Hz. This option also extends the calibrated amplitude range to +30 to −130 dBm.



The 8590E-series offers the user simplified testing.

Advanced Functions Unlock Greater Measurement Power

Spectrum analyzer users have come to expect high level functions such as trace markers and trace math, which make these instruments easier to use than their predecessors. The HP 8590 E-series adds new capabilities to further enhance ease of use.

A "zoom window" feature divides the spectrum analyzer display in two. The top half retains the original display, while the bottom half is used to zoom in on any portion of a signal. Another new function, the peaks table, uses the zoom window capability to automatically determine the ten largest signal peaks and to display their frequency or amplitude values. This eliminates the need to manually test every signal on the display. Onscreen markers have been increased to four, and a marker table function displays their associated frequencies and amplitudes.

Programmability of all spectrum analyzer functions simplifies measurement procedures and allows the analyzers to be left to work unattended.

Built-in capabilities make tasks easier, more efficient, and more accurate.

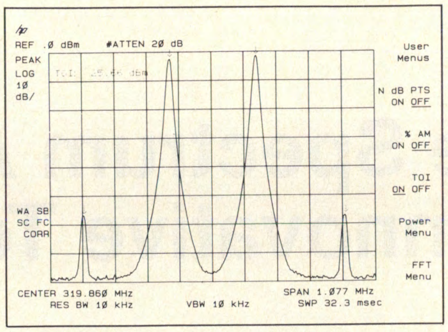


Figure 1. The two highest signals are assumed to be the two tones in a third order intercept measurement. TOI is read out with each sweep.

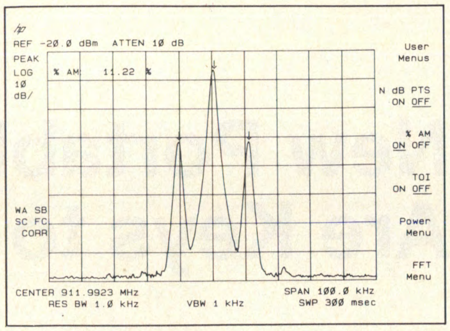


Figure 2. Percent AM is read for the carrier and sidebands marked by arrows. The measurement can be made with linear or log amplitude scaling.

Built-in measurements reduce once complex and time-consuming routines to a single keystroke. These measurements not only perform tests, but calculate and display the results, as well. They also assure measurement repeatability over time, temperature, and calibration variations.

Standard built-in measurements are a Fast Fourier Transform (FFT) for analyzing AM signals; "n" dB points to measure a bandwidth at user-selected points below a signal peak; third order intercept for testing to regulatory specifications; and adjacent channel power and occupied bandwidth for RF communication applications.

Figure 1 displays the result of a third order intercept (TOI) measurement. In the past, the common task of measuring intermodulation products of a device such as a mixer or converter would have taken many steps, including careful tuning and setting of measurement parameters. But the built-in TOI function of the HP 8590 E-series requires only that the user center the two-tone test signals on the display and press a softkey. The analyzer automatically computes and displays the TOI of the two-tone signals, marking them for easy identification. The measurement is repeated with each sweep for real-time optimization of the device or system under test. If a signal fails the TOI criteria, an error message appears.

A percent AM measurement is shown in Figure 2. This measurement can be especially difficult because frequency modulation (FM) may be present in the signal to be measured. The HP 8590 E-series makes use of its powerful internal processing feature, the FFT, to disregard the FM and measure only the AM. If no FM is present, the user positions the double-sideband AM signal on the display and presses a menu softkey. The analyzer then marks the carrier and sidebands and displays the percent AM. With each sweep, the measurement is repeated to accommodate real-time modulation adjustments. If sidebands are not within the frequency span, the measurement stops and an error message is displayed.

Custom Configurations Meet Individual Measurement Challenges

Because many applications require specialized capabilities, hardware options exist for items such as tracking

```
ACTDEF A_MP,/Enter Amplitude Limit?/,0,DBM,
/MOV DL,A_MP; HD; CONTS; ONEOS%MKPK HI;
IF MKA,GT, A_MP THEN PU; PA 60,180;
TEXT $TESTING--Signal Detected$; SAVET TRA,1;
ELSE PU; PA 60,180; TEXT $TESTING        $; END IF;%;/;

KEYDEF 1, /A_MP; SNGLS;/,/TEST¦SIG LEV/;

KEYDEF 2, /DISPOSE ONEOS; CLR DSP; DL OFF; MKOFF; HD;/,
/TEST¦OFF/;
```

Figure 3. An example of downloadable programming.

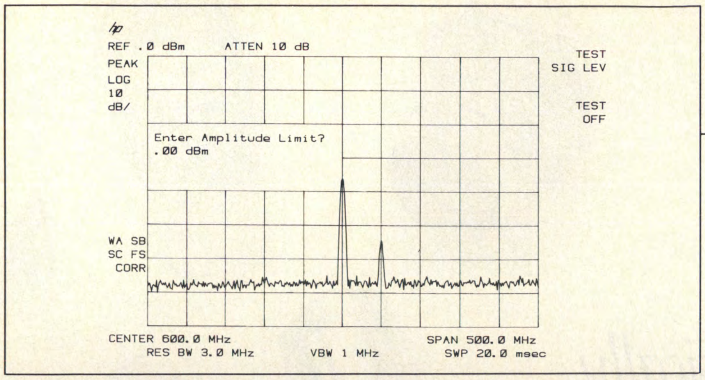


Figure 4. A custom downloadable program prompts the user to enter an amplitude limit for the signal peak being monitored.

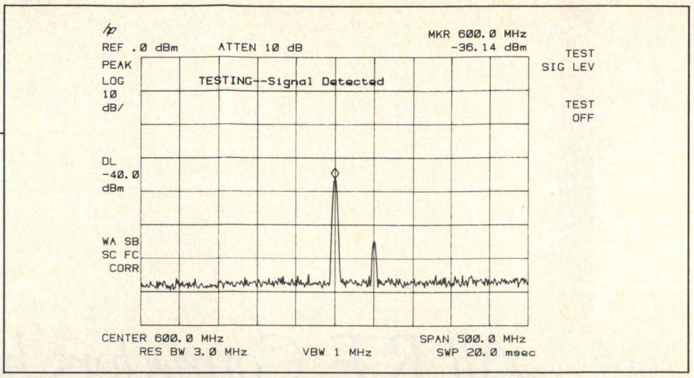


Figure 5. When the signal peak exceeds the user-specified limit, the measurement stops and a "Signal Detected" message is displayed.

generators, an analog-like digital display, time-gated spectrum analysis, an AM/FM demodulator, a quasi-peak detector, and TV-sync trigger. A cardcage in each analyzer for these circuit card options allows many of them to be added at any time.

Although users in different fields can create their own custom programs and configurations, HP has developed measurement "personalities" for some of the most popular types of testing: cable television system maintenance and monitoring, electromagnetic compatibility, digital RF communications (GSM and CT2-CAI), digital radio, and scalar component test.

These personalities on ROM cards simplify complex test routines and make them available with a comprehensive user interface that reduces difficult measurements to one or two key presses.

Downloadable Programs Add Custom Measurements

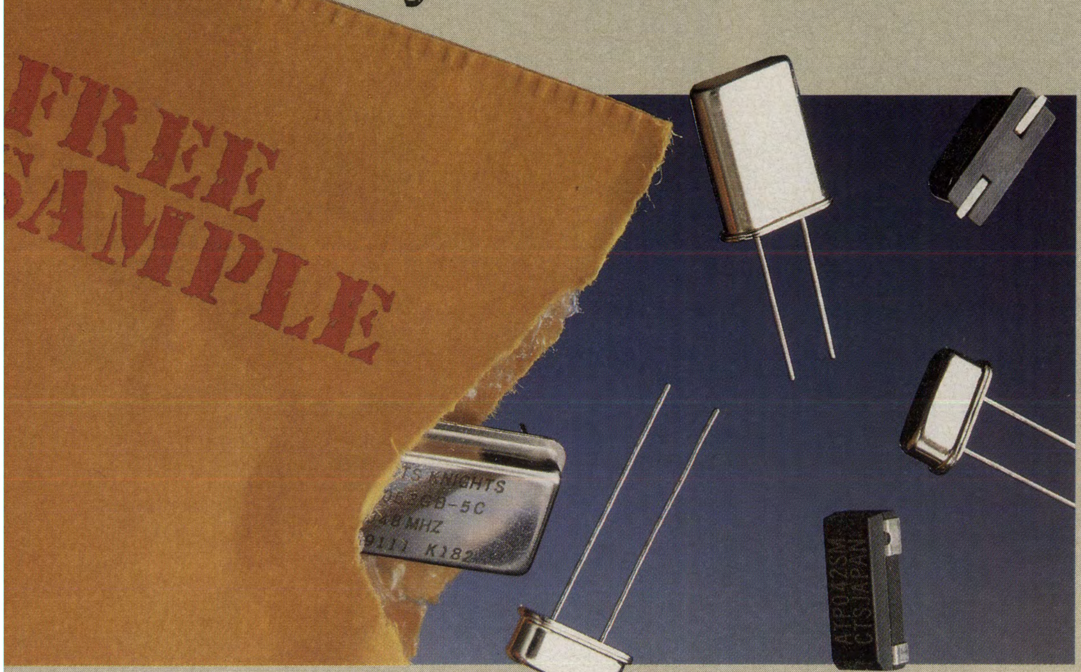
The downloadable programming (DLP) capability of the portable spectrum analyzers allows users to create their own "built-in" measurements tailored for their unique tasks. Once created, DLP custom functions can be stored in the analyzer's 50 Kbytes of RAM and executed from softkey menus.

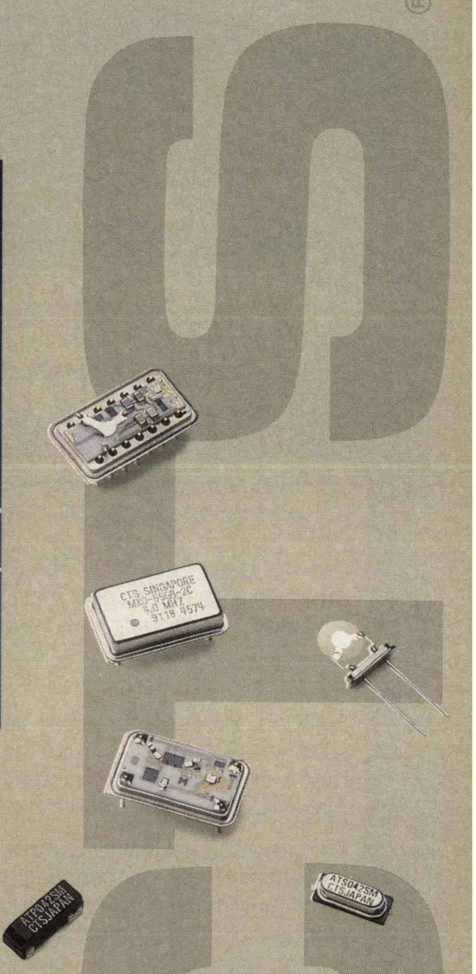
Creating a simple custom function requires only an optional IBM PC/AT-compatible keyboard and IEEE-488 (HP-IB) or RS-232 interface. A built-in DLP editor allows the program to be typed directly into the analyzer, and the DLP is executed with a single key press.

In the example shown in Figure 3, a DLP is written to continuously monitor an onscreen signal peak and to compare its amplitude to a user-specified amplitude limit. First, the analyzer's DLP editor is accessed by pressing an exit key on the keyboard. Then, the program is typed into the analyzer as a single string.

The DLP creates an active function (ATMP) and prompts the user to enter an amplitude limit, shown in Figure 4. The analyzer is placed in continuous sweep mode, and a marker is placed

How Can We Prove The Superiority Of CTS Crystals & Clocks?





Let Us *Give* You An Example.

The best way to prove the superiority of our crystals and clock oscillators is to see it for yourself—with a free sample.

You'll find the highest quality products manufactured to meet the most exacting standards. Vertical integration, including the in-house production of crystals, MRP manufacturing and cycle time reductions, consistently results in superior products and lower total costs.

The reliability of our crystals and clocks allows many CTS customers to utilize our "dock-to-stock" program, bypassing costly and time consuming incoming inspections.

And there's nothing "standard" about our line of standard clocks and crystals. CTS incorporates the latest state-of-the-art technology into our line of standard products.

With one of the broadest crystal and oscillator lines in the industry, CTS has the products, including precision oscillators, for *your* applications . . . from microprocessor crystals to high frequency tri-stateable clocks.

Grab hold of CTS quality. To receive a free sample, fax your request to CTS today at 815/786-9743.

CTS®
CORPORATION

Around The World, Your Single Source For Excellence℠

CTS Frequency Control Division,
400 Reimann Ave., Sandwich, IL 60548, Tel: 815/786-8411, Fax: 815/786-9743

INFO/CARD 53

on the peak of the largest signal on the screen. "TESTING" is displayed until the test is turned off or until the marker value exceeds the amplitude limit. When this limit is exceeded, the analyzer displays "TESTING—Signal Detected," as shown in Figure 5, and saves the trace to an internal trace register. The DLP defines a softkey with the label "TEST SIG LEVEL," which executes the measurement. A second softkey with the label "TEST OFF" executes commands to stop the testing, clear the display, turn off the marker, and clear the active function block. To access the DLP, the user presses a front-panel MEAS/USER hardkey and the "User Menu" softkey. Then, choosing "TEST SIG LEVEL" from the user menu executes the custom measurement in a single step.

In addition to running simple custom DLPs, the PC keyboard can be used to add titles to the spectrum analyzer display and to execute remote commands without a computer.

More complex programs can be created on a computer and executed remotely, or developed on a computer as DLPs, loaded, and assigned to analyzer softkeys. Such programs can be basic functions that recreate frequently used sequences of key presses, or they can be elaborate tests that take front-panel input, perform calculations, and display numerical and graphical results.

Summary

Since portable spectrum analyzers are general purpose instruments, it's hard to predict what capabilities will be important from one measurement to the next, or for any given application. Important measurement parameters will vary.

With the new HP 8590 E-series, the user has the power and flexibility to customize the analyzer for whatever the measurement situation demands. Built-in utilities and high level functions simplify a number of manual and automated measurements. Hardware and software options add specialized capabilities. And downloadable programming can be used to combine various spectrum analyzer keystrokes, to make decisions, and to put all these into a one-button measurement — much like the macro capability on a computer.

The examples above indicate the power and usefulness of this approach in several ways. If a test is performed repeatedly, measurements are easier and time is saved. Perhaps even more importantly, though, this approach adds accuracy and consistency to the user's measurements. *RF*

For more information on this product, contact Hewlett-Packard's Signal Analysis Division or circle Info/Card 228.

About the Author

Mary Jane Pahls is a Marketing Program Specialist with Hewlett-Packard's Signal Analysis Division, 1212 Valley House Drive, Rohnert Park, CA 94928. Tel: (707) 794-2664.

The FS700 LORAN-C frequency standard

10 MHz cesium stability

$4950

Cesium long term stability at a fraction of the cost

Better long-term stability than rubidium

Not dependent on ionosphere position changes, unlike WWV

Complete northern hemisphere coverage, unlike GPS.

The FS700 LORAN-C frequency standard provides the optimum, cost-effective solution for frequency management and calibration applications. Four 10 MHz outputs from built-in distribution amplifiers provide cesium standard long-term stability of 10^{-12}, with short-term stability of 10^{-10} (10^{-11} optional). Reception is guaranteed in North America, Europe and Asia.

Since the FS700 receives the ground wave from the LORAN transmitter, reception is unaffected by atmospheric changes, with no possibility of missing cycles, a common occurrence with WWV due to discontinuous changes in the position of the ionosphere layer. Cesium and rubidium standards, in addition to being expensive initially, require periodic refurbishment, another costly item.

The FS700 system includes a remote active 8-foot whip antenna, capable of driving up to 1000 feet of cable. The receiver contains six adjustable notch filters and a frequency output which may be set from 0.01 Hz to 10 MHz in a 1-2-5 sequence. A Phase detector is used to measure the phase shift between this output and another front panel input, allowing quick calibration of other timebases. An analog output with a range of ±360 degrees, provides a voltage proportional to this phase difference for driving strip chart recorders, thus permitting continuous monitoring of long-term frequency stability or phase locking of other sources.

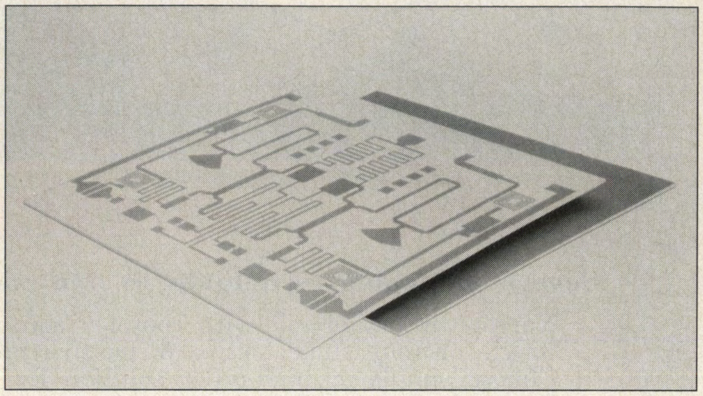
FS700: The optimum frequency management system

SRS
STANFORD RESEARCH SYSTEMS
1290 D Reamwood Avenue ▪ Sunnyvale, CA 94089 ▪ Telephone: (408) 744-9040
FAX: 4087449049 ▪ Telex: 706891 SRS UD

INFO/CARD 56

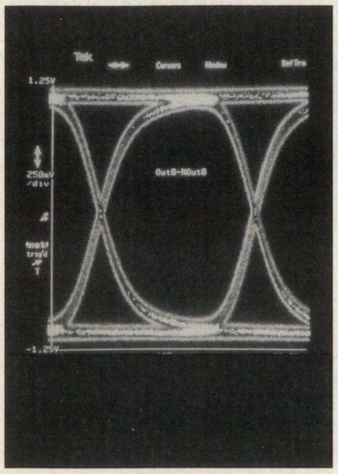
Alumina Substrates for High Performance Circuits

Mini-Systems, Inc. offers thin film 99.6 percent alumina substrates with uniform Rho, excellent gold thickness control and metallization adhesion. Ta2N/TiW/Au metallization assures processability and consistency in etchable materials for photolithographic requirements. Substrates are available to 4×4 inch size in thicknesses of .010, .015, .020 and .025 inch. Loss factor at 1 MHz is .001 and dielectric constant is 9.9 ±2 percent. Specialty materials available include fused silica (quartz), BeO, glass, sapphire and aluminum nitride. One, two or six-side metallization is offered, with through-holes and edge wraps. Ta2N/TiW/Au metallization has Rho values from 25 to 150 ohms per square, with temperature constant of ±150 ppm/degree C standard and ±50 also available. Additional metals offered include nichrome, palladium, chrome, nickel, aluminum, sichrome, copper and titanium. Applications include amplifiers, oscillators, couplers, filters, attenuators and other stripline and hybrid circuits.
Mini-Systems, Inc.
INFO/CARD #225



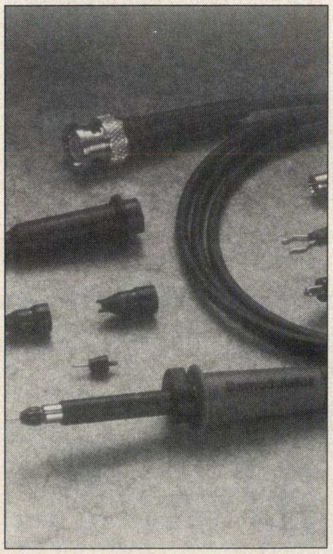
16×16 Crosspoint Switch

TriQuint Semiconductor announces the TQ8016, a fully differential 16×16 crosspoint switch. Data rates up to 1.3 Gigabits per second can be handled, for applications in digital voice, digital video, networks and backplanes. Targeted applications include SONET at 1.244 Gbits/sec, FDDI from 100 Mbits/sec to 1.3 Gbits/sec, Fiber Channel up to 1 Gbit/sec and serial digital video. The TQ8016 is based on TriQuint's source-coupled FET logic standard cells. Differential topology ensures low crosstalk and jitter. Reconfiguration time is 5 ns. Other features include ECL I/O for the data path and CMOS control inputs. Power requirements are +5 and −5 volts at 4.2 watts. Pricing in 1000 qty. is $157.
TriQuint Semiconductor, Inc.
INFO/CARD #224



RF Detector Oscilloscope Probe

The Model 5815 RF Detector oscilloscope probe kit is announced by ITT Pomona Electronics. Designed for any oscilloscope with 10 Megohm input, the detector probe has a bandwidth



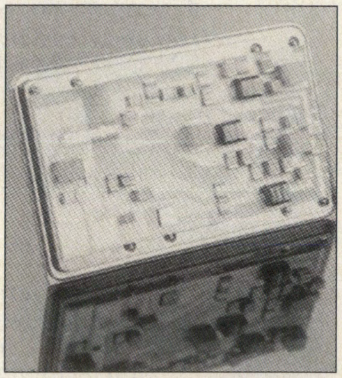
of up to 800 MHz. The probe kit includes interchangeable probe tips, grounding clip and adapters in a reusable plastic case. Modular design offers flexibility in tip styles and interface connections. Replacement parts are readily available. The Model 5815 probe kits are available from stock through Pomona's sales and distribution network. Price of the probe kit is $70.50.
ITT Pomona Electronics
INFO/CARD #223

Microminiature Connectorized Attenuators

Inmet Corporation introduces the 26A microminiature attenuator series, operating from DC to 26.5 GHz with 2 watts average power handling capability at +25C, derated to 0.5 watt at +125C. Attenuation values are offered from 1 through 30 dB with excellent flatness and low VSWR. Attenuators use passivated stainless steel construction per MIL-A-3933 with 2.92 mm connectors per MIL-C-39012. Overall length is 0.86 inch and they are available in either round or hex style housing. The connectors mate nondestructively with K, 3.5 mm and SMA series.
Inmet Corporation
INFO/CARD #222

Voltage Controlled SAW Oscillators

A new line of voltage controlled SAW oscillators (VCSOs) is introduced by Sawtek Inc., offering quartz stability, center frequency tunability, and low phase noise at frequencies from 300 to 1200 MHz. Tuning range is sufficient to maintain the specified center frequency over all environmental and operating conditions. Tem-



perature range is −55C to +85C, operating voltage is 15 volts ±10 percent, and tuning control is +2 to +12 VDC. RF power output is +12 dBm ±2 dBm through 900 MHz, +10 dBm ±2 dBm to 1200 MHz. Spurious outputs are −60 dBc max., with second harmonic −20 dBc and higher harmonics at least −30 dBc. SSB phase noise at 10 kHz is −125 dBc/Hz to 900 MHz, −115 dBc to 1200 MHz. Standard models cover the frequency range in 100 MHz increments.
Sawtek Incorporated
INFO/CARD #221

INFO/CARD 57

SIGNAL SOURCES

Fractional Divider Module

The ALL-80 from Sciteq allows the user to build an arithmetically locked loop synthesizer for fine frequency step resolution and maximum phase noise performance. The ALL-80 divides by (N+1/F), with N available as either 100 to 175 or 400 to 700; F is programmable from 1 to 16. Operation is up to 2.4 GHz using an on-board prescaler.
Sciteq Electronics, Inc.
INFO/CARD #220

Microwave DROs

A line of phase locked dielectric resonator oscillators (DROs) is introduced by Hi-Frequency Dynamics. The oscillators are available from 4 to 22 GHz, with low phase noise and microphonics, up to +22 dBm power and phase lock indicator. Oscillators can be delivered to military specifications.
Hi-Frequency Dynamics, Inc.
INFO/CARD #219

10 MHz OCXO

QK Genwave announces the 250-0502, a precision oven-controlled crystal oscillator for use in instruments, receivers and transmitters. Phase noise at 10 Hz is −120 dBc/Hz; and at 10 kHz is −160 dBc/Hz. Stability is 1.5×10^{-8} over −30 to +70C, with aging of 3×10^{-7} per year. Price of the unit is $355.
QK Genwave Corp.
INFO/CARD #218

Low-Voltage SMT Oscillators

The TCO-787 series from Toyocom features surface mounting, ceramic packaging, and either 5 volt or 3 volt power requirements. The small package (.472×.224×.098 inches) saves space in applications such as palmtop computer clocks. In 10,000 quantities, the price is $2.39 each.
Toyocom
INFO/CARD #217

Wide Tuning Range VCXO

The 2001 70 MHz VCXO from KS Electronics features ±1000 ppm tuning range with tuning voltage of 0 to 9 V. Harmonics and spurious responses are −25 dBc minimum, and power output is specified as +10 dBm into 50 ohms.
KS Electronics
INFO/CARD #216

L-Band Synthesizer

Micronetics announces the FSC-91415 synthesizer, covering 100 MHz from 1.4 to 1.5 GHz with +10 dBm output power. Frequency step size is 25 kHz, and phase noise is −110 dBc/Hz at 1 kHz offset. Harmonics are −30 dBc and spurious outputs −85 dBc. +5 or +24 volt models are offered.
Micronetics
INFO/CARD #215

Low Cost OCXO

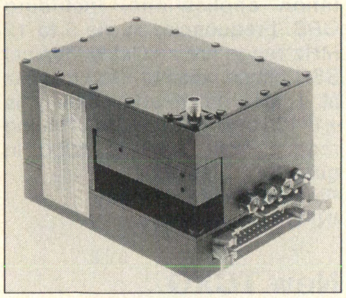
Piezo Crystal Company offers the Model 2920139 OCXO for communications and instrumentation applications, including GPS. Frequencies in the 5 to 12 MHz range are available. Typical SSB phase noise is −158 dBc/Hz at 1 kHz offset and stability is $\pm1\times10^{-8}$ over −40 to +70C. Pricing ranges from $200 to $300 in quantity.
Piezo Crystal Company
INFO/CARD #214

New TCXO Line

Oak Frequency Control Group introduces the 544 Series TCXO, with frequencies available from 3 to 25 MHz. TTL and HCMOS compatibility are offered, with stability of ±1 ppm over the −55 to +85C temperature range. The units operate from a +5 V supply.
Oak Frequency Control Group
INFO/CARD #213

Communications Synthesizers

The ML-S-3000 series from M/A-COM covers 5 to 15 GHz in 500 MHz bands. Power output is



+10 dBm, with phase noise at 10 GHz of −105 dBc/Hz at 100 kHz offset. Spurious responses are −60 dBc. Packaging has an outline of 102×70×64 mm.
M/A-COM Inc.
INFO/CARD #212

Low Power Clock Oscillators

Hybrids International now offers low power clock oscillators with outputs ranging from 1 Hz to 2 MHz. Units are available in either full or half DIP packages. Typical pricing is $3.50 (100 ppm, 32.768 kHz in 1000 qty.).
Hybrids International Ltd.
INFO/CARD #211

TEST EQUIPMENT

Modular Signal Generator

Hewlett-Packard introduces the HP70340A modular signal generator for the HP70000 system. In half-rack size the unit covers 1-20 GHz with better than −55 dB harmonics, and offers AM, FM and pulse modulation. Maximum output power is +14 dBm, accurate within 2 dB down to −90 dBm. High performance modulation specifications and full automatic test controllability make it suitable for many test applications. Price of the HP70340A is $29,500.
Hewlett-Packard Company
INFO/CARD #210

GSM/PCN Test Platform

A test platform for total testing of complete GSM, PCN and digital cellular systems is announced by RHS Harntec. The system can be used in development, manufacturing and installation of these systems, without the need for field trials. Subsystems include the Air Interface Simulator, Mobile Traffic Generator, Propagation Delay Simulator and Signalling Protocol Emulator.
RHS Harntec Ltd.
INFO/CARD #209

2-18 GHz Signal Generator

Dorado International is now importing the G4 series of microwave signal generators from Russia. Three models cover 2-18 GHz in 4 or 6 GHz bands. The units are fully programmable with IEC-625 remote control, offer sweep, CW, AM, PM and FM outputs, and have maximum output levels from +13 to +19 dBm, depending on frequency range.
Dorado International Corp.
INFO/CARD #208

RF Heating Analyzer

A new phase/impedance analyzer for 2.45 GHz RF heating systems is announced by ASTeX/Gerling Laboratories. The GL232 can be used to measure dielectric properties while heating. The unit has digital displays of phase angle and return loss, with Smith chart type outputs to an oscilloscope or plotter.
ASTeX/Gerling Laboratories
INFO/CARD #207

SIGNAL PROCESSING

SMT Filters

KW Microwave introduces surface mount filters to its line of miniaturized lumped-element filters. Filters cover frequencies up to 2.5 GHz with typical insertion loss under 2 dB, VSWR of 1.5:1, and rejection better than 60 dB.
KW Microwave Corp.
INFO/CARD #206

Temperature Variable Attenuator

EMC Technology offers a temperature variable attenuator (Thermo Pad) for passive temperature compensation, in values from 1 to 20 dB in 1 dB steps. Typical temperature coefficient is 0.01 dB per degree C over −55C to +125C. Depending on configuration, the attenuation can either increase or decrease.
EMC Technology, Inc.
INFO/CARD #205

SP6T Coax Switch

The 465 series of multiposition coaxial switches is announced by Dow-Key Microwave. The switch features performance to 18 GHz, 60 dB isolation, 1.5:1 max. VSWR and 0.5 dB insertion loss at 18 GHz. SMA connectors are standard. SP3T and SP4T versions are also available.
Dow-Key Microwave
INFO/CARD #204

Mixer for Cellular

The 800-1050 MHz SYM-860 mixer from Mini-Circuits is offered in a 0.5×0.375×0.15 inch surface-mount package. Drive level is +7 dBm for a conversion loss of 5.6 dB and two-tone third-order intercept point of +17 dBm, typical. Price of the mixer is $8.95 in 1-9 qty.
Mini-Circuits
INFO/CARD #203

L-Band Diplexer

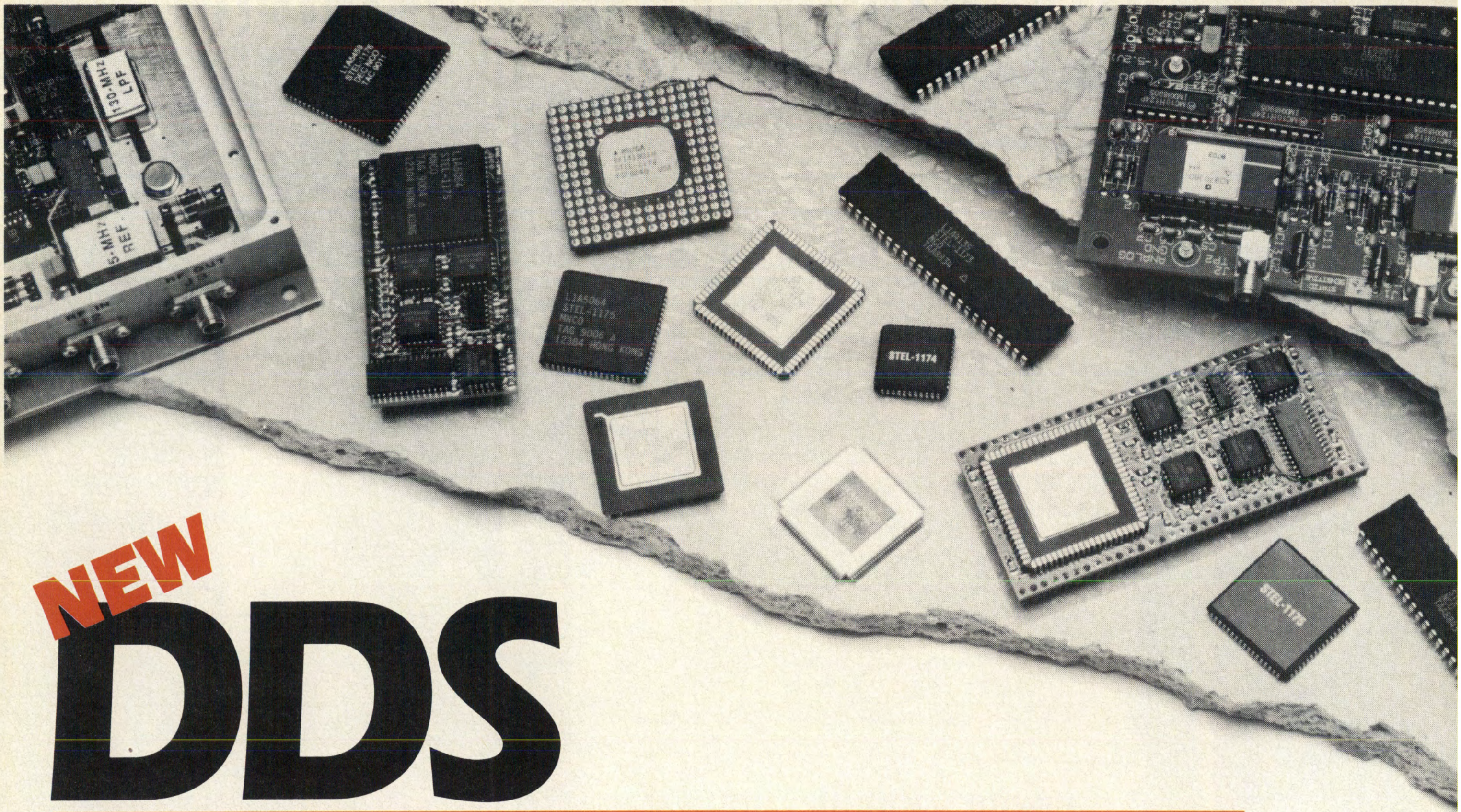
Eastern Multiplexers announces a miniature cavity diplexer for 1486 and 1550 MHz passband frequencies. 3 dB bandwidth is 50 MHz with channel isolation of 50 dB, minimum. Insertion loss is 5 dB or less, and VSWR is 1.5:1 max. The diplexer is just 3.0×1.5×0.5 inch in size.
Eastern Multiplexers
INFO/CARD #202

Low Pass Filters

A new line of 9- and 13-section Chebyshev type filters is introduced by Bird Electronic Corp., for 2-1000 MHz at power levels of 100 through 1500 watts. 5020 Series filters are fitted with QC (Quick-Change) 50 ohm connectors in most standard types, with type N standard. No-solder connector changes can be made at any time.
Bird Electronic Corp.
INFO/CARD #201

Voltage-Tuned Filters

Integrated Microwave now offers voltage tunable filters with low noise figure, high selectivity, and excellent unit-to-unit track-



NEW DDS

PRODUCTS FOR DIRECT DIGITAL SYNTHESIS

Stanford Telecom . . .
continues to lead the way in providing the highest performance at the lowest cost.

These are but a few of the many outstanding products and prices available today and offered by Stanford Telecom for frequency synthesis and digital communications. For the highest performance and most cost effective solutions in integrated digital communications products, Stanford Telecom continues to stand out as the industry leader.

Call today to discuss how Stanford Telecom might become a member of your team.

MONOLITHIC NCOS

STEL-1172B	50 MHz, 32-bit, Quadrature
STEL-1173	50 MHz, 48-bit, High Resolution
STEL-1174	50 MHz, 16-bit, Low Cost
STEL-1175	80 MHz, 32-bit, Phase Modulated NEW
STEL-1176	80 MHz, BCD/Decimal, High Speed CMOS
STEL-1177	60 MHz, 32-bit, full PM, FM, & Quadrature
STEL-1178A	80 MHz, Dual NCO, Phase Modulated NEW
STEL-1179	25 MHz, Serial Input PM NCO, $5 in commercial quantities NEW
STEL-1180	60 MHz, Generator Chirp NEW
STEL-2172	300 MHz, ECL, 32-bit
STEL-2173	1 GHz, GaAs, 32-bit, BPSK, QPSK

BOARD-LEVEL DDS

STEL-1272	based on 1172B, 0-20 MHz
STEL-1273	based on 1173, 0-20 MHz
STEL-1275	based on 1175, 0-35 MHz
STEL-1375A	miniature assembly based on 1175 MIL Spec version now available NEW
STEL-1376	miniature assembly based on 1176
STEL-1377	miniature assembly based on 1177 MIL Spec version now available NEW
STEL-1378	miniature assembly based on 1178 NEW
STEL-1276	based on 1176, 0-35 MHz
STEL-1277	based on 1177, 0-25 MHz
STEL-2272	based on 2172, 0-130 MHz
STEL-2273A	based on 2173, 0-400 MHz NEW
STEL-2373	based on 2173, 0-400 MHz - miniature hybrid NEW

CHASSIS-LEVEL DDS

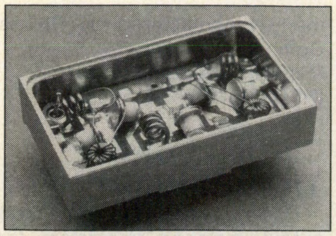
STEL-9272	300 MHz Synthesizer based on 2172
STEL-9275	Synthesizer with 1 GHz internal clock NEW

STANFORD TELECOM®

ASIC & Custom Products Division

2421 Mission College Boulevard
Santa Clara, California 95056-0968
Tel: (408) 980-5684 Fax: (408) 727-1482

INFO/CARD 61



ing characteristics. Insertion loss is 4.5 dbA with a maximum VSWR of 1.4:1. Stopband rejection is greater than 38 dB, with ultimate rejection greater than 50 dB.
Integrated Microwave
INFO/CARD #200

TOOLS, MATERIALS, & MANUFACTURING

Foil Tape

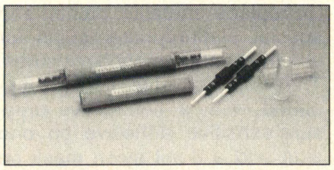
Chomerics, Inc introduces CHO-MASK II®, a conductive foil tape with a peel-off paint mask. The tape is intended to replace metallic paints and special plating/primer coats for electronic equipment enclosures. The tape is 2-mil copper, tin-plated, with a conductive pressure-sensitive adhesive on one side and a 3-mil nylon mask on the other.
Chomerics, Inc.
INFO/CARD #199

Electronic Heat Sinks

Lanxide Electronic Components offers new heat sink products for improved thermal performance. The heat sinks are suitable for backing GaAs and ceramic substrate carriers, as well as for printed circuit boards. Various surface treatments are available.
Lanxide Electronic Components
INFO/CARD #198

Alignment Tools

JDV Engineering offers tuning tools made from zirconia ceramic for high frequency adjustments with little interaction. Six sizes are



available, plus a reversible four-in-one tool.
JDV Engineering Co.
INFO/CARD #197

AMPLIFIERS

100-Watt Lab Amplifier

Wessex Electronics announces the Model RC1004-100, providing 100 watts, at 50 dB power gain, across the 400-1000 MHz range. BITE circuitry provides protection from overdrive and overload conditions. Power monitoring is via a front panel meter.
Wessex Electronics
INFO/CARD #196

Medium Power Amplifiers

New bipolar amplifiers from MITEQ cover 10-500 and 10-1000 MHz with +30 dBm output at 1 dB compression (1 dB lower 500-1000 MHz). Power requirement is 21 VDC, but may be used voltages up to 30 VDC.
MITEQ Inc.
INFO/CARD #195

Broadband Power

Power Systems Technology announces the BHE2758-500, covering 20-500 MHz with 500 watts CW power output in class AB. Input is 0 dBm for full power output. Automatic turndown and graceful degradation allow operation with high VSWR or partial failure.
Power Systems Technology
INFO/CARD #194

SEMICONDUCTORS

Leadless SMT Devices

Micro International announces their line of leadless inverted devices (LIDs), including signal diodes, general purpose and high frequency transistors, including FETs. The line was formerly manufactured by Philips Components.
Micro International, Inc.
INFO/CARD #193

Cellular Power Transistors

Philips announces input and output matched transistors for 800-900 and 900-960 MHz operation. The BLV101A/B devices provide 50 watts output power at 26 VDC supply voltage, with 8.5/7.5 dB gain (minimum). Packaging is a six-lead SOT273 flanged package with all leads isolated.
Philips Semiconductors
INFO/CARD #192

4×1 Analog Switch

Burr-Brown announces the MPC100, a 4-to-1 analog cross-point switch with 100 MHz bandwidth. Operating from ±5 V supplies, the device consists of four identical buffers connected to a common output. Each buffer has high isolation (60 dB) when off. The device is packaged in a 14-pin DIP or SOIC. Pricing is from $7.20 in 100s.
Burr-Brown Corp.
INFO/CARD #191

DISCRETE COMPONENTS

0603 SMT Resistors

Philips Components now offers chip resistors in the 1.6×0.8 mm 0603 package, half the board area of the 0805 size. The devices offer highest levels of miniaturization for hand-held products including cellular telephones and video camcorders. The small size also enhances high-frequency performance. A full range of values and packing options are offered.
Philips Components
INFO/CARD #190

Non-Magnetic Inductors

Sprague-Goodman Electronics has expanded its Surfcoil® line to include a series of non-magnetic chip inductors. The GLU series are 2.5×2.0×1.6 mm in size, and are available in inductance values from .010 to .47 uH. 2000-piece carrier and reel packaging is standard. Pricing is $0.41 in 2000 quantity.
Sprague-Goodman Electronics
INFO/CARD #189

Detector Diode Types and Specifications

Gary A. Breed
Editor

Sooner or later, virtually all design engineers will use diodes as detectors. Whether they are for large or small signals; demodulation or level detection, detector diodes require a little background and thought. This tutorial is based primarily on manufacturers' product and applications data. Hopefully, it will illuminate the performance specifications for these common components.

When it comes to selecting a detector diode, many engineers get by adequately with a little knowledge, a list of typical component choices, and not much more. In most cases, this will result in acceptable performance, since only a few applications require a precisely characterized part.

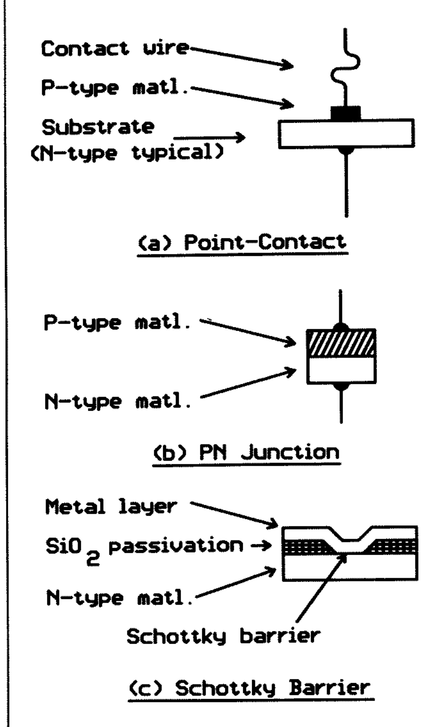


Figure 1. Diode construction methods; (a) point-contact; (b) PN junction; (c) Schottky barrier (passivated with insulating SiO2 layer).

The basic diode types for detector applications are:

Point Contact — As the name implies, these diodes have the PN junction on the surface of the substrate and make contact to the p-type material via a small wire. The junction can be very small, and with the small diameter of the contact wire, these types have the low capacitance needed for microwave operation to 40 GHz. Diodes such as the classic 1N21 and 1N23 are in this family. Point contact diodes are not limited to microwave devices; the venerable general-purpose 1N34 also uses this construction. There are mechanical limitations to this type because the contact wire is unsupported between the diode die and its external connection (metal body or wire lead).

PN Junction — The "ordinary" diode construction uses p- and n-type materials to form the diode junction, with pressure or bonded connections to these materials. Except in small geometries, these are generally not used for RF detectors. However, because of the very low cost of small silicon switching diodes like the 1N914 and 1N4148, they are often used in non-critical applications at LF, HF and low VHF.

Schottky Barrier — Also referred to as hot carrier diodes, this type uses a metal-to-epitaxial layer barrier instead of the traditional PN junction. The advantages of this type include rugged construction due to the bonded junction and conventional die attachments to external connecting points. The physics of its operation are the same as the PN junction diode, but Schottky barrier types offer better high frequency performance because of their lower diffusion capacitance and lower series resistance. Variations on the basic construction include mechanical assembly and connection methods, such as pressure contact, bonded contact, beam-lead, or Hewlett-Packard's mesh construction. Performance features are enhanced by processing for low voltage drop or "zero bias," low switching loss, and lowest noise contribution.

Detector Diodes may be constructed from silicon, germanium or gallium arsenide semiconductor materials, with the same benefits and limitations as transistors using the same substrates. A comparison of diode fabrication methods is shown in Figure 1. Consult manufacturers' data for information on devices for your specific application.

Detector Specifications

Detector diodes have a number of key performance characteristics that differ from switching, mixer, or other diode types. In order of importance, these specifications are:

- Voltage Sensitivity (in V/mW or mV/uW)
- Tangential Signal Sensitivity or TSS (in dBm)
- Video Impedance or Resistance (Z_v or R_v in ohms)

These specifications are derived from basic diode specifications of noise figure, excess noise and forward voltage drop, with other operating conditions defined, as well.

Voltage Sensitivity — This is a measure of detector output per unit of RF power. At a specified bias current, this is given as either voltage per unit power (mV/uW) or in millivolts at a given fixed power level. This measure of sensitivity depends on diode junction capacitance (leakage of RF past the diode) and power level (diodes are non-linear devices).

Tangential Signal Sensitivity (TSS) — Based on a radar display that puts the signal level at the top of the noise level, TSS is a measure of the signal level of an input signal that exactly matches the noise level. This is done at a specified video bandwidth, perhaps 2 MHz, 10 MHz or other, since noise power is a function of bandwidth. Operating frequency is also specified, such as 2 GHz or 10 GHz. The measurement is input power in dBm.

Video Impedance (Z_v or R_v) — This is the diode's dynamic resistance at the specified bias level, specified as a source resistance for a low-frequency

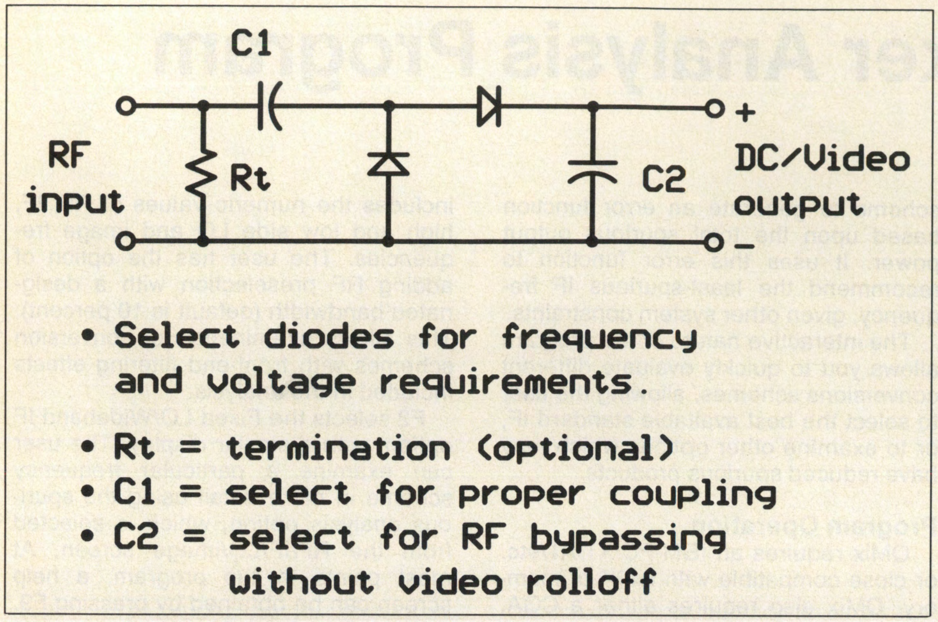


Figure 2. A simple diode sampling detector. Highest operating frequency is determined by device selection and construction method.

signal. Response time is affected by this specification, from the R-C time constant of the diode resistance and diode-plus-circuit capacitance. High resistance diodes tend to be more sensitive, but lower resistance diodes are faster. If your application requires steep rise and fall times, R_v is an important specification to define.

Detector Applications

Video detectors, which are wideband amplitude detectors, can be used for applications with relaxed sensitivity requirements, or for applications which require a short signal path between antenna and detector. Pulsed radar is probably the most common application of this sort; high level monitoring of a transmitter output is another. Figure 2 shows a simple detector for sampling transmitter output.

Power measurement, whether absolute or relative, is another common application. Temperature is an important consideration, since diodes typically exhibit considerable variation in forward voltage drop over temperature. The most common method of compensating for this effect is to use a matched pair of diodes; one for signal detection, and the other used as a reference with only DC bias applied. Both diodes connected to inputs of a differential amplifier and the variations due to temperature are largely canceled.

Bias is another concern for diode usage. If unbiased, the input signal must overcome a forward voltage drop of 350 to 700 mV, which limits signal sensitivity and detected voltage accuracy. Adding a few microamps of bias current, enough to keep the diode turned on, eliminates this offset. However, the DC component must be subtracted from the detected output, and the bias current adds to the diode's noise contribution. "Zero bias" diodes with special junction processing are available, which have voltage drops of under 100 mV for applications where noise or circuit complexity are important considerations.

Summary

Detector diodes are an important group of RF components. They are used in circuits ranging from simply detecting the presence of a signal to precise power measurement or signal recovery. This brief introduction to these components should be augmented with additional reading from manufacturers data sheets and applications notes, as well as treatments of the subject in RF textbooks. *RF*

References

1. *Microwave and RF Designer's Catalog*, Hewlett-Packard Co., Components Div.
2. *Specifications, Applications, Packages*, product catalog, Alpha Industries. Semiconductor Division.
3. Edward A. Wolff, Roger Kaul, *Microwave Engineering and Systems Applications*, John Wiley and Sons, 1988, Chapter 13.

QMIX — Mixer Analysis Program

By Kevin McClaning
Johns Hopkins University

One of the software entries in the 1991 RF Design Awards Contest, the QMix mixer analysis program analyzes frequency conversion schemes. QMix was developed to give the user insight into choosing intermediate frequencies by showing the relationships between the RF, IF, LO and image frequencies in a graphical format. This article describes the general capabilities of the program.

The first section of the program addresses channelized systems with a variable LO and a fixed narrowband IF filter. The user enters the desired RF and IF frequencies and the program calculates and graphically displays the corresponding LO and image frequencies. When a conversion scheme looks promising, the user can evaluate it using a graphical spurious product calculation routine.

The second portion of the program addresses the fixed LO, fixed IF block frequency conversion problem. The data input and graphical displays are the same as the previous option.

QMix also analyzes the spurious output power of a given conversion scheme to generate an error function based upon the total spurious output power. It uses this error function to recommend the least-spurious IF frequency, given other system constraints.

The interactive nature of the program allows you to quickly evaluate different conversions schemes, allowing the user to select the best available standard IF, or to examine other options which may have reduced spurious products.

Program Operation

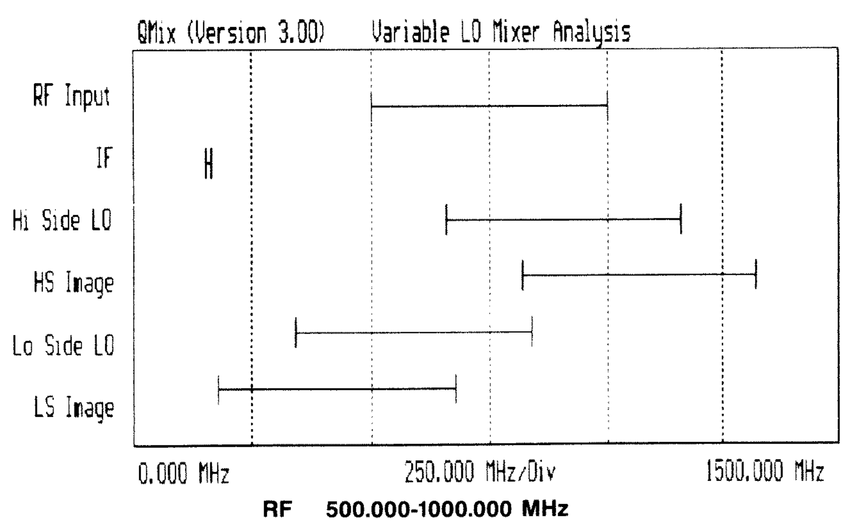
QMix requires an IBM-PC/XT/AT/etc. or close compatible with 640K of memory. QMix also requires either a CGA, EGA or VGA graphics adapter to run. A color monitor and an 8087 numeric coprocessor are recommended but not required. It is also a good idea to run QMix from a hard disk to speed things up, however it can be run from a floppy disk.

Function keys are used to select the various program options. For example, F1 is the Variable LO/Narrowband IF option. Default values or new values entered by the user result in the plot shown in Figure 1. The display also includes the numeric values of RF, IF, high and low side LO and image frequencies. The user has the option of adding RF preselection with a designated bandwidth (default is 10 percent). This allows examination of conversion schemes with front-end filtering effects included in the analysis.

F2 selects the Fixed LO/Wideband IF option, with a similar display. The user can examine a particular frequency scheme in more detail using the spurious analysis option, which is selected from the RF/IF/LO/image screen. At most points in the program, a help screen can be obtained by pressing F9. A reminder of the function key operations is displayed.

An error function (labeled Error Fn) is computed from the spurious analysis data. This is the total spurious power out of the mixer. An optimization routine is available to select an IF with a minimum error function. Frequency increments and total span are entered, and the program displays the frequency at which the minimum error function occurs. A plot of the error function versus frequency is available for visual analysis.

Use of the error function optimization may result in an impractical IF, such as the middle of the FM broadcast band or a TV visual carrier frequency. The error function plot allows the user to select a more usable IF with a reasonable total spurious output.



RF 500.000-1000.000 MHz
IF CF 160.000 MHz BW 10.000 MHz
HSLO 660.000-1160.00 MHz
HS Image 820.000-1320.000 MHz
LSLO 340.000-840.000 MHz
LS Image 180.000-680.000 MHz

Figure 1. Display of RF, IF, LO and image frequency relationships for a variable LO and narrowband IF.

Conclusion

This has been a brief introduction to the QMix program. It has been used in both design and teaching environments to show how choices for IF and LO frequencies affect spurious response. For readers interested in the theoretical basis for the program, references are included below.

The program is available on disk, with additional operating instructions, from the RF Design Software Service. See page 8 for ordering information. **RF**

References

1. Bert C. Henderson, "Mixers: Part I — Characteristics and Performance," *RF and Microwave Designers Handbook*, 1988/1989, Watkins-Johnson Company, p. 752.

2. Henderson, "Mixers: Part II — Theory and Technology," (same as Ref. 1), p. 759.
3. W.A. Hayward, *Introduction to Radio Frequency Design*, Prentice-Hall, Inc., 1982.

About the Author

Kevin McClaning has an MSEE degree from the Johns Hopkins University, and has worked for the Department of Defense for eleven years. He is also a part-time instructor at Johns Hopkins. His design experience includes component-level RF design, receiving system design and frequency synthesizers, with an emphasis on miniaturization. He can be reached at 4117 Croftleigh Court, Jarretsville, MD 21084.

A Low-Frequency Crystal Controlled Oscillator

By Ramon Patron
Instituto Nacional de Investigacion y Capacitacion de Telecomunicaciones

The RF engineer sometimes has to look for an instrument that will check a low frequency quartz crystal unit reliably and rapidly. This is a difficult piece of equipment to find and the engineer often has to consult an electronic circuits handbook for the schematic of a circuit that will perform the task.

Unfortunately, there aren't many such circuits in the technical literature currently available, and when found, they don't always work as expected. A circuit that has been found to work at full satisfaction in the frequency range from 10 kHz to 500 kHz is illustrated in Figure 1.

This 1991 contest entry is a low frequency sine wave oscillator featuring low distortion, wideband operation and crystal control was developed for laboratory use. The circuit uses low cost AF bipolar transistors for the oscillator and amplifier sections and a JFET for loop-gain control. Operation of the circuit in the 10 kHz to 500 kHz frequency range has been found to be excellent, while measured distortion is kept under 0.1 percent.

RESONANT FREQUENCY	SERIES RESISTANCE (TYP.)
10 kHz	40 kohms
50kHz	8 kohms
100kHz	5 kohms
500 kHz	2 kohms

Table 1. Typical values of series resistance.

Theory of Operation

Q_1, Q_2 and associated circuitry form a modified astable multivibrator in which the loop gain is automatically adjusted to the threshold of oscillation by means of field effect transistor Q_3. Q_4 linearly amplifies the signal present at the collector of Q_2 and isolates the oscillator section of the circuit from the output. This stage features wideband operation and delivers a clean 2.5 Volt amplitude sinewave into a resistive load greater than or equal to 20 kohms. The stage comprising Q_5 has a voltage gain of 1 and its sole purpose is to isolate the non-linear effects of rectifier D_1 from the output. Transistor Q_4 also amplifies the minor changes in amplitude of the oscillator's waveform due to temperature effects and/or power supply variations, so a magnified version of the perturbance is fed back to rectifier D_1 producing a corresponding change in Q_3's gate voltage. This action modifies the FET's drain source resistance and hence adjusts the loop gain to a new value slightly above unity, just enough to maintain a constant amplitude in the output.

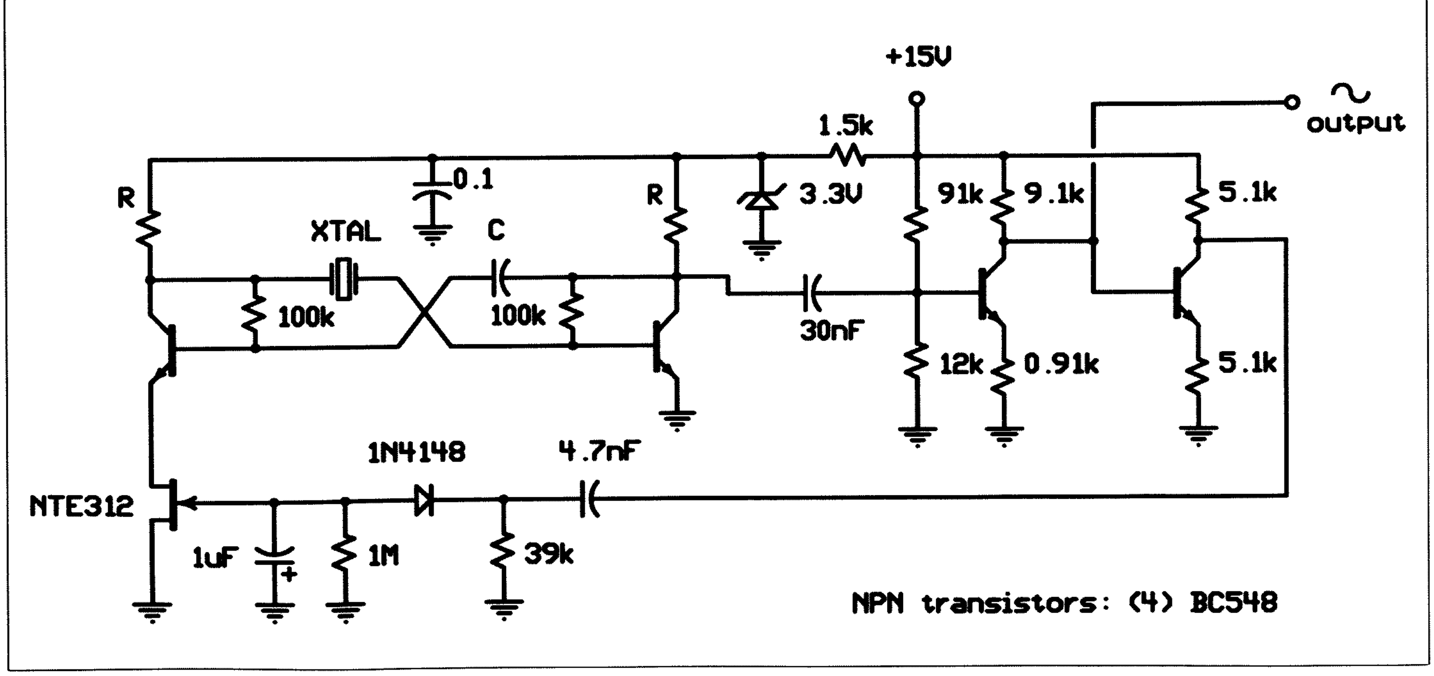


Figure 1. Oscillator circuit.

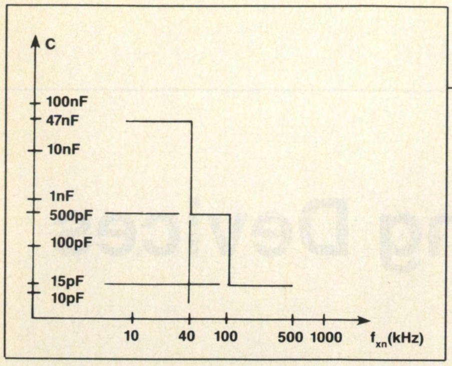


Figure 2. Optimum values for C.

Experimental Results

Figure 2 shows optimum values for capacitor C according to the crystal's resonant frequency. Extra gain is needed from transistors Q_1 and Q_2 at frequencies below 40 kHz. This is due to the fact that low frequency crystals exhibit large values of series resistance, affecting loop gain (Table 1 compares typical values of series resistance for low frequency units). According to what has been stated, resistor R is made 10 kohms for frequencies under 40 kHz. Above this value, 1 kohm will do.

Three final comments are:

1. Better amplitude stability can be attained by increasing the voltage gain of the stage comprising Q_5, but at the expense of reduced oscillator output.

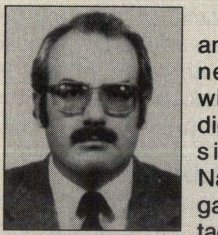
2. The oscillator section is energized from a 3.3 Volt supply. This keeps the crystal power drive level very low, which is in fact desirable.

3. Due to the dynamic action of the JFET the output level is almost insensitive to power supply variations. The 3.3 Volt zener diode further enhances this result. *RF*

References

1. *The ARRL Handbook*, 1986.
2. Bernd Neubig, *Design of Crystal Oscillator Circuits*, Kristall - Verarbeitung Neckarbischofsehim, GmBh.

About the Author



Ramon Patron is an electrical engineer who works with analog and digital circuit design, Instituto Nacional de Investigacion y Capacitacion de Telecomunicaciones of Lima, Peru. He may be reached at Nicaragua 115, Miraflores, Lima 18, Peru.

Measuring Electrically Long Devices with a Network Analyzer

By Barry Brown
Hewlett-Packard Company

A device with a long electrical delay, such as a long length of cable or a SAW filter, presents some unusual measurement problems to a network analyzer. Often the measured response is dependent on the analyzer's sweep time, and incorrect data may be obtained. At faster sweep rates the magnitude of the response seems to drop and looks distorted, while at slower sweeps it looks correct. This could indicate that a cable has more loss than it truly does, or that a filter has some unusual ripple in the passband which isn't really there. This article describes the cause of this behavior, and how to properly measure these electrically long devices. Two examples are presented to illustrate these effects.

To understand this unusual behavior, it is first necessary to briefly consider how a vector network analyzer (VNA) works. Every network analyzer consists of two parts: a source and a receiver. In a VNA, the receiver is a tuned receiver; it uses mixers to down-convert the microwave signals to lower frequency IF signals, where the magnitude and phase information is measured (Figure 1). The source and receiver are always tuned to the same frequency, and this is ensured by a frequency control loop which samples the IF signal in the reference channel. As the VNA frequency sweeps, this loop controls the source and receiver frequencies to make sure they are locked together.

The IF filters set the measurement bandwidth of the receiver, typically between one and ten kilohertz. The IF signals should be centered in the IF filters, and this is accomplished by the frequency control loop.

Measurement Problems

Now consider what happens when using a VNA to measure a device that has a long electrical delay, ΔT. Since the input signal to the device is sweeping frequency, the device's time delay causes a frequency shift between its input and output signals (Figure 2). The frequency shift, ΔF, equals the product of the sweep rate and the time delay:

$$\Delta F = dF/dt * \Delta T$$

In the VNA receiver, the test and reference input signals will differ in frequency by ΔF. The receiver is tuned to the reference signal frequency, because the frequency control loop locks on to the reference channel IF, so the test signal frequency is slightly different than the receiver frequency. This means that the test channel IF signal will not be centered in the IF filter, which causes the VNA to err in measuring its magnitude or phase (Figure 3). The faster the analyzer's sweep rate, the larger ΔF becomes, and the larger the error in the test channel.

Some network analyzers do not sweep at a constant rate. The frequency range is covered in several bands, and the sweeprate may be different in each band. So if the operator sets up a broadband sweep with the minimum sweep time, the error in measuring a long device will be different in each band, and the data will be discontinuous at each band edge. This can produce some very confusing results, and it is difficult to determine the true response, as in Figure 5.

This IF error can occur in other tuned receiver measurement systems, such as a spectrum analyzer and tracking generator combination. However, it does not occur in a scalar network analyzer, because the scalar analyzer uses broadband diode detectors instead of a tuned receiver.

Improving Measurement Results

To reduce the error in these measurements, the frequency shift, ΔF, must be reduced. ΔF can be reduced by decreasing the sweep rate, or by decreasing the time delay, ΔT. The sweep rate can be decreased, of course, by increasing the

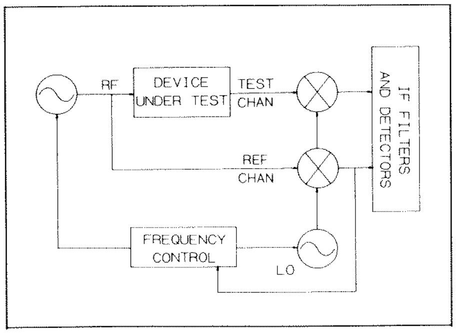


Figure 1. Block diagram of a VNA showing the source and tuned receiver, with their frequencies locked together by the frequency control loop.

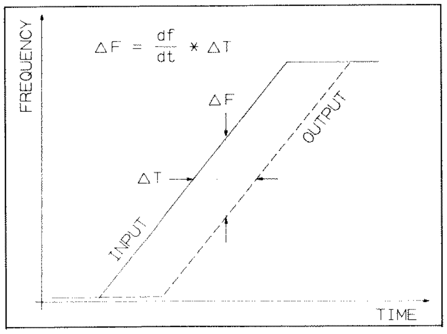


Figure 2. Since frequency is changing with time as the VNA sweeps, the time delay of the DUT causes a frequency offset between its input and output.

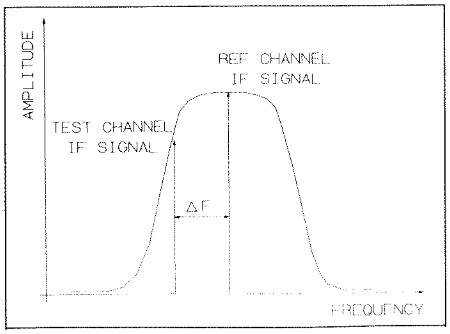
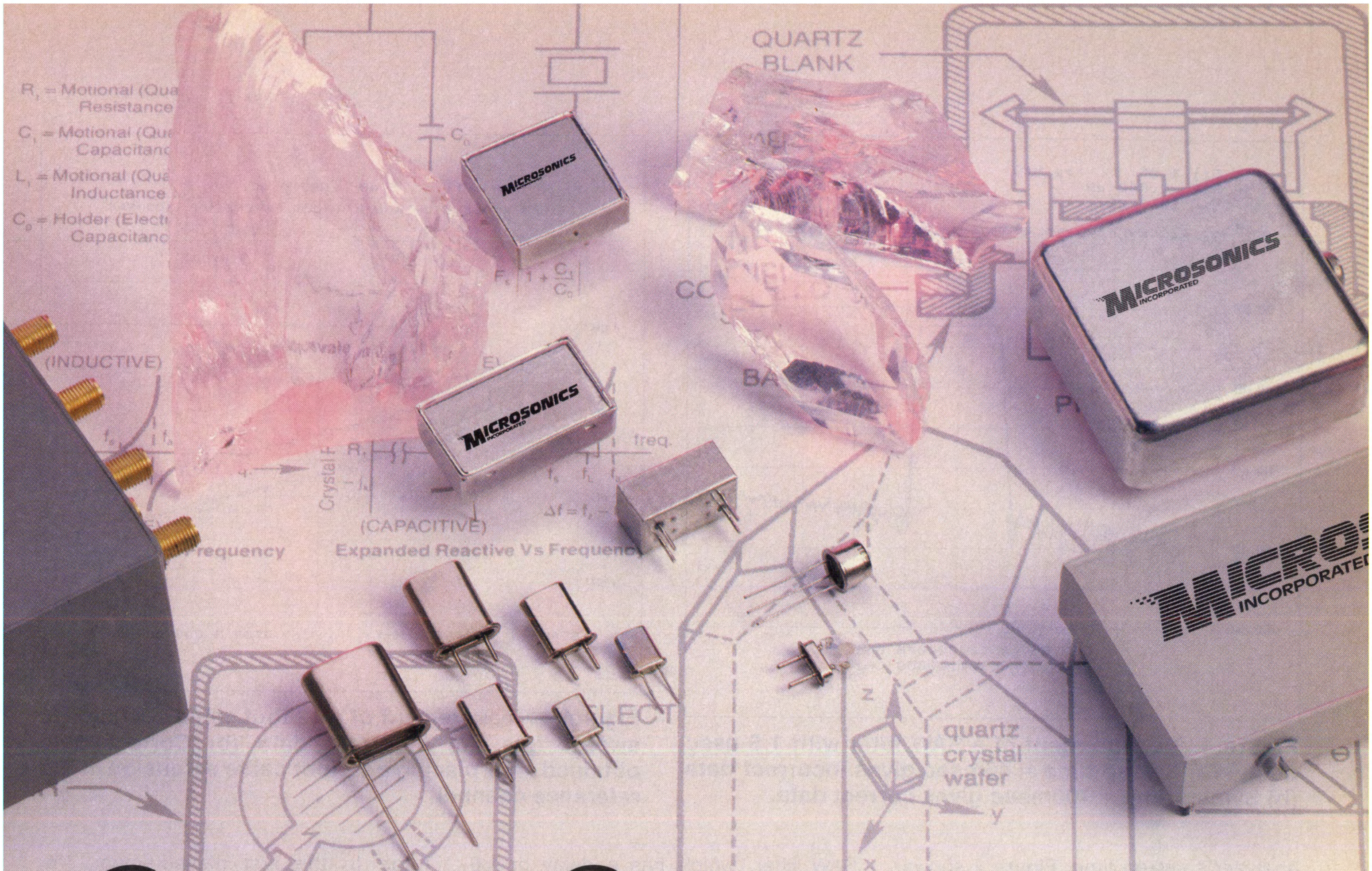


Figure 3. The IF signal in the test channel of the VNA receiver is offset from the center frequency of the IF filter, causing an error in the measurement.



CRYSTAL OSCILLATORS, FILTERS and DELAY LINES

Microsonics, Inc. a subsidiary of Signal Technology Corporation, has supplied high reliability crystal oscillators, filters and delay lines, for more than 30 years.

Our in-house crystal design and manufacturing facility ensures low phase noise and excellent long term stability in all our crystal oscillator products (TCXO and VCXO's) from 1 KHz to 1000 MHz.

Our crystal and LC filters feature low insertion losses and are available in a number of configurations, including narrow and wide bandwidths, from 10 KHz to 200 MHz. Designs are available to meet specific requirements for group delay equalization, amplitude, phase tracking, and time domain response.

Using glass and quartz as a medium, we offer the video, military, and avionics industries a wide range of delay lines from 0.25 μs to 5000 μs. Features include: Wide bandwidths, excellent phase characteristics, temperature stability, small sizes, and low power consumption.

30 years of experience with the ability, and dedication to provide real solutions to customer requirements today, and tomorrow.

Microsonics, Your source for Crystal Oscillators, Filters, and Delay Lines in the 90's.

Call today for more information.

ST
MICROSONICS CORP.

A Subsidiary of Signal Technology Corporation
60 Winter Street Weymouth, MA 02188-3336
(617) 337-4200 FAX (617) 337-4208

INFO/CARD 110

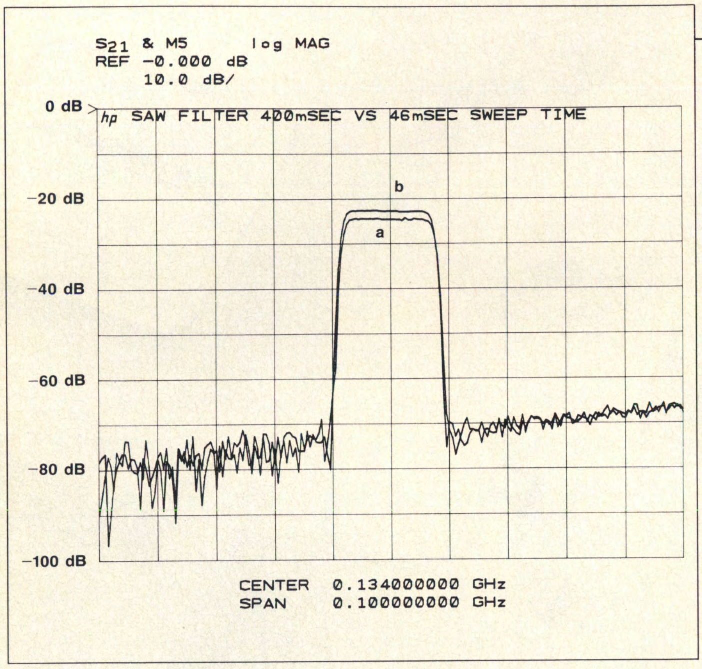


Figure 4. Measurement of a SAW filter with 1.6 usec delay. (a) Sweep time = 46msec gives incorrect data (b) Sweep time = 400msec gives correct data.

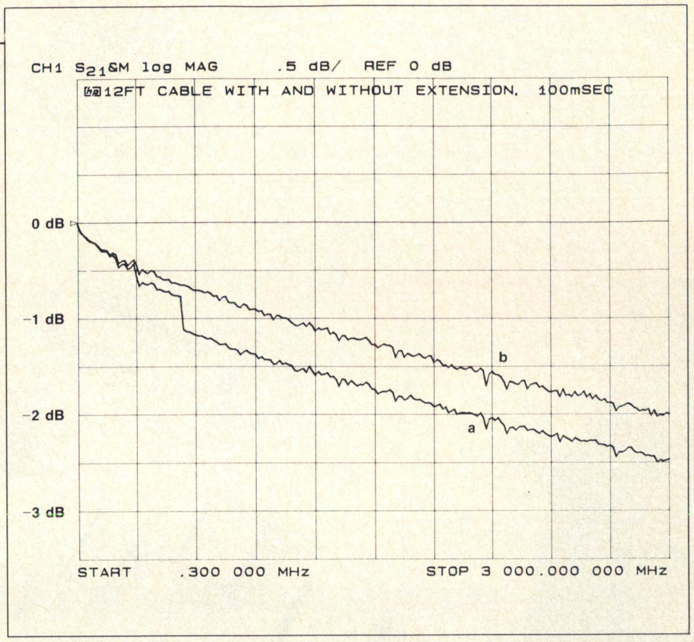


Figure 5. Measurement of a 12 foot cable at 100msec sweep time. (a) Incorrect data (b) Correct data obtained after placing a 12 foot cable extension in the reference channel.

analyzer's sweep time. Figure 4 shows the data from two measurements of a SAW filter, which has a delay of 1.6 usec, on an HP 8510B Network Analyzer. In the first measurement, the analyzer's minimum sweep time (45

msec) was used, while in the second measurement the sweep time was increased to 400 msec. The error in the first measurement is entirely due to the frequency shift incurred when measuring this electrically long device at a fast sweep rate.

Selection of the appropriate sweep time depends on the device being measured; the longer the electrical delay of the device under test, the slower the sweep rate must be. A good way to tell when the sweep rate is slow enough is to put the VNA into a stepped-frequency mode of sweeping, and compare the data. This may be called "List Frequency Sweep" or "Step Sweep" on the VNA's sweep menu. In this mode, the VNA does not sweep the frequency, but steps to each frequency point, stops, makes a measurement, then goes on to the next point. So the error does not occur in the stepped-frequency mode and it can be used to check the data; the disadvantage is that it is slower than sweeping. (Note that the HP 8753C and HP 8720B VNAs switch to stepped-frequency mode automatically if the sweep time is greater than 15 msec * number of points; e.g., 3.1 sec for 201 points.)

The other way to reduce ΔF is by decreasing the time delay, ΔT. At first glance, this seems ridiculous, since ΔT is a property of the device that is being measured! But remember, what is important is the difference in delay times between the paths to the R channel and the B channel. These times can be equalized by adding a length of cable to the R channel which has approximately the same delay as the device under test. Some network analyzers, such as the HP 8510B, provide an external link on their test set for inserting this cable into the R channel path. In other cases, it can be inserted between the test set and the R channel input.

Figure 5 shows the data from two measurements of a 12 foot length of coaxial cable, using an HP 8753C Network Analyzer. The first measurement is taken at minimum sweep time (100 msec) and shows the familiar error. In the second measurement, the sweep-time was unchanged, but another 12 foot cable was placed in the R channel connection between the VNA and the test set, equalizingthe delays between R and B channels.

Summary

It is possible to get erroneous frequency response data when measuring a device with a long electrical delay, but once the cause of the problem is understood, there are some very simple solutions to correct it. With the techniques described in this paper, it is a straightforward matter to make accurate measurements on these devices.

About the Author

Barry Brown is a hardware design engineer with Hewlett-Packard's Network Measurements Division. He has a BSEE from Purdue University and a MSEE from Stanford University. He may be reached at Network Measurements Division, 1400 Fountaingrove Parkway, Santa Rosa, CA 95403. Tel: (707) 577-3449.

Growing Demand for EMC Control

By Liane G. Pomfret
Associate Editor

Electronics manufacturers are faced with a problem that virtually didn't exist twenty years ago. Noise from other sources — power lines, computers and appliances, combined with stricter regulations, have made it difficult to design noise-free electronic equipment. What was once considered the unusual is now the standard when it comes to EMC control products and applications.

Today, the list of equipment and products that use EMC control components is quite extensive. Computers are a well known source of noise and are susceptible to it as well. Today's '386 and '486 16, 25 or 33 MHz computers operate well within the RF range, consequently, computer designers are running into electromagnetic interference problems that they've never experienced before. John Woody, Director of Marketing at Steward, noted that designers are having to address noise problems internally, at the board level. Local-area-networks, even when properly installed, are notorious for EMI/RFI problems. Just the sheer amount of cable used to connect the system can act as a good antenna. As a result, EMC control is a critical part of the design procedure. Ferrites, filters and capacitors, as well as proper shielding, can provide the necessary protection.

Automotive manufacturers are having to deal with EMC problems as more of the cars they build contain a greater number of electronic components. Automotive use has shot up according to Paul Liebman, Marketing Manager for Coilcraft, because of the incredible amount of noise present. An automobile radio is the least of their problems these days. Virtually every system within a car is controlled by a computer. Interference from the other systems in the car as well as from outside sources is unacceptable and manufacturers are having to design-in EMC control at the board level.

The medical industry is also finding more uses for EMC control components. Both external medical equipment and implantable devices are susceptible to EMI/RFI. Because of the critical nature of this equipment, EMC is an especially important issue. This is an area where design-in EMC control becomes critical. It is not easy to retrofit a pacemaker for EMC control once it has been implanted.

Communications equipment suffers from EMI/RFI problems. But because manufacturers have had to deal with the problem longer than other industries, they realized early on that designing EMC filters, ferrites and connectors into their products would save them time and money. Virtually all types of equipment, i.e. cellular base stations and mobile phones are susceptible to power line interference, surges and lightning strikes.

Perhaps one of the most overlooked areas of EMC control is consumer appliances. Everyone is aware of what happens when a blender is turned on while the television is on; there is interference. Manufacturers are being pressured to stop the interference problems caused by dishwashers, washing machines, blenders, sewing machines, power tools, vacuums and virtually any other appliance with an electric motor.

A Growing Need

Changing regulations and an increase in electronic noise over the past decade have led to a broader awareness of EMC problems. Engineers now realize that they need to design-in EMC control at the board level if their product is to be successful. Not only is it less expensive for them in the long run, but it is also faster, because they won't need to retrofit a product because it failed the approvals process. Regulations for testing and approval of electronic equipment have gotten far stricter but as of yet there is no worldwide compatibility standard. While Europe will see conformity under EC92 the lack of a common standard in other parts of the world will continue to hurt manufacturers. As one manufacturer noted, there is no true clearinghouse of information regarding international regulations and this has left many people confused as to which regulations to follow. Kenneth Such, Vice President of KCK America comments, "With so many different specifications, it is extremely difficult to bring to market designs which will satisfy all areas of concern. It remains an on-going problem."

Because of an increase in business there have been changes in performance characteristics and product offerings for the EMC control market. Manufacturers of ferrites and iron powder cores are seeing requests for unusually shaped parts to include in new designs. Another example of the changing market is the market for electromagnetic pulse protectors. Originally some of these products were designed to withstand a nuclear threat, but because of recent changes in world politics, nuclear threat is no longer the problem it was once thought to be. While EMP protectors may originally have been designed primarily as protection from nuclear threat, they are exceptionally well suited for lightning protection as well. More requests are being made for surface mount components, lower cost and high power devices.

For most manufacturers of EMC control components, sales were good last year. The need for EMC control components in everything from computers to vacuum cleaners is obvious based on the amount of business being generated. EMC control is no longer an option for designers. Tighter regulations and increased ambient noise have made control of EMC a must, wheth er it be shielding a product from outside noise or preventing a product from interfering with other equipment. ***RF***

For reprints of this report, contact Cardiff Publishing Company at (303) 220-0600. Ask for the Circulation Department.

PLL Circuit Software

PLL2 Version 1.0, patterned after PLL3 offers the designer an interactive tool in developing second order phase lock loop circuits. Dynamic Bode and transient plots offer the engineer a visual indication of performance during the design process. Loop filter components, damping, noise, lock range, and lock time are some of the additional parameters calculated. PLL2 Version 1.0 is IBM compatible, requires DOS 3.2 or higher, an EGA monitor and 256K of memory. Cost is $35 plus $3 shipping.
SW.I.F.T. Enterprises
INFO/CARD #250

Electromagnetic Software

Sonnet Software's em performs electromagnetic analysis on circuit layouts. The software now comes with a color-coded visual interface. Various colors indicate where current is flowing and can help the engineer revise a design without having build it every time. The software works on UNIX workstations with 8 MBytes or more of RAM. It can also be used on all X-Window stations within a network.
Sonnet Software
INFO/CARD #249

Frequency Stability Analysis

STABLE is a PC/MS-DOS program for the analysis of frequency stability. It includes all the functions necessary to manipulate, analyze and plot phase and frequency stability data for precision frequency sources. STABLE time domain analysis functions include the normal, modified, overlapping and time Allan variances. Frequency-domain analysis functions include the power spectral density of frequency, phase and time fluctuations. High-resolution screen, plotter and printer graphics are supported. The price is $195.
Hamilton Technical Services
INFO/CARD #248

Noise Figure Firmware

Maury Microwave is now offering revised firmware to enhance the functional performance of the Maury Model MT2075B Noise Gain Analyzer formerly known as the Eaton 2075B, with improved measurement functions and plotter routines, and more efficient error correction and recovery, as well as expanded front panel storage and recall capability.
Maury Microwave Corporation
INFO/CARD #247

HiWIRE Release

Wintek Corporation has released version 2.0r2 of its schematic-capture and PCB-layout software package, HiWIRE II. New features include an AutoCAD DXF file translator, an enhancement to allow Spice simulation input files to be created directly from a HiWIRE II schematic. There is also a Gerber Import utility which allows designers to view the Gerber photoplot output from HiWIRE II or import Gerber drawings from other CAD systems. The upgrade is $95 to USA and Canadian licensed users and $120 to other licensed users.
Wintek Corporation
INFO/CARD #246

Windows-Based Schematic Capture

A new PC-based schematic capture software, ACEPlus PC Entry is available from DAZIX. The software is Microsoft Windows 3.0 compatible and offers transparent integration into CAE, CAD and CAM workstation design environments. The designer can start from any level of abstraction, using the ACEPlus automated top-down and bottom-up design capabilities. ACEPlus PC Entry works on IBM PC-AT compatible PCs including the 286, 386, 486 and PS/2 (386 or higher is recommended). Price of the software is $3500.
DAZIX
INFO/CARD #245

Software Application Notes

Two application notes are available showing how MMICAD™ software can be used to design oscillators with linear tuning characteristics. The first note calculates varactor diode capacitance and discusses the development of a MMICAD user-defined model. The second note discusses the problem of linearity in oscillator design.
Optotek Limited
INFO/CARD #240

Frequency Conversion Products

A new 92-page mixer products catalog features the recently combined RHG and M/A-COM Control Components Division frequency conversion products. The catalog covers mixers, modulators and preamps in addition to a custom products checklist for specifying special features.
M/A-COM Control Components
INFO/CARD #239

RF and Microwave Components

A 250-page, four color catalog is available from Daico Industries. The catalog features their complete line of RF and microwave components including switches, attenuators, amplifiers, phase shifters, and GaAs MMIC products. High density thin-film integration capabilities and build-to-print services are also described.
Daico Industries, Inc.
INFO/CARD #238

Coaxial Switch Catalog

Wavecom's complete line of coaxial switches is covered in its new 112-page catalog. The catalog provides a glossary of terms and a graphical how to order section that explains the part numbering system. Complete specifications are given for each product, including options, schematics, and outline drawings.
Loral Microwave-Wavecom
INFO/CARD #237

RF/microwave Connector Catalog

A 120-page catalog detailing Amphenol's line of coaxial and twinaxial connectors, adaptors and accessories for use in non-military industry standard and commercial applications. Included are a cross reference for data transmission applications and a complete guide to between series adapters, together with plating, dielectric and dimensional call-outs for all parts. Complete assembly instructions and a selection of assembly tools are also included.
Amphenol Corporation
INFO/CARD #236

RF Communications Handbook

A new data handbook for RF semiconductor products is available from Signetics. The 870-page book presents complete specification, packaging and ordering information on more than 150 integrated circuit and chip-set RF products. A collection of design application notes is also included.
Signetics Company
INFO/CARD #235

Microwave Cable Assembly Catalog

QMI's 1992 catalog features their line of high performance and test port flexible cable assemblies. Also included are a large selection of general purpose flexible cables, complete information on custom semi-rigid capabilities, and details on a full line of custom and low loss cables.
Quality Microwave Interconnects
INFO/CARD #234

RF design

MARKETPLACE

WHEN YOU ARE READY TO BUY-SELL-TRADE CALL *RF DESIGN* MARKETPLACE

Increase your REVENUES with ***RF Design Marketplace*** advertising! Over 40,000 prospects read and buy from this section each month. To reach this sophisticated, targeted market call today **(303) 220-0600.**

O.E.M. Electronic Products

• 13 Year Product History • Custom, RF/Digital ASICs • Computerized Instrumentation • Spread Spectrum Communications • RF Systems • Complete, Fulltime Professional Staff • Hitachi Authorized Design Center

LocUS, Incorporated

1842 Hoffman St., Madison, WI 53704

608/244-0500 FAX 608/244-0528

INFO/CARD 79

ANALOG & RF MODELS

RF SPICE MODELS

- BIPOLAR, FET, DIODE
- NON-LINEAR MODELS
- CLASS C POWER
- OPTO, LOGIC, OPAMPS

6987 N. Oracle Rd., Tucson, AZ 85704

PHONE (602) 575-5323 FAX (602) 297-5160

INFO/CARD 121

NOVA RF Systems, Inc.

The Complete RF/Microwave Solution

- RF/Microwave Systems
- Custom Design/Consulting
- Simulation Software
- Synthesizers (PLL/DDS)
- Complete Lab/Machine Shop
- TDMA/CDMA/Spread Spectrum

1740 Pine Valley Dr. • Vienna, Virginia 22182

(703) 255-2353

INFO/CARD 80

Analog, RF, and Microwave Design and Development

- Circuit Design from DC to several GHz
- Prototype development
- Computer simulation, optimization, analysis
- Circuit board layout using PCAD
  - GPS Applications
- Technical writing
- Proposal assistance
- Custom software development

Aerospace Consulting

P.O. Box 536, Buckingham, Pa. 18912

(215) 345-7184 FAX (215) 345-1309

★ DESIGN TOOLS ★

ASP 3.11 Weak Signal Amp Designs. Interactive & Auto Routines, NF Opt., Plots, Matching, K, Library & more. **PLL3 and PLL2** Interactive Phase Lock Loop Design. Dynamic BODE Plot, Phase Margin, Damping Factor, Lock in Freq, & Times, Loop BW, VCO Poles, & more. Programs include Help & Docs. For >DOS 3.2 EGA ASP \$75 PLL2, PLL3 ea. \$35 + \$3 S/H 7.5% IL.Tax

SW.I.F.T. Enterprises

955 Concord Lane

M.O. Check ***Hoffman Ests., IL 60195*** MC Visa

708-776-2119

INFO/CARD 81

Quality doesn't cost... It pays...

Over thirty years of providing high quality RF products.

TROMPETER ELECTRONICS, INC.

INFO/CARD 82

RF SYNTHESIS SOFTWARE

Smithsoft Plus by Somersoft

PC Software for Every RF Engineer

INTERACTIVE SMITH CHART

Data are entered directly onto the chart by using the mouse, keyboard, or by loading a disk file. Component arcs, including parasitic effects, are drawn on the chart by making component selections from the top menu bar. A schematic is automatically generated and displayed as components are selected. Once a circuit is entered, the circuit editor allows you to randomly tune, cut, copy or paste any component. This makes it very easy to experiment with many different kinds of circuit topologies in order to achieve the best design. This also makes the software very educational for those who are just learning the Smith chart.

... PARTIAL LIST OF FEATURES ...

Network Analyzer Z-Theta Chart

H, S, Y, Z, ABCD Conversions

Common B ↔ Common E ↔ Common C

Simultaneous Multiple File Analysis

Operating and Available Power Gain Circles

Unilateral Power Gain Circles

Noise Circles Stability Circles

S-Parameter Stack for Recursive Operations

Data Tables on Screen or Dump to Printer

Internal Graphic Screen Dump

***\$259.00, Somersoft*, (707)829-0164**

INFO/CARD 83

Surface Mount Chip Component Prototyping Kits— Only \$49.95

CC-1 Capacitor Kit contains 365 pieces, 5 ea. of every 10% value from 1pf to .33μf. CR-1 Resistor Kit contains 1540 pieces; 10 ea. of every 5% value from 10Ω to 10 megΩ. Sizes are 0805 and 1206. Each kit is ONLY \$49.95 and available for Immediate One Day Delivery!

Order by toll-free phone, FAX, or mail. We accept VISA, MC, COD, or Pre-paid orders. Company P.O.'s accepted with approved credit. Call for free detailed brochure.

COMMUNICATIONS SPECIALISTS, INC.

426 West Taft Ave. • Orange, CA 92665-4296

Local (714) 998-3021 • FAX (714) 974-3420

Entire USA 1-800-854-0547

INFO/CARD 84

SPREAD SPECTRUM COMMERCIAL DESIGNS

- Specialize in High Volume, Low Parts Costing
- Long/Short Range
- 900 MHz / 2.4 GHz
- Complete RF Lab Facilities
- Patented, FCC Approved Designs

AXONN CORPORATION

101 W. Robert E. Lee Blvd., 2nd Floor

New Orleans, Louisiana 70124

(504) 282-8119

INFO/CARD 85

RF Engineer

The MIT Plasma Fusion Center has an opening for an RF Engineer to work in the Toroidal Confinement Division's Alcator C-MOD Engineering Group. Individual will be responsible for design, construction and operation of multi-megawatt VHF sources for plasma heating experiments on the Alcator C-MOD tokamak. System responsibility is emphasized, and the engineer must be competent and interested in the areas of protection and control systems as well as high power VHF generation and transmission.

The position requires a B.S. in Electrical Engineering and a minimum of four years' experience in design and construction of high-power VHF systems. Excellent communication and interpersonal skills a must. Knowledge of PLC hardware and software helpful.

INTERESTED PERSONS should submit their resume and cover letter referencing position #PFC/RF-R9205 to: Prof. Ronald R. Parker, Director, MIT Plasma Fusion Center, 167 Albany Street, NW16-288, Cambridge, MA 02139.

MIT is an Affirmative Action/ Equal Opportunity Employer

MIT is a non-smoking environment

Axonn is a rapidly expanding New Orleans company specializing in custom spread spectrum radio and microprocessor high volume product development. Positions are available for the following:

RF Senior Level Designer — 6+ yrs. exp. required. Must be expert in Touchstone or equivalent, HP network analyzers or equivalent and 800 to 2500 MHz design, prefer experience with high volume, low cost constraints.

Project Manager — 5+ yrs. exp. in electronic product development, preferably in high volume or RF related applications. This position requires an energetic problem solver with a demonstratable track record.

Assembly Language Programmer — 5+ yrs. exp. with realtime, single chip processors required, data communications and signal processing background preferred.

RF Technician — 3+ yrs. exp., aid to Sr. Engineer, must have 800+ MHz exp. in product development.

Please respond with current resume, salary history and cover letter detailing relevant experience to:

AXONN CORP.
101 W. Robert E. Lee, Suite 202
New Orleans, LA 70124
(504) 282-8119

CAREER OPPORTUNITIES

Hundreds of Engineering positions available Nationwide

Send resume, salary requirement & relocation availability info to address below. Fees are company paid.

Communication Resources
P.O. Box 141397 • Cincinnati, Oh 45250
606-491-5410/FAX 606-491-4340

TAKE COMPLETE CONTROL! FROM DESIGN TO MANUFACTURING TO CUSTOMER ACCEPTANCE.

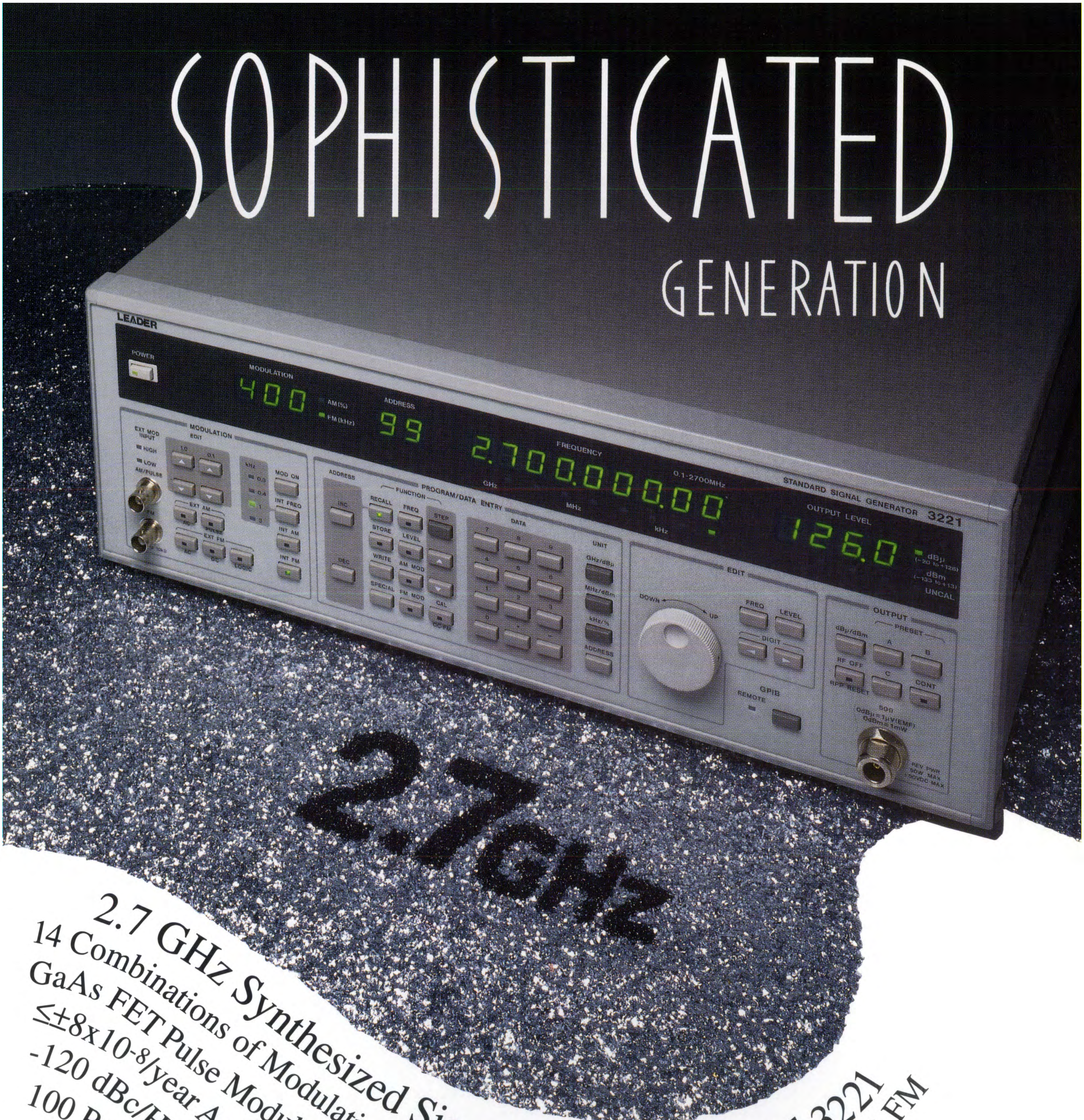
Monicor Electronics, a leader in high performance RF data networking, is seeking an experienced senior RF engineer responsible for next generation radiomodem design.

Minimum 5 years experience with BSEE, MSE preferred. Extensive experience in design for manufacturing a must. High tech working environment with outstanding benefits package available.

Send resume in confidence to:

MONICOR ELECTRONICS CORP.
HUMAN RESOURCES / RFDES.
2964 NW 60th ST.
FT. LAUDERDALE, FL 33309

Advertising Index



2.7 GHz Synthesized Signal Generator Model 3221

14 Combinations of Modulation Modes – Pulse, Logic-FM, DC-FM, AM, FM

GaAs FET Pulse Modulator • ±0.05 ppm Frequency Accuracy

≤±8x10-8/year Aging Rate • -30dBc Spurious/Harmonic

-120 dBc/Hz SSB Phase Noise • ±1.5 dB Amplitude Accuracy

100 Presets of Front Panel Operation

GPIB Standard

Call toll-free
1 800 645-5104
In NY State
516 231-6900

LEADER
FOR PROFESSIONALS WHO KNOW THE DIFFERENCE

Leader Instruments Corporation, 380 Oser Avenue, Hauppauge, New York 11788
Regional Offices: Chicago, Dallas, Los Angeles, Atlanta. In Canada call Omnitronix Ltd., 416 828-6221

INFO/CARD 77