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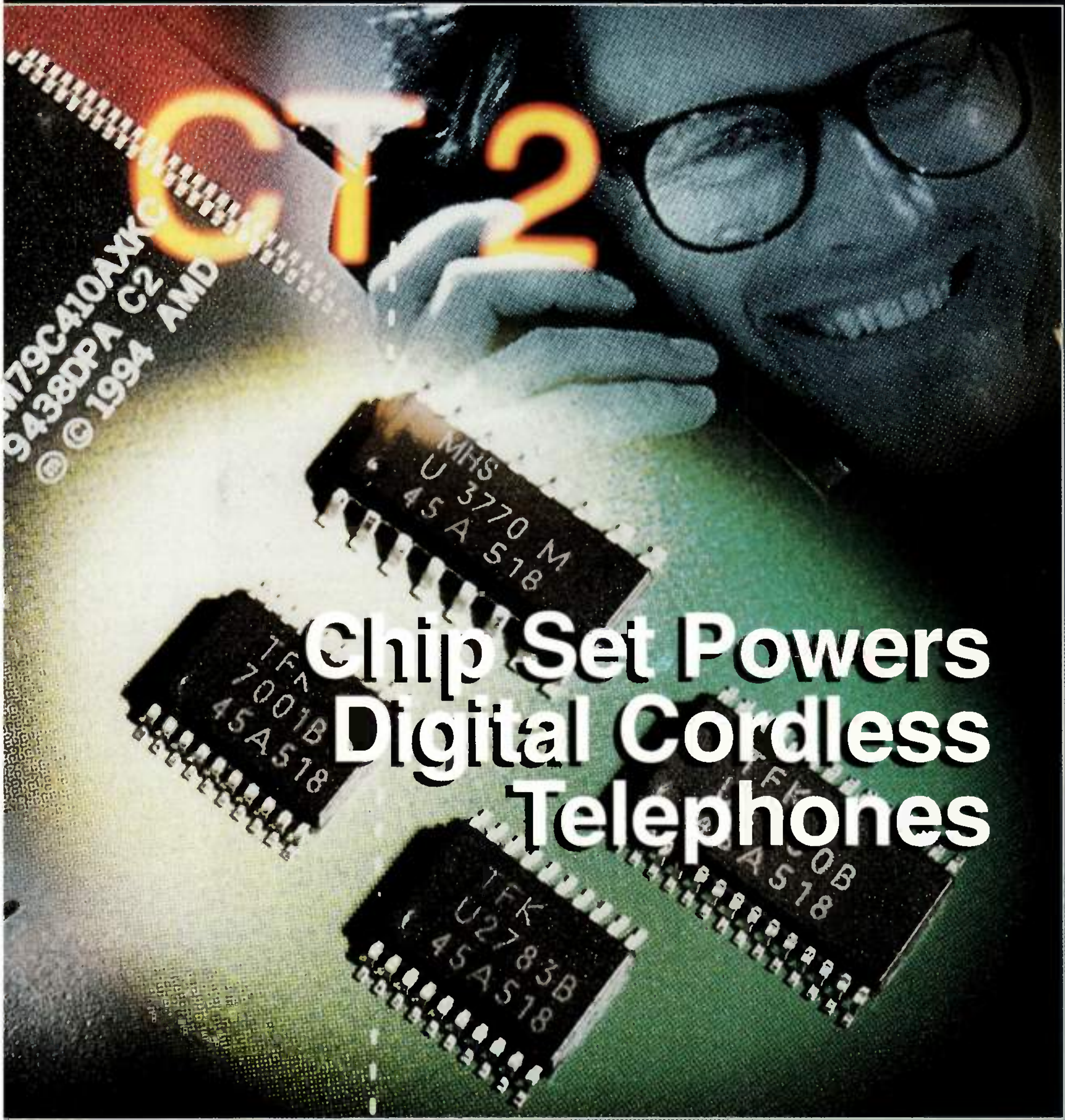
engineering principles and practices

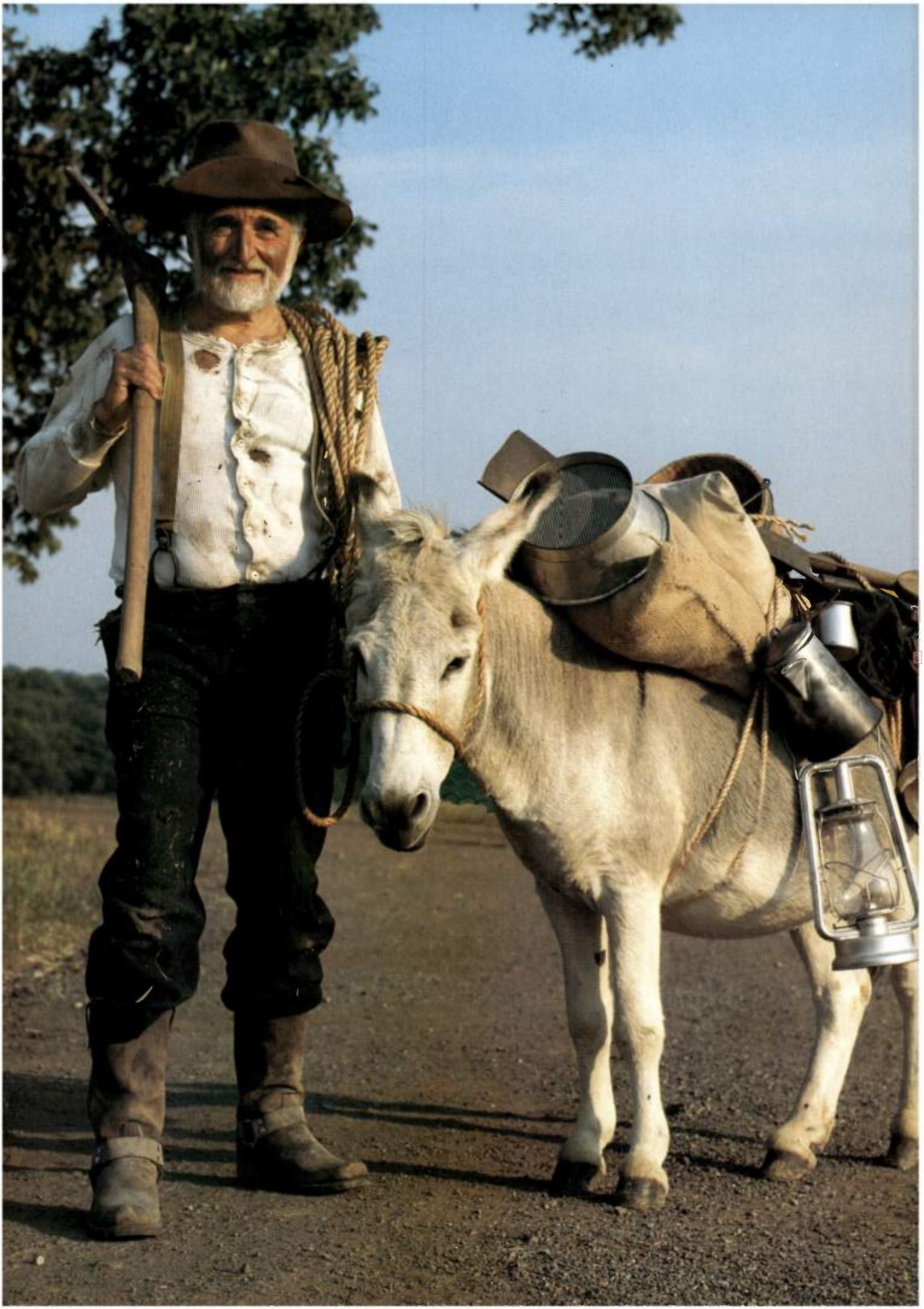
December 1995



Chip Set Powers Digital Cordless Telephones

Tutorial —
Crystals and Oscillators

Plus —
1994-1995 Article Index



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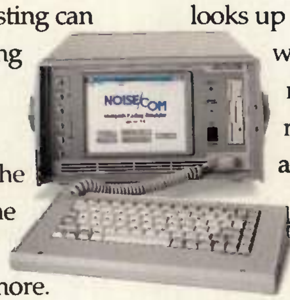

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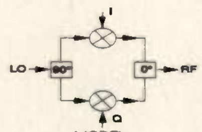

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MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	σ	CARRIER REJ. (-dBc) Typ.	SIDEBAND REJ. (-dBc) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	5xI/Q	PRICE $ Qty. (1-9)
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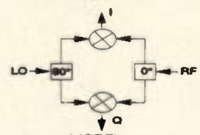
MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95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



I/Q DEMODULATORS

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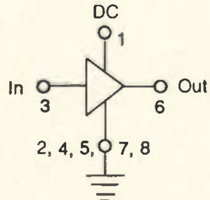

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Gain (dB) typ.	14.0	17.0	18.0	16.0
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I P 3rd Order (dBm) typ.	+27	+27	+27	+27
VSWR Output typ.	1.5:1	1.7:1	1.7:1	1.5:1
VSWR Input typ.	6.4:1	2.8:1	2.0:1	1.4:1

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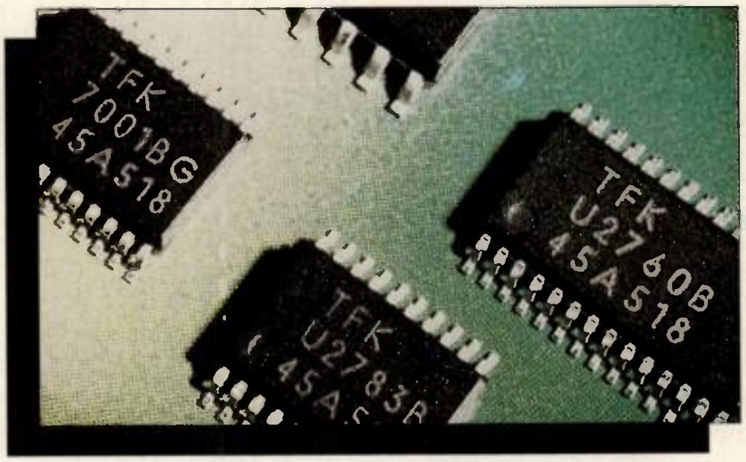

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RF editorial

International Affairs Have Big Effects on Our Business

By Gary A. Breed
Editor

International politics, economics, and war are prominent in today's news. But, somehow the distance makes it too easy for us to think that those events have only a minor effect on our lives.

No way! International business and global economics are stronger forces than many of us realize. Here are few things to think about:

A few companies I've talked with recently, both large and small, have noted that they would be out of business if not for international sales. A few of them claim that a full 40 percent of their business is sales to customers in other countries. Large or small, that is indeed enough business to make or break a company.

A number of large companies that are growing rapidly in the U.S. are foreign-owned. They have come here for the creativity and productivity of our engineering and manufacturing professionals, and to establish plants here in the world's single largest market. The best of these companies are truly development partners, not just siphoning off our brain power or meeting made-in-America requirements.

On the other side of the coin are a few troubling observations:

In a few years, our trade deficit with the People's Republic of China will exceed what we have with Japan. In 1999, Hong Kong returns to their possession, and the Taiwan situation may never be resolved. The cultural and political differences between the U.S. and China are far greater than the differences we have with Japan.

In the mean time, Eastern Europe slowly is pulling itself together, but not without troubles in Georgia, Azerbaijan, Armenia and the Balkan states that formerly were Yugoslavia.

I won't even try to suggest what will happen with India, Pakistan, and all of Africa. Developments there have been under-reported here in the U.S. Keep your eyes and ears open.

All of these things have a direct effect on us, not an indirect one. Many developing countries are implementing wireless communications in a big way because they don't have a wired infrastructure in place. Other places are catching up so quickly economically that they are changing the balance of economic power.

Communication is finally approaching the kind of worldwide universality that was predicted 30 years ago. As part of that industry, we cannot help but see huge influences in our lives as a result of global development and technological growth. Communication is what brings worldwide events closer to us, affecting our work and the rest of our lives.

See You in Dallas

Plan now to attend the first of the RF Design Seminar Series, to be held January 16-18, 1996 at the Sheraton Park Central Hotel in Dallas, Texas. Go to your supervisor and insist that your company will see great benefits from your enhanced knowledge of key RF engineering techniques.

We intentionally scheduled our seminars for a region of the country that has not been supported by other educational providers. Yet, Texas and the entire lower Midwest region have been growing in importance in wireless technology and all electronics.

See the announcement on page 61, or call our conference management group at (800) 828-0420 to get more information.

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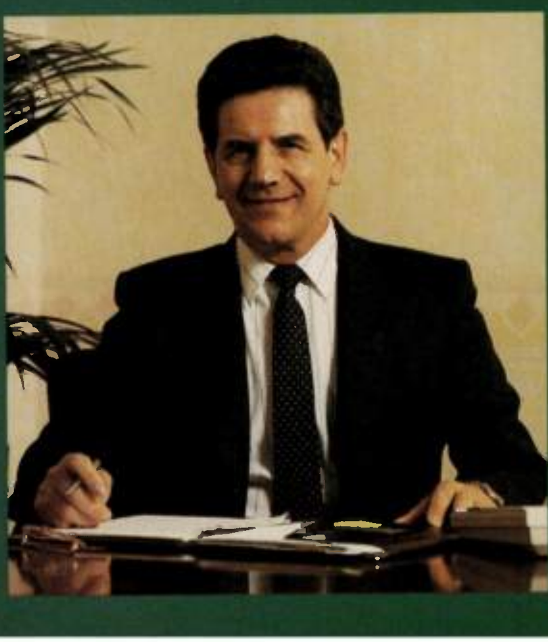
"As we move closer to global EMC regulations, Kalmus remains steadfast to its engineering heritage and is committed to producing reliable and cost effective RF amplifiers for EMC testing. Call Kalmus or your Thermo Voltek distributor for complete information."

Frank Kalmus
Technical Director

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



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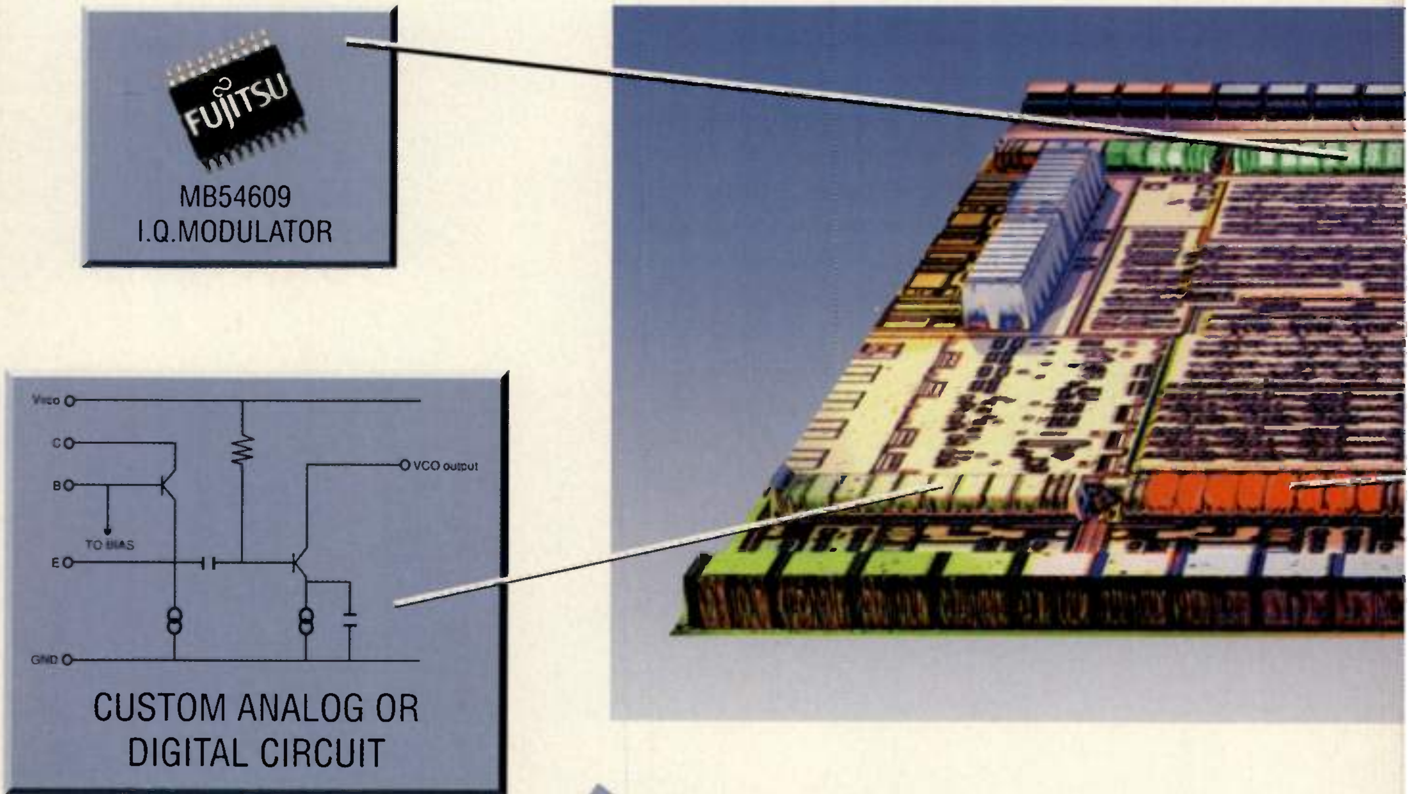
INFO/CARD 8

THE ROADMAP TO SEAMLESS RF INTEGRATION



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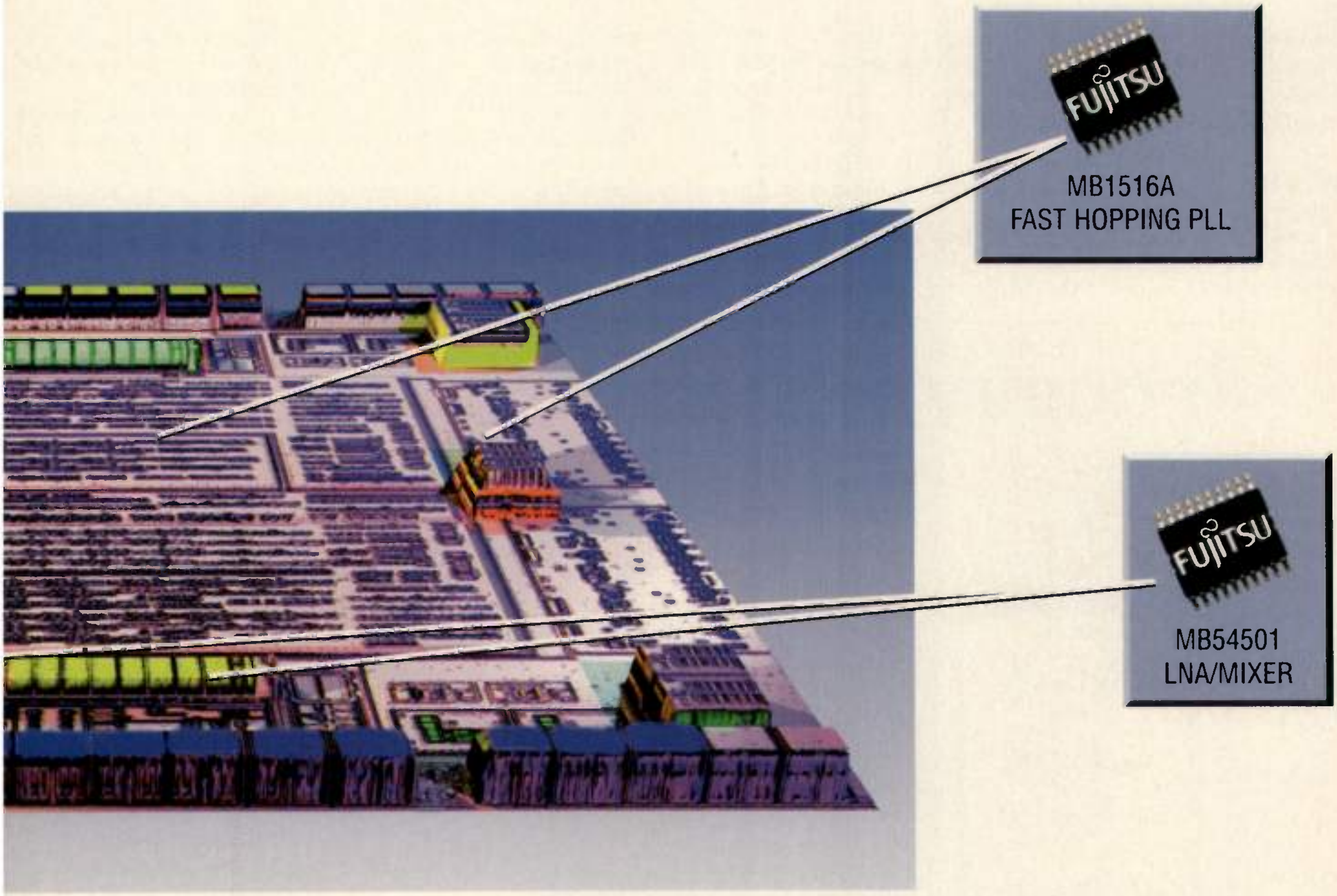

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INFO/CARD 9

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

Poor Reception for Antenna Article

Editor:

I enjoy reading *RF Design*, but must take exception to some of the imprecision in your article, "Antenna Basics for Wireless Communications," in the October 1995 issue.

1. The loop responds to both electric and magnetic fields in its far-field and when in the far-field of a source. Only in the near-field does the loop behave differently. One often sees this misconception, that a loop responds differently to magnetic and to electric fields.

2. A patch antenna is resonant when the width is half-wave in the dielectric substrate, not half-wave in air as implied in the article.

3. In Figure 7, where a monopole is fed with a quarter-wave sleeve, the performance is poor because the sleeve does not act as an effective balun. Experience has shown that there are considerable currents on the coax feed cable, and that ferrite beads or chokes are usually needed.

4. The IEEE and industry in general have well accepted definitions for directivity and gain. Directivity is indeed the peak concentration of energy normalized to the isotropic value. But gain, unlike your definition, involves directivity diminished by conductive losses and by impedance mismatch. The conductive losses may be due to imperfect metals, dielectric substrates, etc. while the mismatch loss is just $|\Gamma|^2$. The dissipative portion is unusually small except for loop antennas and sometimes for patch antennas, but the mismatch is almost always a significant factor, producing gain well below directivity.

Robert C. Hansen, Ph.D.
Tarzana, CA

In response to Dr. Hansen's points:

1. Yes, the simplified explanation of loop antenna behavior should have noted that magnetic-field-only response is limited to the near-field.

2. The patch antenna note did not imply that the half-wave dimension was in air. It simply noted that "L = 1/2 wavelength." Wavelength is always determined by the dielectric constant of the medium.

3. The information is correct, and serves as additional detail.

4. Again, this information adds to that provided in the article, although I would differ on the statement of mismatch loss "almost always" being a significant factor. There are many antenna configurations in which mismatch loss is minimal.

Our tutorials are directed to engineers with no experience, and are intended to introduce concepts in a very general manner. As such, the information may seem incomplete to an experienced engineer. Once a reader is aware of the issues regarding a particular area of engineering, he or she can augment the "incomplete" information through further reading and study.

Gary Breed, Editor

Our new RF-IC lets you handle wireless standards with ease.

Telefunken Semiconductors now offers the first RF-IC that can be used across different frequencies, from cordless phones to wireless LANs.

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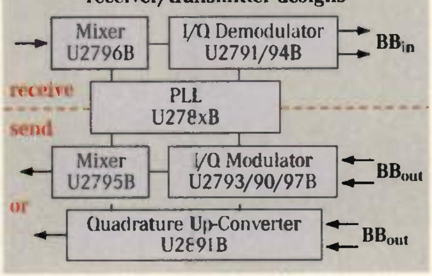

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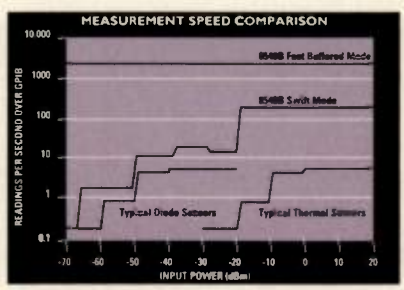

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RF calendar

December

10-13 **IEEE International Electron Devices Meeting**
Washington, D.C.
Information: Melissa Widerkehr, 101 Lakeforest Blvd., Gaithersburg, MD 20877, Tel.: (301) 527-0900. Fax: (301) 527-0994.

11-15 **20th International Conference on Infrared and Millimeter Waves**
Orlando, FL
Information: Dr. Jim Wiltse, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0801. Tel: (404) 894-3494. Fax: (404) 894-9875.

January

17-19 **RF Design Seminar Series**
Dallas, TX
Information: Argus Trade Shows, 6151 Powers Ferry Road, N.W., Atlanta, GA 30339. Tel.: (800) 828-0420 or (770) 618-0499. Fax: (770) 618-0441.

February

12-16 **Wireless Symposium & Exhibition**
Santa Clara, CA
Information: Mary Begley, Penton Publishing, 611 Route 46 West, Hasbrouck Heights, NJ 07604. Tel: (201) 393-6289.

March

3-7 **IPC Printed Circuits Expo '96**
San Jose, CA
Information: Institute for Interconnecting and Packaging Electronic Circuits (IPC), 2215 Sanders Road, Northbrook, IL 60062-6135. Tel: (708) 509-9700. Fax: (708) 509-9798.

12-14 **DSPx**
San Jose, CA
Information: Reed Exhibition Companies, 383 Main Avenue, Norwalk, CT 06851. Tel: (203) 840-5856. Fax: (203) 840-9856.

25-29 **12th Annual Review of Progress in Applied Computational Electromagnetics**
Monterey, CA
Information: Richard W. Adler, ECE Dept./Code ECAB, Naval Postgraduate School, 833 Dyer Road, Room 437, Monterey, CA 93943. Tel: (408) 649-1111. Fax: (408) 649-0300. Email: rwa@mcimail.com

April

17-19 **International Wireless Communications Expo (including the RF Design Seminar Series)**
Las Vegas, NV
Information: Argus Trade Shows, 6151 Powers Ferry Road, N.W., Atlanta, GA 30339. Tel.: (800) 828-0420 or (770) 618-0499. Fax: (770) 618-0441.

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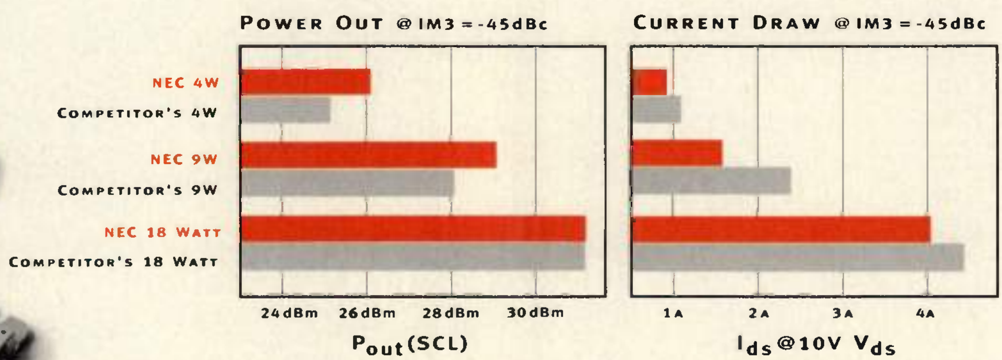

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RF courses

Analog & RF Printed Circuit Design
February 14-16, 1996, Milwaukee, WI
Information: Center for Continuing Engineering Education, University of Wisconsin-Milwaukee, 161 W. Wisconsin Ave., Suite 6000, Milwaukee, WI 53203. Tel: (414) 227-3159.

Wireless Digital Communications
February 26-March 1, 1996, Tempe, AZ
Information: College of Engineering and Applied Sciences, Center for Professional Development, Arizona State University, P.O. Box 877506, Tempe, AZ 85287. Tel: (602) 965-1740. Fax: (602) 965-8653.

Applied RF Techniques I
January 15-19, 1996, Los Altos, CA
RF and Wireless Made Simple
January 22-23, 1996, Los Altos, CA
Applied RF Techniques II
January 29-February 2, 1996, Los Altos, CA
Wireless RF System Design
January 22-26, 1996, Los Altos, CA
Information: Besser Associates, 4600 El Camino Real, Suite 210, Los Altos, CA, 94022. Tel.: (415) 949-3300. Fax: (415) 949-4400. E-mail: BesserCourse@delphi.com. World Wide Web: http://www.bessercourse.com.

Antennas: Principles, Design and Measurements
March 13-16, 1996, San Diego, CA
May 14-17, 1996, St. Cloud (Orlando), FL
Information: Kelly Brown, Northeast Consortium for Engineering Education, 1101 Massachusetts Ave., St. Cloud, FL 34769. Tel: (407) 892-6146. Fax: (407) 892-0406.

RF and Wireless Engineering
January 19-21, 1996, Dallas, TX
April 24-26, 1996, Las Vegas, NV
Practical High Frequency Filter Design
January 19, 1996, Dallas, TX
April 24, 1996, Las Vegas, NV
Oscillator Design Principles
January 20, 1996, Dallas, TX
April 25, 1996, 1996, Las Vegas, NV
Digital Modulation and Spread Spectrum for Wireless Communications
January 19, 1996, Dallas, TX
April 25, 1996,
RF Power Transistors and Amplifiers
January 20, 1996, Dallas, TX
April 25, 1996, Las Vegas, NV
Wireless Communications for Non-Engineers
January 19-20, 1996, Dallas, TX
April 23, 1996, Las Vegas, NV
Information: RF Design Seminar Series, Argus Trade Shows, 6151 Powers Ferry Rd., N.W. Atlanta, GA 30339. Tel: (800) 828-0420.

Short Course in Electromagnetic Interference Metrology
January 22 & 23, 1996, Anaheim, CA
Information: Edit Haakinson, NIST, 325 Broadway, Boulder, CO 80303. Tel.: (303) 497-3321, Fax: (303) 497-6665, e-mail: haakinso@micf.nist.gov

Modern Digital Modulation Techniques
December 4-8, 1995, Alexandria, VA
New HF Communications Technology: Advanced Techniques
December 4-8, 1995, Washington, DC
Satellite Communications with Emphasis on Mobile Systems
December 6-8, 1995, Alexandria, VA
Modern Radar Technology: An Introduction
January 22-24, 1996, Washington, DC
Electromagnetic Interference and Compatibility (EMI/EMC): A Practical Approach to Testing and Problem Solving
February 12-16, 1996, Washington, DC
Hazardous RF Electromagnetic Radiation: Evaluation, Control, Effects, and Standards
June 12-14, 1996, Washington, DC
November 13-15, 1996, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Academic Center, Room T-308, 801 22nd Street, N.W., Washington, DC 20052. Tel: (202) 994-6106 or (800) 424-9773. Fax: (202) 872-0645.

DSP Without Tears™
December 4-6, 1995, San Jose, CA
January 8-10, 1996, Atlanta, GA
February 12-14, 1996, Scottsdale, AZ
March 6-8, 1996, Long Beach, CA
Information: Z Domain Technologies, 325 Pine Isle Court, Alpharetta, GA 30302. Tel.: (800) 967-5034 or (404) 587-4812. Fax: (404) 518-8368. E-Mail: dsp@mindspring.com

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RF & Microwave Measurements & Applications
January 8-11, 1996, Washington, DC
January 29-February 1, 1996, Monterey, CA
Error Correcting Codes with Applications for Communications Systems
December 11-14, 1996, Washington, DC
Electronic System Design for Testability
January 22-23, 1996, Monterey, CA
Information: University Consortium for Continuing Education, 16161 Ventura Blvd., M/S 752, Encino, CA 91436. Tel: (818) 995-6335. Fax: (818) 995-2932.

Digital Wireless, Enabling Technologies
December 11-18, 1995, San Jose, CA
Information: EETutor, P.O. Box 20415, San Jose, CA 95160-0415. Tel.: (408) 268-6891. Fax: (408) 927-6880.

Radar Signal Processing: Theory, Technology and Application
January 31-February 2, 1996, Atlanta, GA
Coherent Radar Performance Estimation
February 5-8, 1996, Atlanta, GA
Antenna Engineering
February 13-16, 1996, Atlanta, GA
Principles of Pulse Doppler Radar: High, Medium and Low PRF
February 13-15, 1996, Atlanta, GA
Radar Cross Section Reduction
March 26-29, 1996, Atlanta, GA
Information: Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel: (404) 894-2547.

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ITU Report Comments on Information Superhighways

In 1994, the info-communications industry (computers, telecommunications and audio-visual) represented 5.9 percent of the global domestic product — US$ 1.43 trillion — with growth at twice the rate of the rest of the economy. As an important part of the world economy, this industry has been analyzed in the *World Telecommunication Development Report*, issued by the International Telecommunication Union. The report observes that overall communications capacity has reached the point where supply exceeds the demands of traditional voice communications, and new services such as multimedia are being rapidly developed for their revenue potential. With some caution, the ITU summary says, "The truth is that no one really knows which multimedia services will prove popular and which will flop." The report also views the Internet as an evolutionary step toward a larger *global information infrastructure*, a network made up of many regional or national networks. Another significant note is that the ability to use high capacity telecommunications is related to age, and as youthful users grow up familiar with advanced communication technology, the predictions of large-scale usage will be fulfilled. To obtain a copy of the report, contact the ITU Press Office at +41 22 730 5111, or consult an online version of the report at the Internet address: http://www.itu.ch/WTDR95

Single-Mode Fiberoptic Market to Hit $3.1 Billion

A report by KMI Corporation forecasts compound 22 percent growth for single-mode optoelectronic devices, reaching a market size of $3.1 billion by the year 2000. Telecom, cable TV and other networks are driving the growth, according to KMI.

ESD Association Approves New Standards

The ESD Association, and ANSI accredited standards development organization, approved one revised standard, one draft standard, and one advisory document at its September meetings. The revised standard, ESD-S4.1-1995, *Work Surfaces — Resistive Characterization*, updates the existing worksurface standard by proposing a maximum resistance to a groundable point of 1×10^9 ohms and a minimum resistance of 1×10^6 ohms. The earlier document did not specify a minimum resistance, and included a maximum value of 1×10^{10} ohms. The new draft standard covers resistive characterization of seating, including chairs and stools, and the advisory document approved was ADV11.2-1995 — *Tribo-electric Charge Accumulation Testing*. The document provides end users with information to aid in understanding the phenomenon of triboelectric charging, and reviews the procedures and problems associated with the various test methods often used to evaluate the phenomenon. The ESD Association can be reached at 7902 Turin Rd., Suite 4, Rome, NY 13440; tel: (315) 339-6937; fax: (315) 339-6793.

University of Nevada, Reno Develops EMC, Antenna Test Facility

The University of Nevada, Reno has developed one of the largest university antenna anechoic chambers in the western U.S. The chamber is available to interested parties for antenna pattern and electromagnetic compatibility (EMC) pre-qualification measurements on either a lease or contract basis. The chamber is 15 × 30 × 11 feet, manufactured by Ray-Proof with 100 dB attenuation of ambient radiation. The laboratory is fully equipped with instrumentation for EMC and antenna measurements. Contact the Department of Electrical Engineering, University of Nevada, Reno, tel: (702) 784-6927; fax: (702) 784-6627.

Cellular Deal Brings Service to the Hearing-Impaired

Motorola and Phoenix Management have announced an agreement to modify several Motorola cellular telephones for use with Phoenix' HATIS™ (Hearing Aid Telephone Interconnect System). The HATIS device connects to the cellular telephone's audio interface and couples to the user's hearing aid with a t-coil. Phoenix Management is a Fountain, Colorado-based company founded by Jo Waldron, who is deaf, and Shirley Crouch, who is hard of hearing. The patent-pending HATIS device was developed out of Waldron's frustration with being unable to use telephones, including cellular.

Coil Winding Exhibition Seeks Papers

The Electrical Manufacturing & Coil Winding '96 Exhibition and Conference has issued a call for papers. Preference will be given to hands-on success stories. Topics may include adhesive bonding, automatic coil winding systems, balancing methods, coating and impregnating, cost-saving tips, computer-aided manufacturing, ISO-9000 and other appropriate subjects. Abstracts should be submitted by January 31, 1996 to: Charles E. Thurman, Electrical Manufacturing and Coil Winding Association, P.O. Box 278, Imperial Beach, CA 91933; tel: (619) 575-4191; fax: (619) 575-5009. The conference will be held September 24-26, 1996 in Rosemont, Illinois.

IEPS Awards Education Grant to Florida Institute of Technology

The Education Committee of the International Electronics Packaging Society (IEPS) has announced that the Florida Institute of Technology is the recipient of of $5,000 Education Grant for 1995. The award was based on the merit of the submission by the institute, and will enable a student to investigate the use of low-temperature SiN (silicon nitride) deposition for passivation and protection of plastic electronics packaging. The IEPS is a 501(C)3 non-profit professional group dedicated to the education of those involved with both electrical and mechanical electronics packaging.

Digital Video and Image Compression Markets to Boom

BIS Strategic Decisions predicts that video and image compression technology will transform the way business and consumers convey information. Applications that currently are nearly zero in usage of compression will fuel the growth, according to BIS. Broadcasting, including video-on-demand, plus information and entertainment, will change the technology from a laboratory and still-image emphasis to mass markets.

Business Briefs

Communications Instruments and Kilovac Merge — Communications Instruments Inc and Kilovac Corporation announce the merger of the two companies. The companies supply a wide range of standard and custom electromechanical, solid state, high voltage and hybrid relays.

CEL Begins Automated FAX Information Service — California Eastern Laboratories now has an automated FAX system for instant access to NEC RF, microwave and NEPOC™ product data. CEL/Fax can be accessed in the U.S. and Canada at (800) 390-3232.

EMC Integrity Opens Pre-Compliance Lab — EMC Integrity, a consulting firm assisting companies to meet global EMC requirements, has opened a pre-compliance testing facility in Longmont, Colorado. Contact facility manager Kevin Hight at (303) 776-7249.

Boonton sets Alliance with GMME — Boonton Electronics Corporation has established a strategic partnership with General de Mesurees de Maintenance Electronique S.A. (GMME), Europe's leading test equipment manufacturer. The partnership will create Boonton/Metrix, a distribution channel that will sell GMME equipment in the U.S.

Sonnet Software Makes the Inc. 500 List — Sonnet Software, developer of microwave electromagnetic software, has been included in this year's Inc. 500 list. The list includes the 500 fastest-growing privately-held companies.

Compact Software U.K. Distribution Set — ECS Electronic Software Components, the European Compact Software distributor, has announced that Rohde & Schwarz UK, Ltd. has assumed exclusive distributorship and support center for the U.K. and Ireland.

UL Installs two Anechoic Chambers for EMC Testing — Underwriters Laboratories Inc. has begun construction on two new anechoic chambers that will increase capabilities for UL's EMC testing services. Both chambers allow testing from 26 MHz to 40 GHz.

Hughes Assembly & Test Products Become Palomar Products — A new company, Palomar Products has been formed by the investor group the recently acquired Hughes Aircraft Company's Technology Products Division. The operation provides automated manufacturing for the telecommunications, computer, medical and automotive industries

Contracts

LNR Delivers Earth Stations to Taiwan — LNR Communications, Inc. has delivered three SAFARI™ Digital Video Flyaway Earth Stations for use by a single broadcaster in Taiwan. TVBS will use the units for special event and news coverage in Taiwan and other Pacific Rim locations.

VI Technology to Develop RF Metrology Software — Fourth State Technology has hired VI Technology to develop software for a new radio-frequency metrology system for use in plasma processing and wafer manufacturing plants. The process control software will issue warnings and fault alarms on several channels.

Maury Microwave Receives Automated Tuner Development Contract — Lockheed-Martin and the U.S. Government have awarded Maury Microwave a $315,000 contract for development of a WR10 waveguide automated tuner system. The system will be used for automated power, intermodulation distortion, and noise characterization for devices at 94 GHz. The award was made as part of the Microwave and Analog Front End Technology program, a follow-up to the MIMIC program.

RF news *continued*

Business Briefs *continued*

MIDISCO Moves — The new address for MIDISCO is 1707-32 Veterans Memorial Highway, Islandia, NY 11722-1581. Tel. (516) 234-3505. Fax: (516) 234-3913.

National Semiconductor, Noise Cancellation Technologies Agree on License — Noise Cancellation Technologies, Inc. announces a Memorandum of Understanding with National Semiconductor that encompasses NCT's expertise in active noise reduction. Under the MOU, National will license electronic technologies for potential use in high-end semiconductor applications.

E/M Corporation Opens Expanded Facility — With an open house on November 16, E/M announced completion of a 7800 sq. ft. expansion of its facility, including a new computer-controlled electroless plating line. The company provides copper and nickel plating for shielding and EMI control.

Merix and Hewlett-Packard Finalize Acquisition — Merix Corporation announces finalization of its purchase of Hewlett-Packard's Lovelend printed circuit board facility. 85 percent of the facility's 290 employees accepted positions with the new company. Merix was originally Tektronix Printed Circuit Board Division, and was spun off in 1994.

Wide Band Systems Gets Detector Patent — A U.S. patent has been awarded to Wide Band Systems, Inc. for a Coherent Threshold Detector used in its microwave receivers. The threshold technique is based on an estimation of the instantaneous signal-to-noise ratios of received signals.

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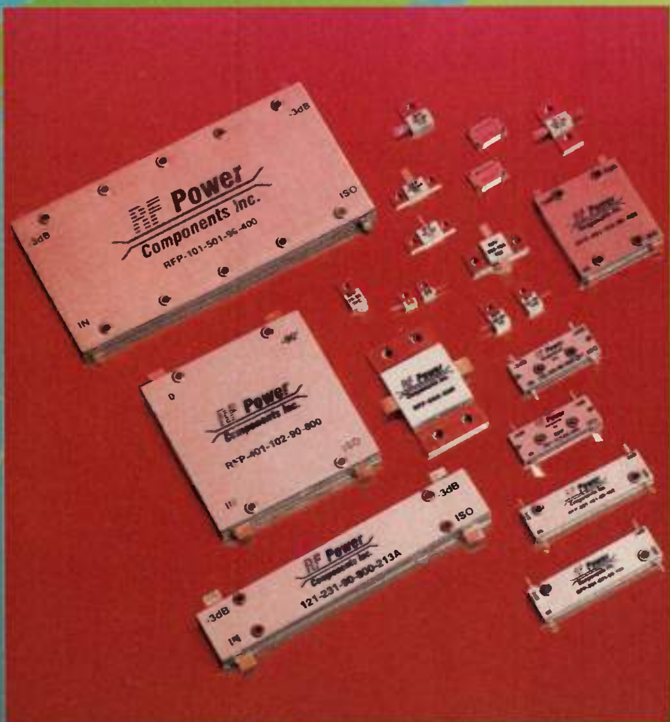

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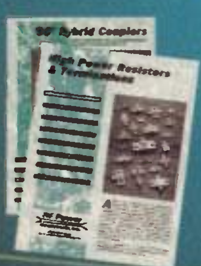

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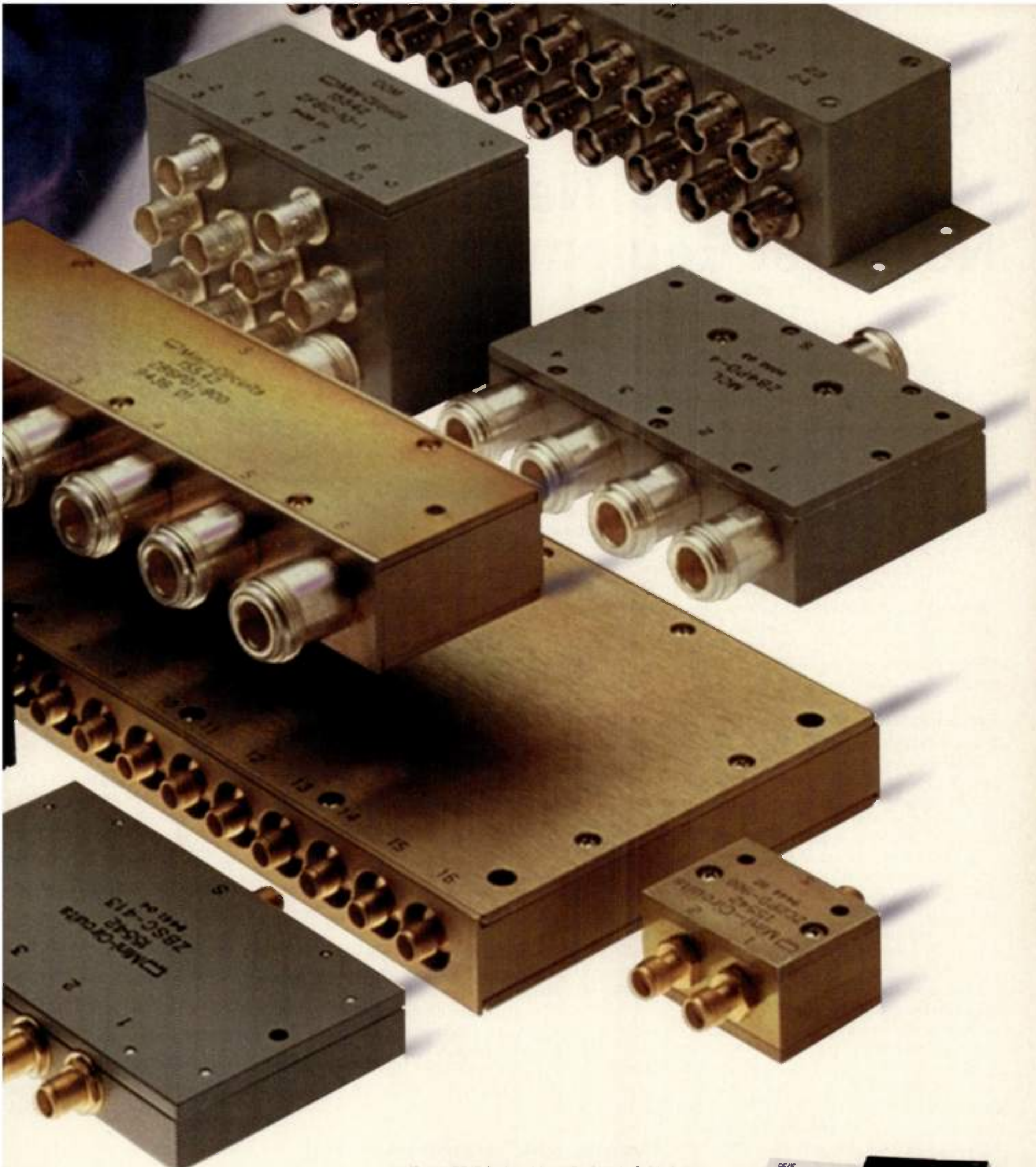



RF/IF Designer's Handbook

New Systems, New Regs Spawn New Test Equipment Opportunities

By Andy Kellett
Technical Editor

Three different U.S. PCS systems are about to be implemented using tens of thousands of base stations. At the same time, European EMC regulations are about to take effect, new television standards are being developed and a number of new wireless devices are being unleashed on a demanding market. The effect is to create a lot of work for RF test equipment manufacturers. This report will look at how PCS requirements and new European EMC regulations are affecting RF test equipment manufacturers.

Servicing a Forest of Base Stations

While cellular systems have been around for more than a decade, the problems associated with operating micro-cellular system with a forest of base stations will be starkly outlined when PCS systems are installed.

One problem is how to handle multipath fading when so many base stations are in close proximity. In the past it was possible to combat fading simply by upping the power of the affected base stations. However, as more base stations are installed, this strategy becomes less effective because higher power means more interference in adjoining cells.

"One of the biggest set-asides in communications systems has been for fading margin," says Bent Hessen Schmidt, V.P. of Marketing and Communications for Noise Com. "People realized they can do with a smaller fading margin if they design their systems right," says Hessen Schmidt. Several companies, including Noise Com, make fading simulators.

Another problem is how to inexpensively maintain systems that contain thousands of transmitters. "We are concentrating on boosting the efficiency of service providers," says Jan Whitacre, Marketing Communications Manager for Hewlett-Packard's Spokane Div. HP is currently trying to increase efficiency by automating test procedures in test sets, and in the future will help by enabling technicians to monitor the health of the network without having to visit each cell site, says Whitacre.

Multiple Standards, Multiple Test Sets

Test equipment manufacturers have their own challenges. To attack the U.S. PCS testing market, manufacturers have to deal with three separate systems. A version of Europe's GSM digital cellular system is being adapted for use at 1900 MHz, code division multiple access (CDMA) is being used in some areas, and IS-136, a 1900 MHz version of the current digital cellular system, is also being built.

Manufacturers are producing test sets for each of these systems. In addition, different software is required for each test set for each manufacturer's base station. For example, Ericsson software must be loaded into an IS-136 test set to test an Ericsson base station. Add to that, test sets made for the 800 MHz cellular systems and the test sets for communications systems used overseas (Europe's GSM and DECT and Japan's Personal Handyphone System (PHS), among others) and you have scores of different test sets.

Designing New Test Equipment

Actually designing a test set for each standard is a burden that many test equipment manufacturers have chosen to bear so that they may take advantage of every part of the rapidly expanding test market. "If the U.S. settled on one standard, like Europe settled on one standard, it would have made things a lot easier for us," says Steve Wendel, Wireless Business Development Manager at Wavetek. "Our customers are following all three major [U.S. PCS] specs, so we are following all three specs," says Wendel.

While many of the systems used in one test set can be re-used in a design for a different test set, it is by no means a trivial design problem to go between systems. Jim Hebert, Product Marketing Manager at Tektronix gives the example of going from a GSM test set to a CDMA test set. "They use the same mainframe, upconverter, and display system, but the link handler is brand new," says Hebert. "It's a substantial new set of signalling; it's almost the same type of effort as it is to design the new phone."

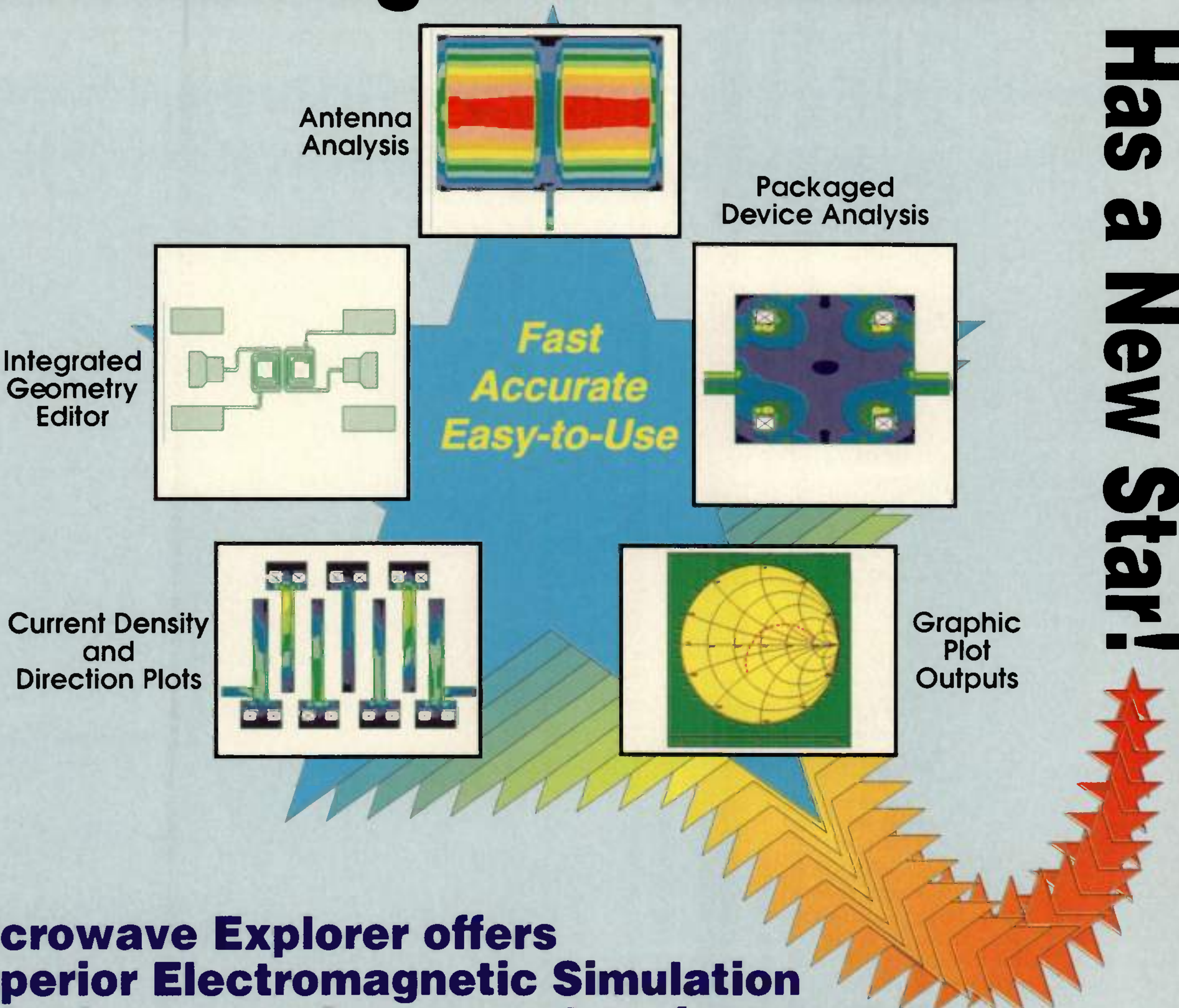
European EMC Certification

People have been scurrying to get European electro-magnetic compatibility (EMC) certification before Europe-wide EMC regulations go into full-force on January 1, 1996. These regulations have prompted many manufacturers to buy "pre-compliance" equipment – EMC equipment used to test equipment to make sure it will pass official (and expensive) EMC-certification-testing later on. Dick Rogers, Marketing Manager for Amplifier Research says his company has seen plenty of business in this area, however, most of it has been overseas. "The bulk of what we think the U.S.business will be is still out there," says Rogers.

Conclusion

Test equipment manufactures have the opportunity to sell a lot of equipment to users who will have massive systems to maintain. If their equipment allows PCS service providers to simultaneously keep their systems running and keep service prices at a point where PCS is widely accepted by the public, test set makers will have had a part in maintaining the growth of this new market segment. *RF*

Electromagnetic Simulation



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Electrolytic Grounding Solves Failures for Alyeska Pipeline

By Betty Robertson
Lyncole Industries, Inc

Low-resistance grounding is essential for safety, stability, and EMI control of electrical and electronic equipment. Our EMC topic for this issue is electrolytic grounding, which offers a solution for difficult grounding situations in industrial plants, communications facilities, and other electronic installations.

Alyeskan Pipeline facilities are located on rock, where ordinary ground rods are ineffective, and the floating grounding grid was found to be unsatisfactory.

Built into the side of a mountain, the facilities of an Alyeskan Pipeline Terminal were experiencing unexplainable equipment failures due to an inadequate grounding system. These "phantom failures" were occurring much too frequently and represented a serious problem for the pipeline.

The Pipeline is a transportation company that brings oil from Prudhoe Bay on the Arctic float, down to the harbor at Valdez. There, it is stored and transferred to tanker ships for transport to a final destination. With the potential for an ecological disaster, even though remote, the Pipeline was not willing to take any chances with continued equipment failures.

"You certainly can't afford to have equipment just going out on you for no reason at all when you're trying to run a smooth operation," says Fred Yawit, former Alyeskan Pipeline Manager.

The facilities of the Alyeskan Pipeline are scattered over a mass of rock measuring three-quarters of a mile long and rising from its base at sea level to 600 feet on the mountain, where there are a number of massive tanks, each approximately 375 feet around and 35 feet high. Along with the oil tanks, the unique parcel of land houses its own power generation plant, ballast water, treatment plant, administrative control buildings, and maintenance facilities for equipment and vehicles.

These facilities and the equipment housed in them needed to be grounded properly, but this is difficult in an area made of solid rock. The existing system, a floating grounding grid that tied everything together, was inadequate. When an inspector found that potential ground readings were close to 1000 ohms (compared to the National Electric Code requirement of under 25 ohms), Manager Yawit started to make inquiries.

His research into electrical earth grounding eventually led him to Lyncole, manufacturer of the XIT grounding system, a self-maintaining, environmentally safe system. See the section, "How Electrolytic Grounding Systems Work," for details of the system's construction and operation.

The Pipeline Manager was particularly interested in the grounding system's performance in cold weather. After being assured that their experience in Canadian installations was satisfactory, 21 of the XIT rods were ordered. Installation proved difficult, with drilling occasionally reaching water, which meant that a new hole had to be drilled. Rods of different sizes were needed, and positions had to be adjusted to complete the installation in the mountainside.

The immediate effect was to bring the ground readings down to the NEC specifications. The system was monitored for two months to assure consistent performance. Readings remained around 15 ohms, and continued to be acceptable in the wintertime.

The phantom failures, which were commonplace before the grounding improvements, ceased altogether. The Pipeline is now confident that their grounding problems are gone, and they can transport oil with greater confidence.

How Electrolytic Grounding Systems Work

Many applications require very low resistance grounding — shielded rooms, instrument calibration laboratories, semiconductor fabrication plants, hospitals, communications facilities, and many others. Low resistance ground improves protection from power surges, static charges, and other large-scale problems. It also reduces the small-signal problems of shield currents (ground loops) and electrolysis of metal-to-metal joints.

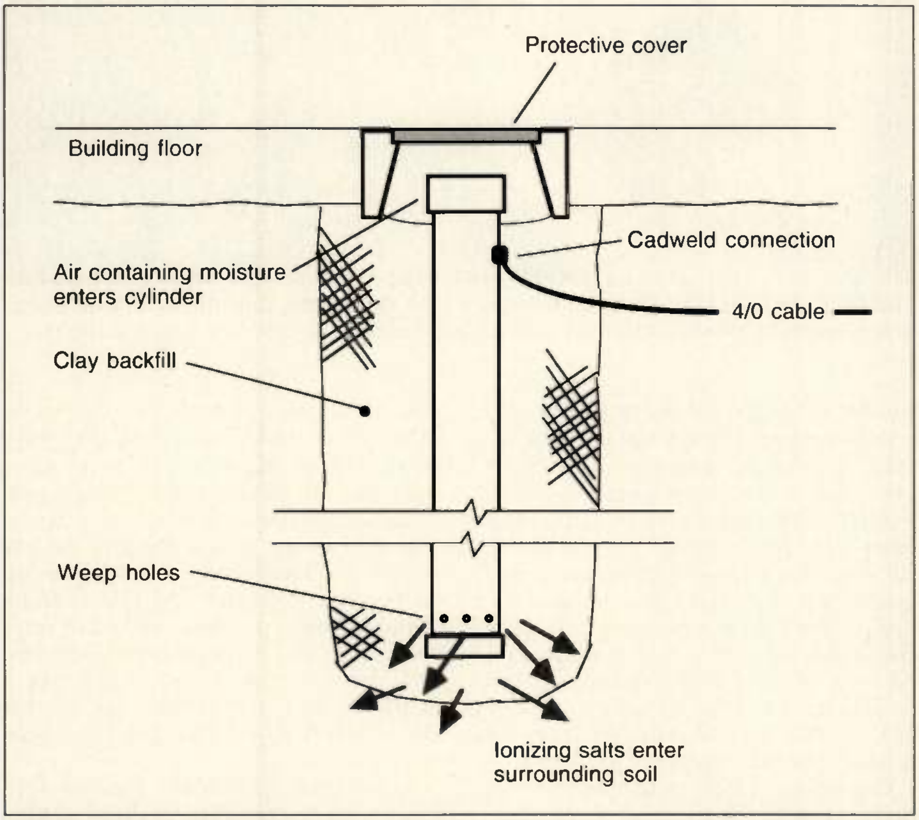
One method for obtaining a ground with minimum resistance is electrolytic grounding, using a system like Lyncole's patented XIT system. Figure 1 shows how the system works in one particular installation method. A copper pipe is filled with natural earth salts, then capped at both ends. Air holes are drilled at the top, and weep holes at the bottom. Moisture from the air is absorbed by the salts, and the solution flows out the weep holes, forming a region of highly conductive ionized salt solution in the surrounding earth. The use of natural metallic salts, and the slow rate of their release minimizes the environmental impact.

The use of copper, a soft metal, requires that an installation hole be augered or drilled. The space around the rod is typically filled with compatible material, such as Bentonite, a viscous clay. The length of the rod can vary, depending on the application, but are usually similar to conventional ground rods (10-12 feet long).

Life testing results extrapolate to a predicted service life of 25 years or more. Copper is more resistant to corrosion than most metals, and even as it corrodes, the remaining copper continues to provide good conductivity, unlike copper-clad materials. Cadwelded connections from the XIT system to the user's equipment will maximize reliability, as well.

The use of this type of grounding can reduce ground resistance to 2 to 5 ohms or less. The nature of the base soil (or rock) will determine how many rods are needed to obtain the desired performance.

For more information on the Lyncole XIT grounding system, contact: Lyncole Industries, Inc., 3547 Voyager Street, Suite 104, Torrance, CA 90503. Tel: (310) 214-4000; Fax: (310) 214-1114. *RF*



A typical electrolytic grounding installation below a building's concrete floor. Expected life of the system is 25 years or more.

Chip Set is Designed for Low-Cost CT2 Cordless Telephones

Temic Telefunken has introduced a new CT2 chip set, co-developed with the French company Wavecom. The ship set consists of four ICs that represent the complete RF part of the telephone, plus an AMD Am79C4xx controller. Together with passive components, p.c. board and appropriate packaging, they create a complete telephone.

In contrast to older analog standards like CT1, CT2 offers the advantages of digital transmission — high transmission quality and low susceptibility to eavesdropping. It is expected that DECT standard will dominate business applications, but the CT2 standard will dominate in the private/residential market sector, where cordless telephones are already widely used.

All four Temic ICs are provided in SSO or SO packages to save space. The GaAs front-end U7001BG integrates the antenna switch, low-noise amplifier and power amplifier. In the receive mode, this chip draws 4 mA, and while transmitting, it draws just 39 mA since the power amplifier has an efficiency of 45 percent.

The RX/TX U2760B is a bipolar silicon chip. It includes mixers, VCOs, demodulator and RSSI circuits. Simple external circuitry is a key feature, and its power consumption is 23 mA.

The U2783B is a twin-PLL, a bipolar silicon chip operating at frequencies up to 1250 MHz and 400 MHz for each of the PLLs, respectively. Both can be operated with a single external reference frequency.

The final Temic device is the U3770 I/Q modulator, a CMOS IC that also generates the system clock frequency.

Completing the system is an Am794xxA CT2 PhoX™ Controller. This highly integrated, low-voltage chip implements the baseband and control functions of audio processing, protocol control, data formatting and peripheral functions.

The CT2 chip set from Temic includes all RF functions, and offers a total cordless telephone design solution with an AMD controller and Wavecom circuitry.

System Design Options

Because the chip set has been developed as a complete system, CT2 product designers have two options.

First, the engineers can develop their own design based on the Temic RF system solution. Samples and test boards for the parts are available for evaluation and development. In this case, the RF portion is a complete, adjustment-free subsystem, and the designers can develop the remainder of the system to suit their particular product requirements.

The other option is to use the full know-how of Temic and Wavecom. Wavecom can provide the customer with a demonstration board (for the complete telephone) along with schematics, bill of material and software license. Wavecom can also support the full product integration and transfer to production. In this case, the telephone manufacturer gets a complete phone with a standby time of more than 70 hours and talk time of about 7 hours, using a 500 mAh battery. This is a low-voltage design, as well, requiring only a two-cell battery. A photo and block diagram of the demonstration board are shown in Figures 1 and 2.

Temic does not compete with its customers in the finished-product arena, and is committed to providing an easy-to-build design solution.

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JMS mixers mean unparalleled performance and reliability. Solder plated J leads provide improved reliability of the solder connection while significantly reducing thermal stress and leaching. All-welded internal construction withstands reflow temperatures up to 240°C for 5 minutes, and rugged construction enables JMS mixers to pass tough MIL-M-28837 shock and vibration tests. Additionally, the all-ceramic surface mount package has a cover pull strength of 20 pounds! Other quality features include 4.5 sigma repeatability unit-to unit, automated assembly for low-cost and fast, guaranteed 1 week shipment, tape and reel availability plus a 5 year Ultra-Rel™ guarantee. If value is a must...specify JMS mixers from Mini-Circuits.

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SPECIFICATIONS

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

Note: *10-49 qty.

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The U7001BG Front-End IC

The U7001BG is a monolithic GaAs transmit/receive front end with a power amplifier, low-noise amplifier and an antenna switch. It is specifically designed for operation over 839-952 MHz with external matching. It is packaged in a SSO-20 plastic package. Features and specifications of the device include:

- 3.6 V typical, 2.7 V min. power supply voltage
- nominal 50-ohm operating impedance at all RF ports
- 30 dB (2.7 V) or 33 dB (3.6 V) typical power gain in power amplifier
- 46% power added efficiency PA
- Power down and gain control for the power amplifier
- Optional high power (50 mw) with a 5.0 V supply
- 16 dB typical gain in the low-noise amplifier
- –17 dBm low-noise amplifier third order intercept point
- 2.0 dB max. noise figure for the low-noise amplifier
- Power down pin for the low-noise amplifier
- 23 dB typical (20 dB min.) isolation in the antenna switch
- 2 µs turn-on and 5 µs turn-off times

Figure 3 is a diagram of the U7001BG in a minimum component count application.

The U2783B-FS Twin PLL

The U2783B is a low power twin phase-locked loop IC. The two PLLs operate in the appropriate frequency ranges for the first local oscillator and the baseband up-conversion LO. Prescaler and power-down functions are included. In addition to CT2 applications, the U2783B can be used for CT1, GSM, IS-54 and other systems. Features and specifications include:

- Low current consumption: 10 mA with a 3 V supply
- 2.7 V to 5.5 V supply range
- Maximum input frequency: 1250 MHz (PLL1), 400 MHz (PLL2)
- Separate power down for each PLL
- ÷64/65 prescaler for PLL1
- ÷32/33 prescaler for PLL2
- 3-wire serial bus
- External reference input: 20-40 MHz sine wave, 100 mV_{rms} AC-coupled
- ESD protected according to MIL-STD 833, method 3015 cl.2
- Separate analog and digital grounds

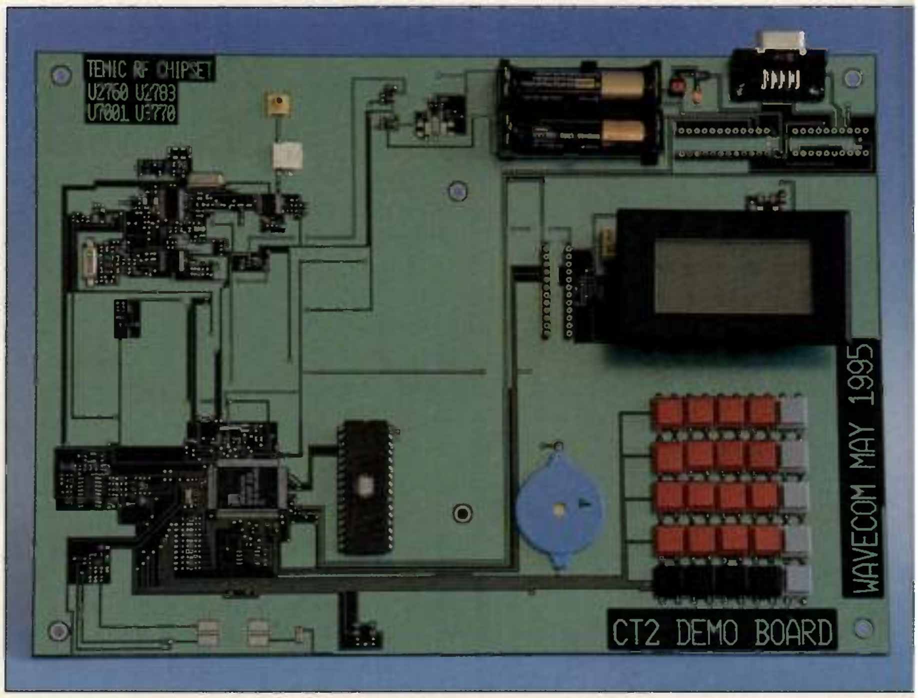


Figure 1. A demonstration board developed by Wavecom provides a complete working telephone for evaluation and development.

The U2760B RX/TX IC

Dual up-conversion, down-conversion, and demodulation are performed in the U2760B RX/TX integrated circuit. This device typically converts the 800 kHz baseband modulated signal to an IF of 254 MHz, which is then up-converted to the final output frequency of about 900 MHz. In the receive mode, the input from the low-noise amplifier is down-converted to the 254 MHz IF, filtered and converted again to 800 kHz. A limiting IF amplifier includes RSSI circuitry, and is followed by a quadrature demodulator and data slicer. The recovered data

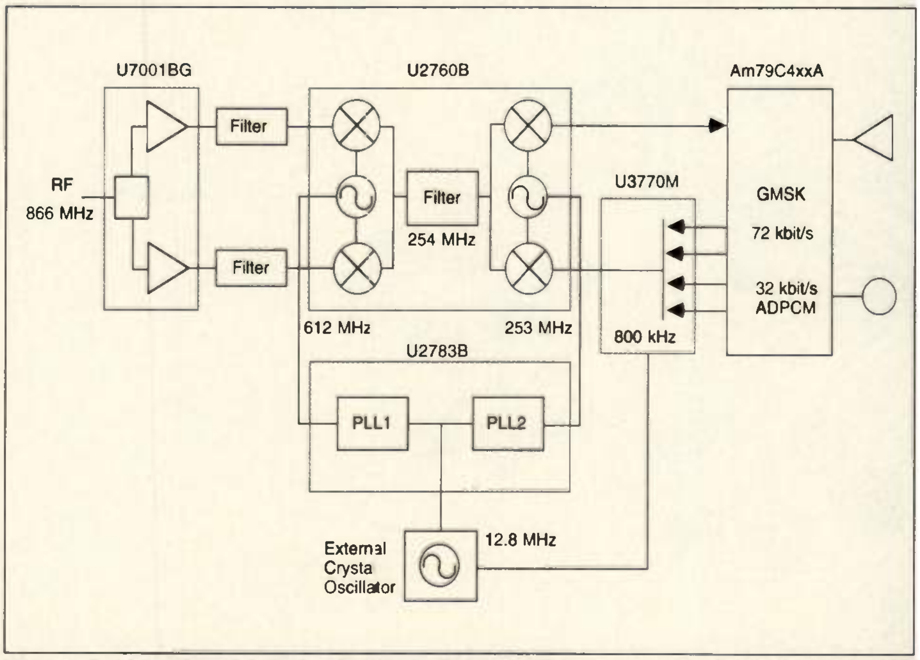


Figure 2. Functional block diagram of the radio portion of the Wavecom CT2 demonstration board.

stream is then sent to the baseband/controller IC. Features and specifications include:

- 2.7-3.3 V supply range
- 3 mA current draw at 2.9 V
- Integrated UHF and VHF VCOs
- 10 dB noise figure in receive path
- RX and TX power down
- First IF filter used in both TX and RX modes
- 100 dB gain limiting IF
- Temperature compensated RSSI with 75 dB dynamic range
- SSO-28 plastic package
- VHF VCO frequency of 252.45 MHz
- UHF VCO range of 610-698 MHz

Figure 4 is a functional block diagram of the U2760B.

The U3770M I/Q Modulator with Clock Circuitry

This CMOS IC is designed specifically to work with the components of this CTS chip set. The chip includes 0.8 or 1.6 MHz quadrature modulated carrier generation along with generation of an 18.432 MHz CMOS-level clock signal. Specifications include:

- Uses 12.8 MHz external reference frequency
- 2.7-3.3 V supply (6 V max)
- 2 mA current consumption (3 V power supply)
- 1 V_{p-p} input level
- 30 dB LO and sideband suppression of modulated output
- SO-16 package or die form

Figure 5 is a functional block diagram of the U3770M.

Conclusion

This new chip set and demonstration board offers a complete low-cost design solution for digital cordless telephones. Designed to work together, the Temic devices provide all required RF functions, and an AMD controller/baseband IC completes the system. Wavecom's demonstration board offers the option of simply duplicating a proven design, modified only to fit the cordless phone manufacturer's chosen packaging style.

For more information, readers should contact Temic, Attn: Perry Mistry, 2201 Laurelwood Road, P.O. Box 54941, Santa Clara, CA 95056-0951. Their telephone number is (408) 970-5321; fax: (408) 970-3959. Or, readers may circle Info/Card #251. *RF*

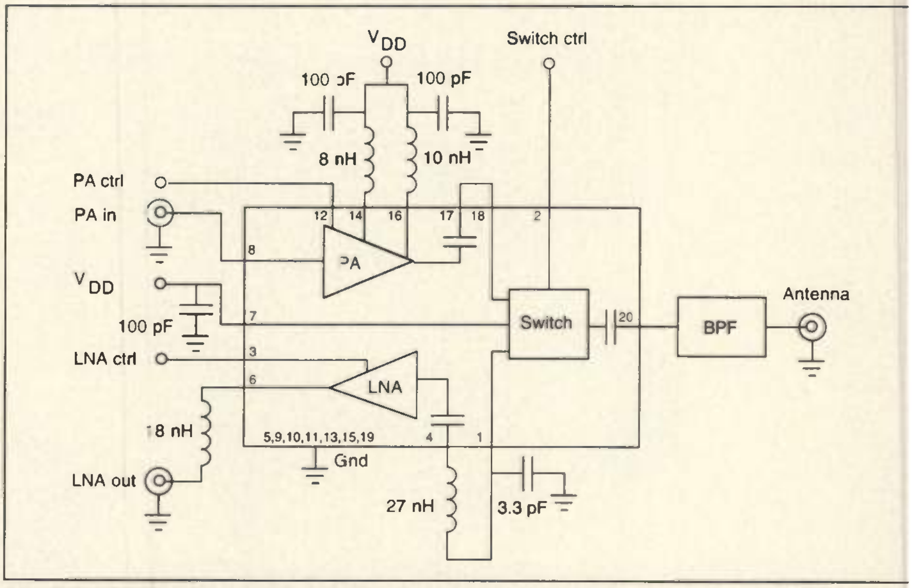


Figure 3. Minimum component application of the U7001BG front-end IC.

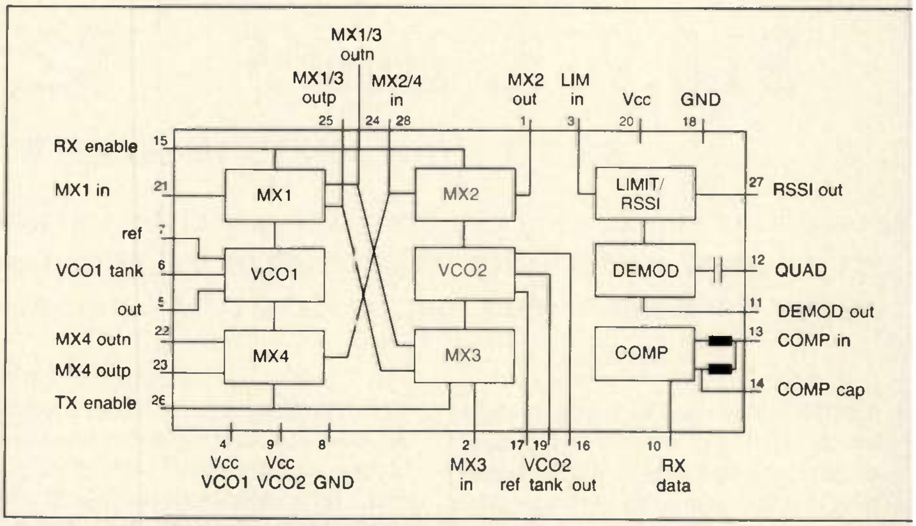


Figure 4. Block diagram of the U2760B RX/TX IC.

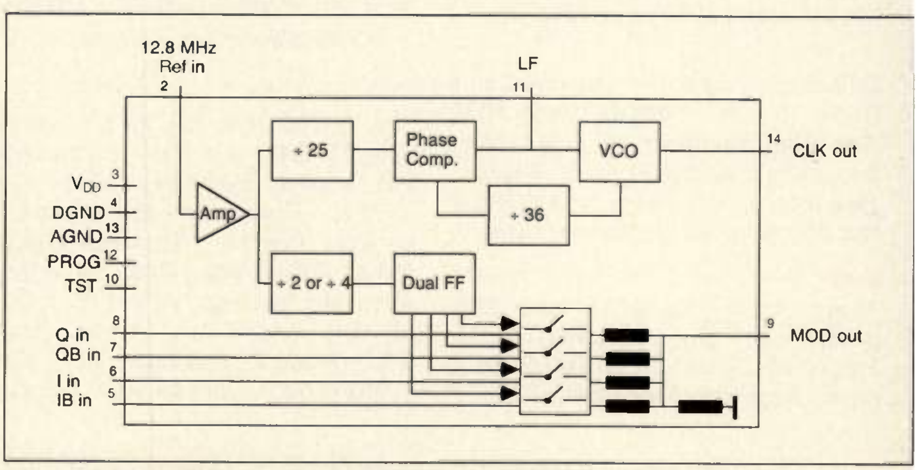
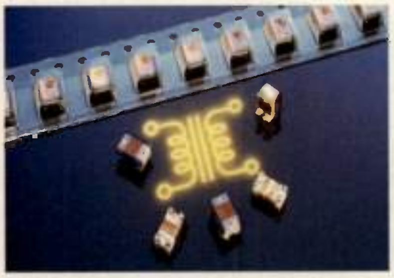


Figure 5. Block diagram of the U3770M I/Q modulator and clock IC.



Wideband RF transformers are smallest available

These surface mcunt wideband RF transformers feature exceptionally low insertion loss and high current ratings. Built on a standard 1812 ferrite/ceramic body, their tops are encapsulated to protect the winding and provide a flat surface for pick and place equipment.

These 1:1 and 2:1 transformers come in 9 models covering the frequency range from 350 kHz to 680 MHz. Insertion loss is less than 1.5 dB and DC current handling ranges from 200 up to 700 mA.

Other turns ratios and ceramic body transformers for higher frequencies are also available.

For more information, contact **Coilcraft**, 1102 Silver Lake Road, Cary, IL 60013. 708/639-6400.

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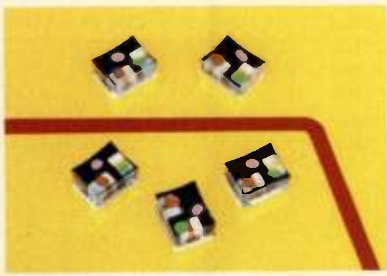


Surface mount LC filters are pretuned, tight tolerance

These space-saving low pass filters are pre-tuned, tight tolerance modules which serve a wide variety of filtering requirements.

They feature 3rd order Butterworth alignment, less than 0.3 dB insertion loss, 50 Ω characteristic impedance, and a compact 1812-size construction ideally suited for auto insertion and reflow soldering.

There are six standard models with 3 dB cutoffs from 15 to 500 MHz. All offer the benefits of an LC design: low insertion loss, high power handling, and controlled group delay.

For more infcrmation, contact **Coilcraft**, 1102 Silver Lake Road, Cary, IL 60013. 708/639-6400.

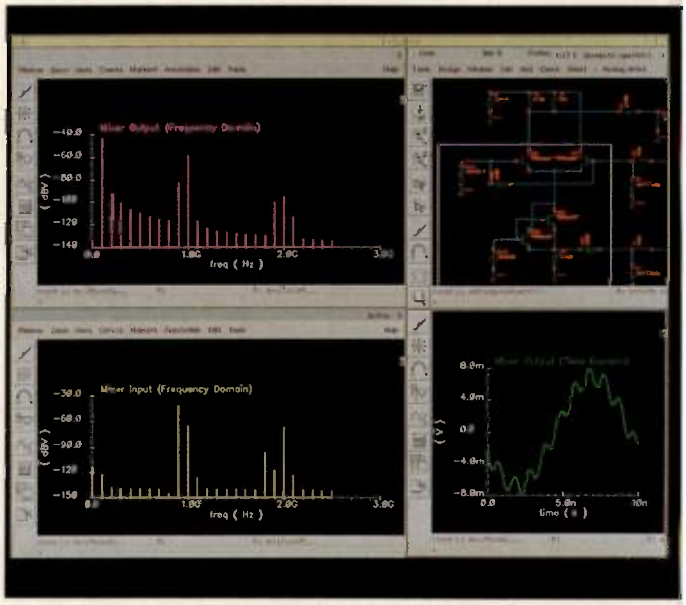
INFO/CARD 27

INFO/CARD 29

RF Simulation Package

Cadence Design Systems has developed an RF simulator, known as SpectreRF™. The new software has proven to be orders of magnitude faster for multi-frequency circuits than SPICE and is capable of handling circuits not addressed by existing microwave simulators. Cadence has applied for basic patents on the technology. SpectreRF is integrated with the company's popular SPICE-based simulator Spectre™ for IC and board-level design. SpectreRF can be used in a top-down design environment that takes design from initial concept and analog behavior modeling using an Analog Hardware Design Language (AHDL) through final silicon. SpectreRF easily simulates large circuits and nonlinear circuits and contains "time-domain" simulation algorithms based on "shooting-Newton methods." The software also includes a Fourier analysis mode and noise analysis capability. SpectreRF runs on UNIX platforms and is sold as an option to Spectre. It is available now for RF IC design, and available in Q2 1996 for RF PCB and multichip module design. Pricing is set at $15,000 for a floating license. Spectre is priced at $30,000 for a floating license.

Cadence Design Systems, Inc.
INFO/CARD #250



5 GHz Reed Relays

A line of ultra-small surface mount reed relays featuring high switching speed and low insertion loss have been introduced by Coto Wabash. The Coto 9800 series surface mount reed relays can pass RF signals up to 5 GHz with less than 60 ps rise times and less than 0.2 dB insertion loss at 1 GHz. These 1-Form-A devices measure only 0.370 × 0.180 × 0.160 inches and are available in gull-wing, "J" bend and axial lead packages. The relays have a 5 VDC coil with 150 ohm resistance. They switch voltages up to 100 VDC and current to 0.25 amps, with a contact rating of 3 watts.

Coto Wabash
INFO/CARD #249

3V RF and Baseband ICs

Oki Semiconductor has introduced three GaAs RF and three Si baseband products offering 3V capability for wireless communications, specifically, the fast-growing personal communications services (PCS) market.

Oki's 3V RF devices, which operate from 850 to 2,400 MHz, include two power amplifiers (KGF1606 and KGF1608/38) and one medium-power driver (KGF1262). The baseband products include a CODEC (MSM7702), a modem IC (MSM7582) and an echo canceller (MSM7602). The 1606 power amplifier has power output greater than 31.5 dBm, and the 1608 power amplifier has power output greater than 33.5 dBm. The 1262 driver produces more than 20 mW. The KGF1606 is priced at $10.74; the KGF1608 at $11.53, and the KGF1638 is $8.34 for quantities greater than 1,000 pieces.

Oki Semiconductor
INFO/CARD #248

Extended Communications Test Set

Wavetek has introduced a quickly-installed option for its Stabilock 4032 test sets that extends the test set's coverage to 2.3 GHz. Even older models of the 4032 and the widely-used Stabilock 4031 can be retrofitted. The option also increases the permissible bandwidth when modulating and demodulating signals. Carriers with bandwidth of up to 2 MHz can now be handled. The Stabilock

4032 has capabilities and versatility beyond that of a Go/NoGo tester, it can also be used for in-depth analysis of signals.

Wavetek, Wireless Communications Div.
INFO/CARD #247

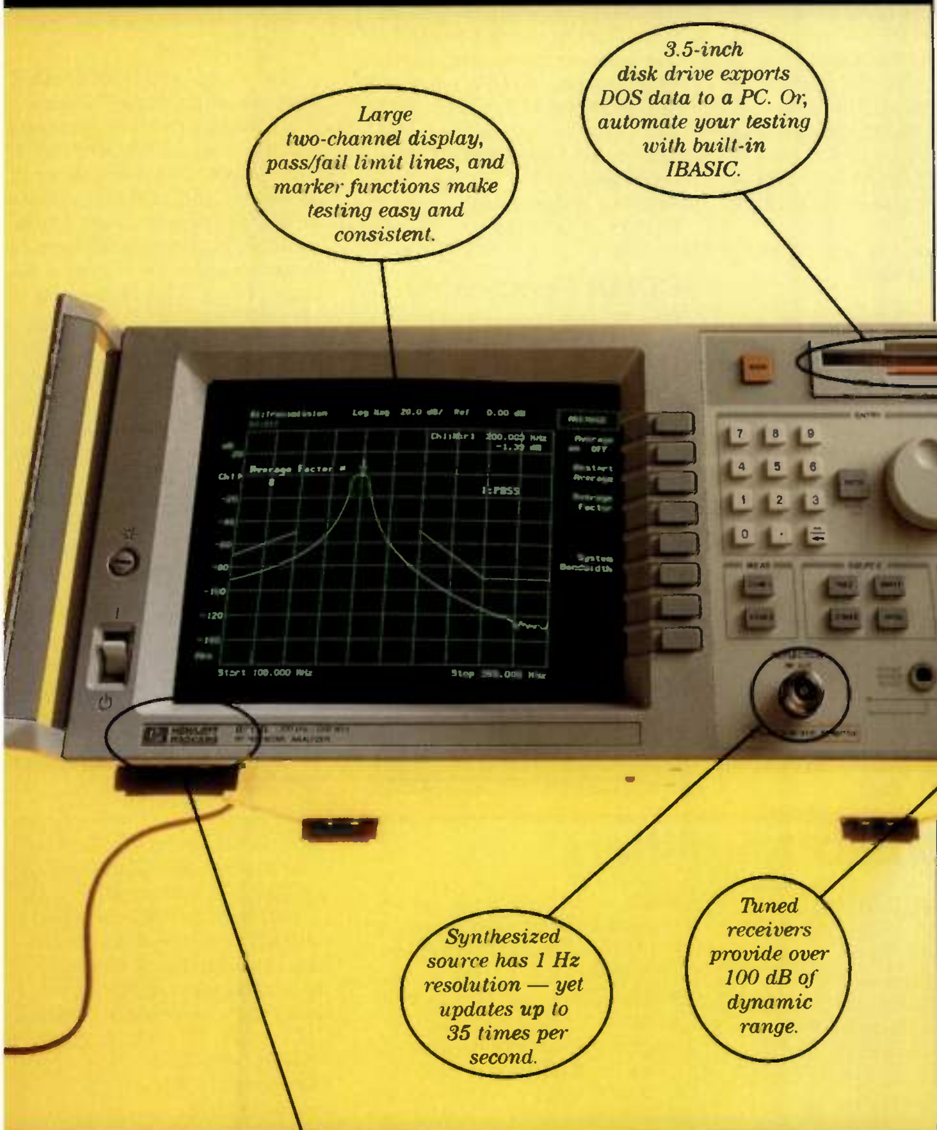
Upgraded Oscillators

Wenzel Associates has upgraded the standard Streamline AT series oscillator. Phase noise performance is better than –130 dBc at 10 Hz offset from the carrier and better than –165 dBc at 1 kHz off-

set with a 5 MHz AT-cut crystal. The Streamline AT oscillator improvements include proprietary low-noise exciter circuit design and special crystal selection. Low-noise regulator design and careful handling of oven currents keep signal purity high. Temperature stability is better than $\pm 1 \times 10^{-8}$ from 0 to +50 °C. Package size is 2 × 2 × 1 inches. Aging is 5×10^{-9} per day. Supply voltage is +15 VDC and steady-state power consumption is less than 2.2 W at +25 °C.

Wenzel Associates, Inc.
INFO/CARD #246

At only $9,500, some features on this RF network analyzer will surprise you.



But one will really amaze you.

If you thought you could never afford this kind of performance, think again. The HP 8711B family of network analyzers puts it well within your grasp.

Starting at just $9,500, select from four models in your choice of scalar or vector, 1.3 or 3 GHz. Each complete system has an integrated synthesized source and test set. So you can tune and test your RF communications devices faster and more economically than ever before.

To find out about all the features the HP 8711B network analyzer family has to offer, call HP DIRECT. It's the fast, easy way to get all your questions answered. With one simple call, you can get quick product specifications or any technical literature you may need to make the right decision. Or if you want one-on-one technical support, you can speak to an engineer who has firsthand experience with HP products. And, of course, if you're ready to order, we can help you do that, too.

So give us a call. You'll be surprised how affordable HP performance can be.

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INFO/CARD 30

TEST EQUIPMENT

Fading Simulator

Model SOFI 04 is a radio channel emulator, based on high-speed DSP technology, with 35 MHz bandwidth, up to 312 paths, two channels, and one-hundred 2,700 MHz frequencies. Radio channel models may be based on real measurements or on realistic synthetic models generated using SOFI 04 software.
AxTrade Inc.
INFO/CARD #242

Microwave Test Set

The 6200B series RF and microwave test sets (MTS) from Marconi Instruments feature EEPROM-corrected scalar detectors, a built-in dynamic calibrator and a new oven-controlled crystal oscillator, giving the 6200B high accuracy. The instrument incorporates a scalar network analyzer, synthesized sweep generator, power meter, frequency counter and voltage /current source. Five frequency versions are available, from 10 MHz to 2 GHz up to 10 MHz to 46 GHz.
Marconi Instruments, Inc.
INFO/CARD #241

Digital Cellular Test Module

The MG0307A π/4 DQPSK Modulation unit from Anritsu Wiltron is the latest in a series of product enhancements for the MG3670B/MG3671A digital modulation signal generators. The module is designed to test wireless consumer premises equipment (WCPE), personal handy-phone systems (PHS) and personal access communications systems (PACS). Pricing is $5,200.
Anritsu Wiltron Co.
INFO/CARD #240

CDMA Personality for Spectrum Analyzer

Hewlett-Packard offers the HP 85725B CDMA measurements personality software with the HP 8590 E-Series spectrum analyzer. With the new software, the analyzer enables interactive troubleshooting and testing of out-of-band spurious signals as part of its complete

set of customized, one-button CDMA measurements. All tests meet EIA/TIA/IS-95, -97, and -98 CDMA standards. U.S. Price for the HP 85725B CDMA measurements personality is $3,000.
Hewlett-Packard Co.
INFO/CARD #239

GPS Clock

The Model 100 GPS Clock™ from Absolute Time™ consists of a compact receiver, antenna module and a 25-meter cable. The clock provides highly accurate and stable 10 MHz and 1 pulse-per-second outputs. Frequency accuracy is better than 5×10^{-12} over a 24-hour period. The Model 100 is priced at $2,795.
Absolute Time Corp.
INFO/CARD #238

Network Emulation

Telecom Analysis Systems announces the Cellular-Ready Series II, which provides cellular network and PSTN network emulation in one instrument. The telephone network emulator includes cellular audio processor module, PCM/ADPCM links module, and extended PCM/ADPCM links module. Cellular-Ready Series II allows the thorough testing of cellular modems in a laboratory setting.
Telecom Analysis Systems
INFO/CARD #237

EMC/Lab Amplifiers

15W Amplifier

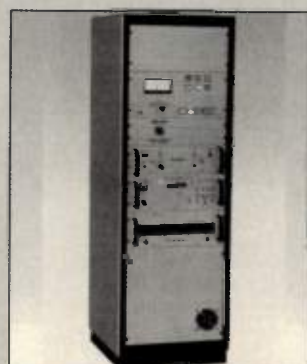
The GTC model GRF3038 is a solid-state, 15 W broadband amplifier module covering 25 to 1000 MHz. This linear amplifier utilizes RF power-MOSFET devices that provide high gain, wide dynamic range, good 3rd order intercept point and high saturation power level. The amplifier operates off a 28 to 32 VDC source. An optional internal ALC circuit keeps the output power constant over wide input power and frequency ranges.
GTC RF
INFO/CARD #245

10W, 800 to 4,200 MHz Amplifier

Model 10S1G4 from Amplifier Research is a solid-state broadband microwave amplifier providing a minimum of 10 watts at its maximum power output setting. The class A amplifier has instantaneous 800 MHz to 4.2 GHz bandwidth. The broad bandwidth permits its use as an RF source for susceptibility and other testing of many cellular, PCS and other products. Gain is adjustable over a minimum of 10 dB with ±1.5 dB flatness. Typical third-order intermodulation intercept point is 48 dBm. Price is $14,000.
Amplifier Research
INFO/CARD #244

Dual-Power Amplifier

IFT's CMX 5001 is comprised of a 100 W solid-state amplifier ranging from 200 to 1000 MHz and a 500 W distributed tube amplifier ranging from 10 kHz to 220 MHz. The air-cooled amplifier is designed to meet the demands of the evolving IEC-801 test specification as well as MIL-STD-461. Gain control is greater than 40 dB. The amplifier has a single RF input and output. Self-diagnostic circuitry is standard for the CMX 5001, as well as high-VSWR protection.
Instruments For Industry, Inc.
INFO/CARD #243



Four believable features of this RF spectrum analyzer.

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SUBSYSTEMS

VSAT Broadband Receiver

Stanford Telecom has introduced the STEL-9236A VSAT demodulator receiver assembly, the latest model in the STEL-9236 board-level receiver series. The assembly is a less than 1.5 inches high by four inches wide by six inches long. The series includes a wide range of fixed data rate BPSK or QPSK demodulator assemblies suitable for operation in the 19.2 to 2048 kbps range.
Stanford Telecom
INFO/CARD #236

VXIbus-Format Receivers

Racal Instruments introduces two high-performance, single-slot VXIbus communications receivers. The Model 2551 covers the frequency range 10 kHz to 30 MHz with 1 Hz tuning resolution and 51 standard bandwidths, while the 2561 covers 30 to 1,200 MHz with 10 Hz tuning resolution and 15 standard bandwidths. Both receivers provide quadrature (I&Q) outputs and detection modes of AM, FM, LSB, USB, ISB, and CW. The 2551 and 2561 start at $7,500.
Racal Instruments, Inc.
INFO/CARD #235

Spread Spectrum Development Board

Associated Professional Systems announces the release of its spread spectrum development platform (SSDP). The SSDP is an IBM PC ISA-format board which can produce three independent linear recursive sequence streams with lengths up to 4,394,967,295 bits long. Several RF daughter boards are available, and a Windows™ control program and C drivers are included.
Associates Professional Systems
INFO/CARD #234

Power MOSFET Modulator

Model 327 power MOSFET modulator for magnetron transmitters is designed to operate magnetrons up to 150 kW. The continuously-variable pulse width range is 0.15 to 2.0 µs at pulse repetition frequencies up to 5 kHz. Pulse rise-time is 100 ns and fall time is 150 ns. IEEE-488 and RS-232 remote control is available.
Applied Systems Engineering, Inc.
INFO/CARD #233

Receiver Multicoupler

Mu-Del model MDP-201200DB2 is a wide-band receiver multicoupler consisting of two independent removable half-racks, 1 input, 10 outputs each. Operating frequency is 20 to 1200 MHz. Each has 0±1.5 dB gain, VSWR input/output 1.5:1, noise figure ≤ 9 dB, input level +3 dBm, and third-order intercept of +15 dBm. Minimum input to output isolation is 60 dB, and minimum output to output isolation is 60 dB.
Mu-Del Electronics, Inc.
INFO/CARD #232

DISCRETE COMPONENTS

High-Frequency Crystals

KVG is expanding its product range to higher frequencies by introducing a line of quartz crystals using the inverted-mesa structure. Quartz crystals with fundamen-

tal frequencies up to 155 MHz are available in standard HC-52 housings.
KVG North America, Inc.
INFO/CARD #231

Surface Mount Crystal

New surface mount quartz crystals from Raltron have a 1.0mm profile height and are available in fundamental and overtone frequencies from 16 to 100 MHz. Model H-10 crystals are rated at ±50 ppm at +25 °C. Maximum shunt capacitance is 7.0 pF. The crystals have a 0.1 mW drive level. Model H-10 crystals are priced at $1.50 each in lots of 1,000.
Raltron Electronics Corp.
INFO/CARD #230

Low Capacitance, Precision Trimmer

Voltronics announces a new line of multi-turn air trimmer capacitors that tune from 0.1 to 1.0 pF. These products are designed for high resolution tuning at 900 to 2,000 MHz. Two sizes are available, each 1/2-inch long. The KET1 is 0.23 inches in diameter and the ET1 is 0.3 inches in diameter. The parts are O-ring sealed to withstand 40 p.s.i. Temperature coefficients are below 50

ppm/°C. The ET1 is $3.46 for 1,000 pieces, and the KET1 is $4.25 for 1,000 pieces.
Voltronics Corp.
INFO/CARD #229

SIGNAL SOURCES

1700-1900 MHz VCO

Z-Communications has introduced the V660ME02 surface mount VCO The VCO generates frequencies between 1700 and 1900 MHz within 1.5 to 10.5 volts of control voltage. Average gain is 60 MHz/V over the 200 MHz bandwidth. Phase noise typically is –95 dBc/Hz at 10 kHz offset from the carrier. The V660ME02 operates from a nominal +10 VDC while drawing less than 35 mA.
Z-Communications, Inc.
INFO/CARD #228

VCXO Series

M-tron's MVS series consists of surface-mount voltage-controlled crystal clock oscillators is available in frequencies from 1.5 to 25.0 MHz. The series features J-leads for mechanical stability during thermal expansion and contraction. The lid is grounded for reduced electromagnetic interference. The MVS series operates from +5 VDC supplies.
M-tron Industries, Inc.
INFO/CARD #227

SC-Cut OCXO

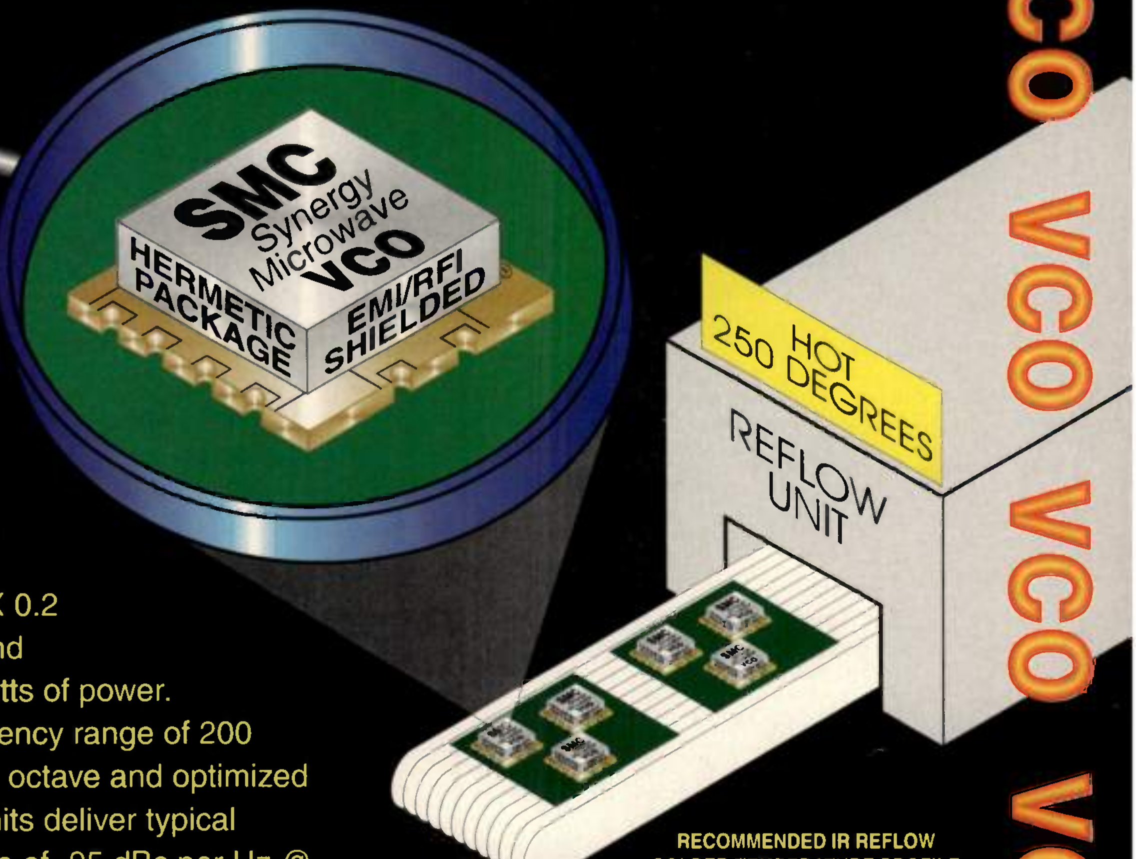
Oak Frequency Control Group's 4597S oven-controlled crystal oscillator (OCXO) has

VCO VCO VCO VCO VCO

Synergy Microwave Corporation,

a recognized innovative leader, introduces its latest ***miniature*** SMT voltage controlled oscillator product line.

VCO VCO VCO VCO VCO



These small, frequency generating modules occupy a volume of 0.5 X 0.5 X 0.2 inches (L x W x H) and consume only 0.2 watts of power. Available in the frequency range of 200 MHz to 3000 MHz, in octave and optimized bandwidths, these units deliver typical phase noise response of -95 dBc per Hz @ 10 kHz offset. These devices are EMI/RFI shielded, moisture resistant and can withstand the automated assembly techniques used in high volume manufacturing. Other package styles and sizes are available, including plug-in, hermetic packages.

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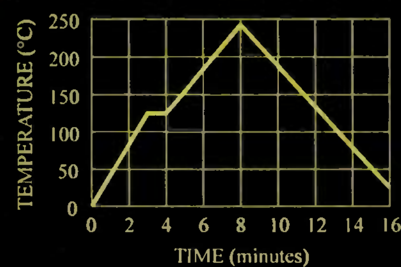

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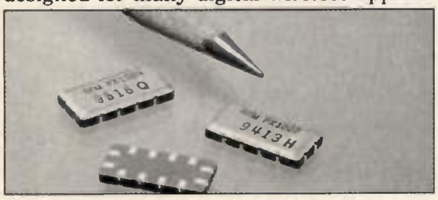
a footprint measuring only 30.3 × 30.3 mm, and its height is only 10.2 mm. The oscillator is available from 10 to 25 MHz. Using an SC-cut crystal, the 4597S meets its temperature stability spec of ±7 × 10^{-9} over 0 to +70 °C. It operates from a +5 V supply with steady-state power consumption of 1 W. Phase noise at 100 Hz offset is –140 dBc/Hz.
Oak Frequency Control Group
INFO/CARD #226

SIGNAL PROCESSING COMPONENTS

Digital Wireless SAW IF Filters

The PX-series surface acoustic wave (SAW) IF filters from RF Monolithics are designed for many digital wireless applica-



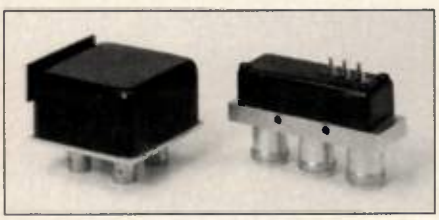
tions. The PX1002 has a center frequency of 86.85 MHz, and the PX1004 has a center frequency of 82.20 MHz. These filters feature a minimum insertion loss of 4 dB, minimum 3 dB-bandwidth of 30 kHz, and 65 dB image-rejection at –910 kHz. The filters cost $12.50 each in 1,000-piece quantities.
RF Monolithics, Inc.
INFO/CARD #225

Power Splitter/Combiner

Mini-Circuits has introduced a 2-way, 0° power splitter/combiner designed for high-power applications in the 1500 to 2000 MHz PCN band. The ZN2PD-1900W can handle up to 10 W input with maximum internal power dissipation of 1/8th W (as a combiner). The 50-ohm device typically displays 0.2 dB insertion loss (beyond the 3 dB splitting loss). Amplitude and phase balance are typically better than 0.3 dB and 3°, respectively. In quantities less than ten, ZN2PD-1900W is $64.95 each.
Mini-Circuits
INFO/CARD #224

Electromechanical Switches

Model SEM129 is a SP2T switch; model XSEM329 is a transfer switch. Both switches from Loral Microwave-Narda operate



from DC to 1 GHz and come equipped with 24V failsafe activation, indicator circuits, and BNC connectors.
Loral Microwave-Narda
INFO/CARD #223

Power Dividers/Combiners

Technical Research and Manufacturing offers two new power divider/combiners. DMM 3089C is a 3-way power divider/combiner which operates over 800 to 980 MHz. Maximum insertion loss beyond splitter-loss is 0.4 dB. DMM 2089C is a 2-way power divider/combiner operating over 800 to 980 MHz. Maximum insertion loss beyond splitter-loss is 0.2 dB.
Technical Research and Manufacturing, Inc.
INFO/CARD #222

Quadrature Hybrid

Sage Laboratories announces the availability of the FH4826 3dB quadrature hybrid, designed for use in a space environment. The hybrid covers 1760 to 2300 MHz and has maximum VSWR of 1.25:1. Coupling is 3 dB +0.2 and insertion loss is better than 0.2 dB. Peak power rating is 150 W, 15 W average. Model FH4826 measures 1.57 × 0.50 × 0.38 inches plus SMA connectors.
Sage Laboratories, Inc.
INFO/CARD #221

GPS Receiving Multicoupler

AML Communications offers a range of GPS receiving multicouplers. Model AMC1216-16N with 16 outputs offers 10 dB of gain and operates on 110 VAC. Features include bias-tee injection of the DC power to operate a mast-head low-noise amplifier and DC loading of each output to simulate the mast-head amplifier current-draw.
AML Communications
INFO/CARD #220

SEMICONDUCTORS

PLL Frequency Multiplier

Connor-Winfield introduces a phase-locked-loop (PLL) based clock multiplier IC, available packaged and as dice. The PLL IC accepts a low-frequency crystal oscillator input and outputs a high-frequency PECL-level signal. Three devices are available to cover the frequency range from 115 MHz to 820 MHz. Power consumption is 500 mW, and jitter is less than 10 ps rms. Prices start at $22.30 each.
Connor-Winfield Corp.
INFO/CARD #219

Reflective Switches

Daico Industries introduces three GaAs switches: DS0710RN (reflective SPST), DS0702RN (reflective SP2T) and the DS0702HR (high-power, reflective SP2T). All three switches operate from DC to 2,500 MHz and have 33 dB isolation at the 1,000 MHz. The high-power DS0702HR has a 1 dB compression point of 33 dBm. All three switches are packaged in plastic SO8 surface-mount packages. The DS0702RN is currently only $1.79 in quantities of 2,500 to 9,999 pieces.
Daico Industries, Inc.
INFO/CARD #218

DSP for Two-Way Messaging

AT&T offers the POMP™ DSP1615. designed for two-way N-PCS messaging devices. The IC operates in the 2.4 to 3.6 V range and contains a codec, memory, clock generation and controller peripherals. The A/D converter is rated at 38.4 kilo-samples per second. On-board memory consists of 48 kbytes of ROM and 4 kbytes of SRAM. Target pricing for ROM-coded TQFP production volumes is under $16 each in 100k quantities.
AT&T Microelectronics
INFO/CARD #217

Low-Noise 350 MHz Op Amps

Maxim Integrate dProducts introduces the MAX4106/MAX4107, 350 MHz, ±5V, wideband, voltage-feedback op amps. The op-amps have noise performance of 0.75 nV/√Hz while delivering a 350 MHz (MAX4106) and 300 MHz (MAX4107) bandwidth. The MAX4106 is compensated for closed-loop gains of 5 V/V or greater, while the MAX4107 is stable in closed-loop gains of 10 V/V. Prices start at $3.88.
Maxim Integrated Products
INFO/CARD #216

16-bit Fixed-Point DSPs

The ADSP-21csp01 is the first in a new family of 16-bit fixed point DSPs from Analog Devices. A new 16-bit fixed-point core powers the 21csp family of concurrent signal processors. The ADSP-21csp01 integrates a highly-parallel, 50-MIPS DSP core, a parallel DMA port, a parallel memory port, and two multi-channel serial ports. The DSP core is capable of executing 550 million operations per second. The 10,000 unit price is $33.00.
Analog Devices, Inc.
INFO/CARD #215

DECT Processor

VLSI Technology has introduced a processor, the VP23030, that supports all 12 DECT channels and implements all the baseband digital processing needed for DECT systems. The device is optimized for infrastructure applications such as PBX, wireless local loop, and public-access Telepoint. The VP23030 features a robust software-programmable radio interface with the ability to operate with a wide range of industry-standard microcontrollers.
VLSI Technology, Inc.
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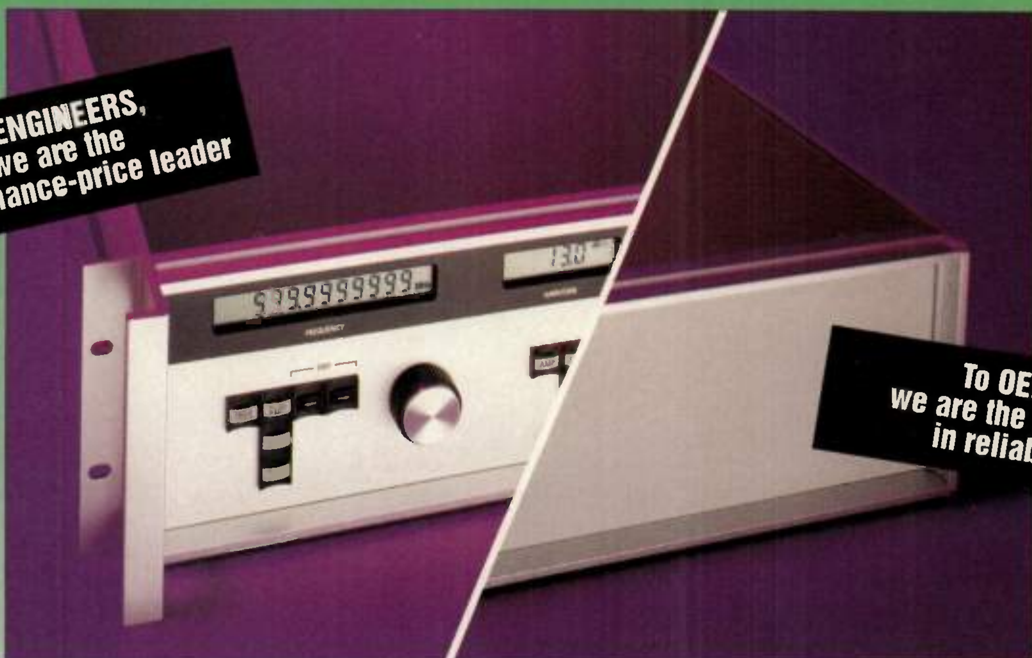

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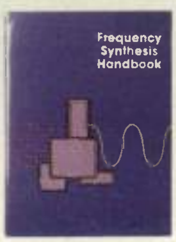

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INFO/CARD 38

A Versatile Wideband Crystal Oscillator

By R. Partha and Shanthi Krishnakumar
ITI Limited

From a manufacturing as well as a design point of view, a crystal-oscillator circuit that can generate a stable frequency over a wide frequency band without changing its configuration and with minimum change in components is always welcome. In this article we present the analysis of a circuit that provides stable oscillation from 6 to 120 MHz merely by replacing the resonating crystal element and a few components.

Two requirements must be met to produce an oscillator that operates over a wide frequency range. One – the circuit should generate a negative resistance over that frequency range, and two – the negative resistance circuit should be properly matched to the resonator over the entire frequency range. Even in such a wideband oscillator circuit, it will always be neccessary to select a different crystal for each frequency needed. Also, ordinarilly, one also has to change frequency-dependent L and C components when changing frequency.

The Colpitts, Clapp, Butler, Pierce and a few other configurations have become so standard that the design of crystal oscillators consists of selecting the suitable configuration for the frequency range of interest. However, an analytical derivation is not readily available for these circuits, nor is any single configuration applicable for an entire range of VHF frequency applications.

The main purpose of this article is to undertake an analytical exercise to obtain the input impedance characteristics of the crystal oscillator circuit facing the crystal unit, so that the performance of the circuit can be estimated. Specifically, we set out to calculate the negative resistance of the circuit under consideration and the condition for resonator matching for various frequencies across the VHF band.

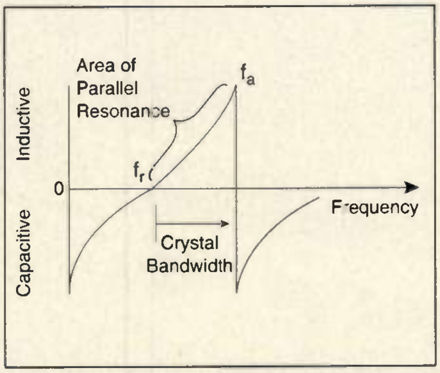


Figure 1. Crystal impedance versus frequency showing series resonance point and parallel resonance region.

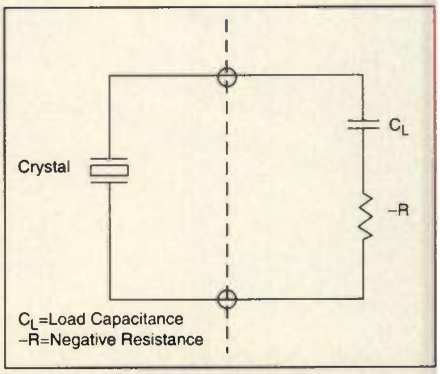


Figure 2. Crystal and the one-port negative resistance model used to simulate the rest of the oscillator circuit.

Basic Principle

Crystals are designed to resonate at either a series resonant frequency f_r, or a parallel resonant frequency f_a, which is slightly higher than f_r (Figure 1). Alternately, by altering the capacitive load for the parallel resonant circuit, the crystal may be operated at some frequency between f_a and f_r, i.e., f_L. In an ordinary crystal oscillator circuit, the crystal is operated within that frequency range in which it exhibits an inductive reactance. Facing the crystal unit, the input impedance of the oscillator circuit can be represented by the series circuit composed of an equivalent capacitance C_L and a negative resistance –R as shown in Figure 2. The crystal resonator may be repre-

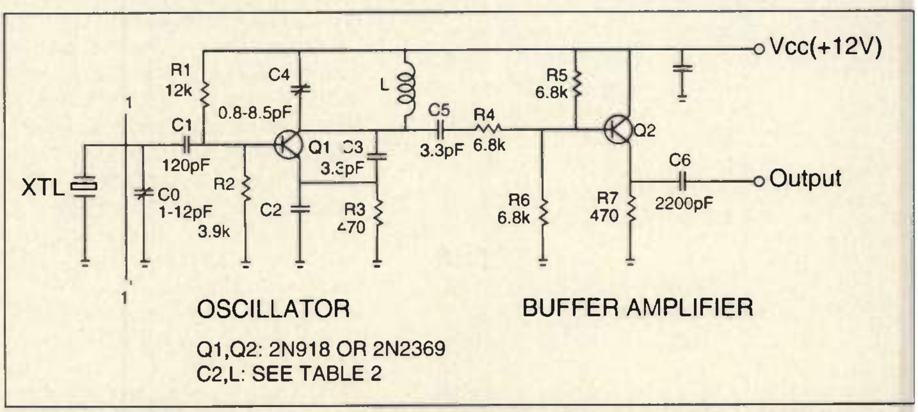
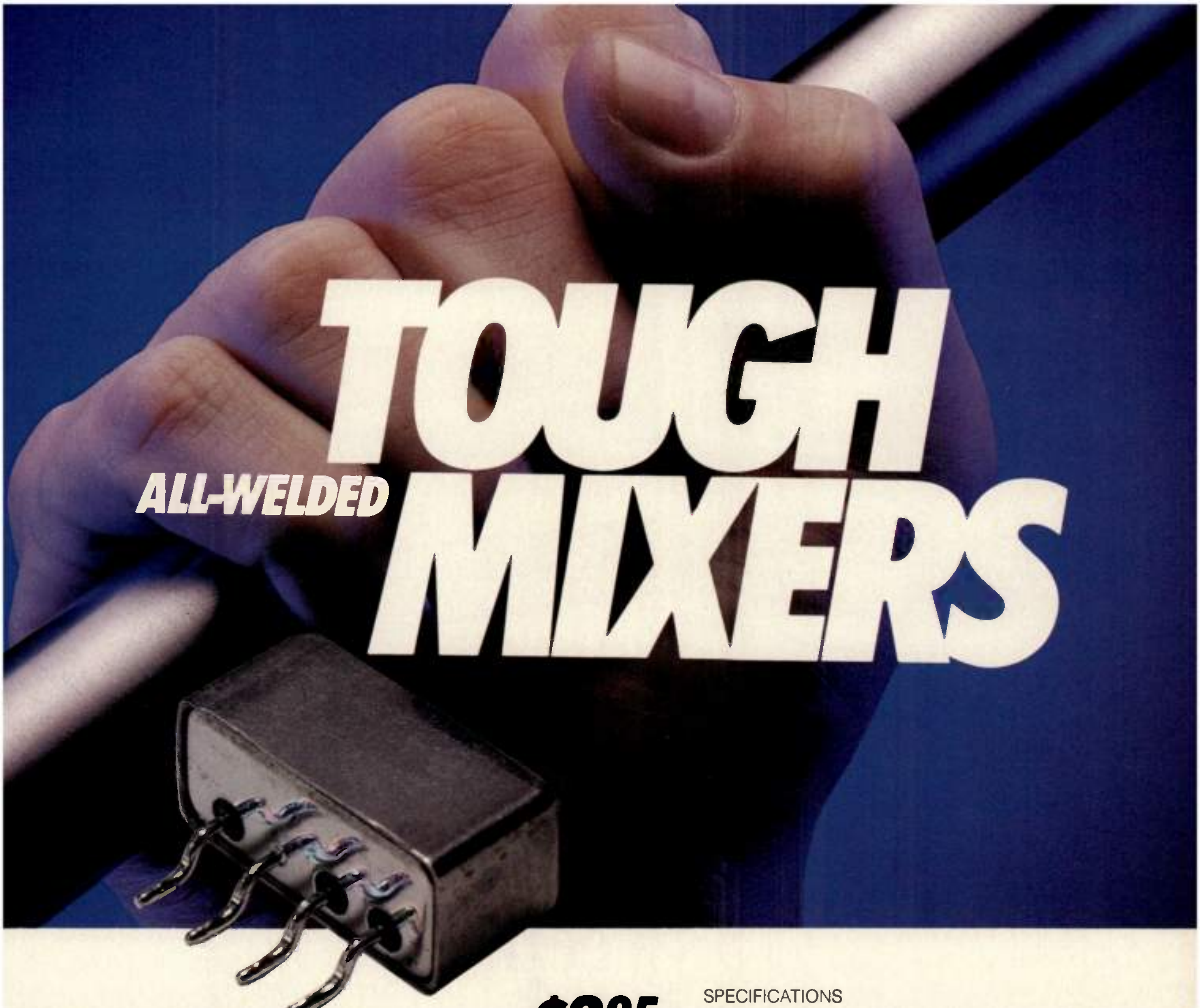


Figure 3. Crystal oscillator which operates from 6 to 120 MHz by changing only C2 and L.



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Model	LO Power (dBm)	Freq. LO/RF (MHz)	■ Conv. Loss (dB) $\bar{X}$	δ	Isol. L-R (dB)	Price,$ Ea. 10 qty
TUF-3	7	0.15-400	4.98	0.34	46	5.95
TUF-3LH	10		4.8	0.37	51	7.95
TUF-3MH	13		5.0	0.33	46	8.95
TUF-3H	17		5.0	0.33	50	10.95
TUF-1	7	2-600	5.82	0.19	42	3.95
TUF-1LH	10		6.0	0.17	50	5.95
TUF-1MH	13		6.3	0.12	50	6.95
TUF-1H	17		5.9	0.18	50	8.95
TUF-2	7	50-1000	5.73	0.30	47	4.95
TUF-2LH	10		5.2	0.3	44	6.95
TUF-2MH	13		6.0	0.25	47	7.95
TUF-2H	17		6.2	0.22	47	9.95
TUF-5	7	20-1500	6.58	0.40	42	8.95
TUF-5LH	10		6.9	0.27	42	10.95
TUF-5MH	13		7.0	0.25	41	11.95
TUF-5H	17		7.5	0.17	50	13.95
TUF-860	7	860-1050	6.2	0.37	35	8.95
TUF-860LH	10		6.3	0.27	35	10.95
TUF-860MH	13		6.8	0.32	35	11.95
TUF-860H	17		6.8	0.31	38	13.95
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TUF-11AMH	13		7.4	0.20	33	17.95
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*To specify surface-mount models, add SM after P/N shown.
■ $\bar{X}$ = Average conversion loss at upper end of midband ($f_u/2$)
δ = Sigma or standard deviation

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

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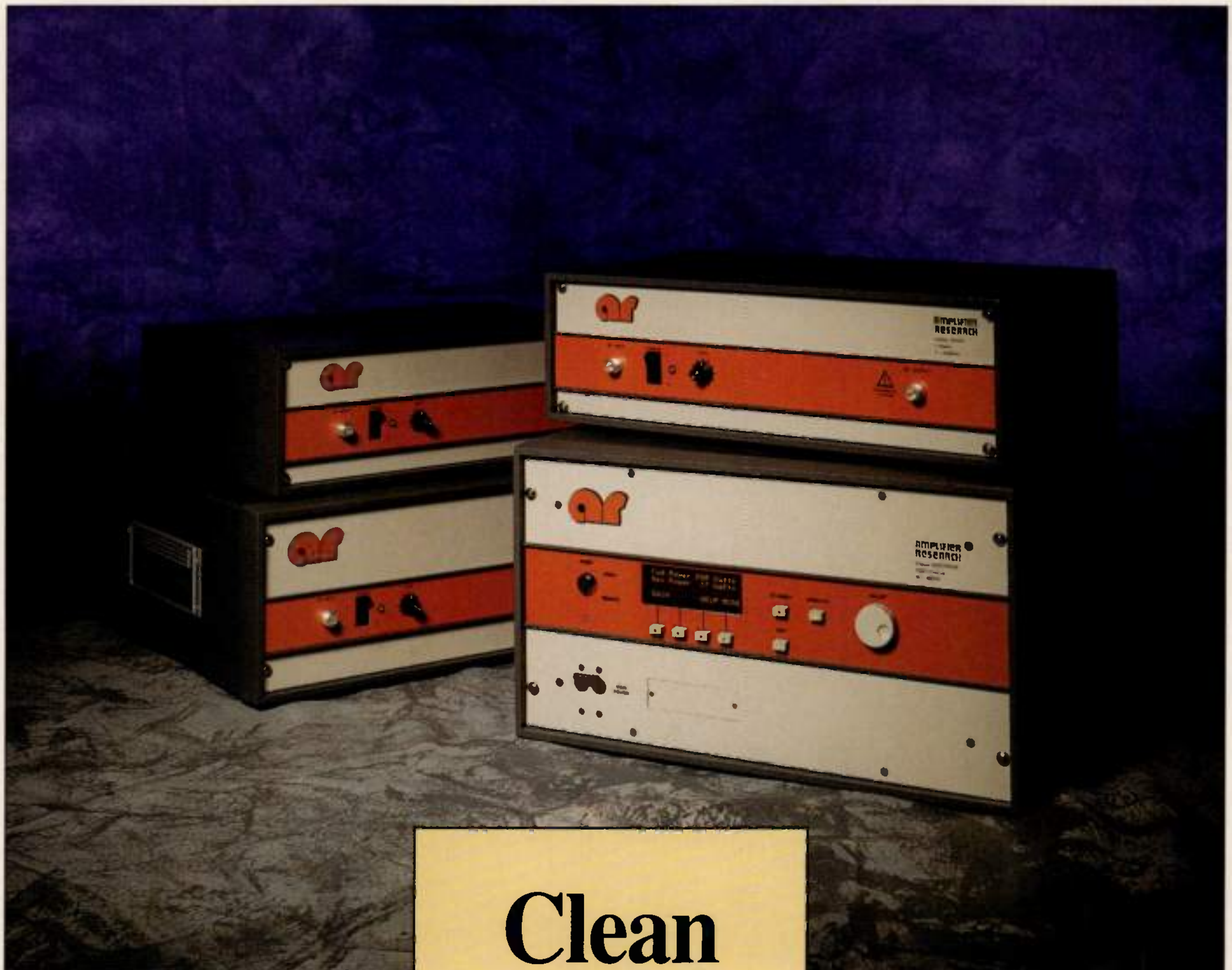

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sented by a set of equivalent series circuit parameters comprising of a resistance and an inductive reactance.

Oscillator Circuit

The circuit shown in Figure 3 oscillates over the band of 6 MHz to 120 MHz, requiring only change in values of L and C2. Crystals available at our facility were selected so as to cover the entire frequency band of interest. Particularly, the circuit was tested for crystal frequencies at 120.0 MHz, 104 MHz, 73.0 MHz, 45.454 MHz, 34.29 MHz, 20.0 MHz, 12.0 MHz and 6.40 MHz. We shall presently examine the negative resistance and reactance ("load capacitance") offered by the circuit at all these frequencies. We proceed by first reducing the circuit to the right of A-A' (Figure 4) to a one-port model in a step-by-step process.

Two-Port Reduction

A two-port black box can be described by its Y parameters given by $y_{11} = g_{11} + jb_{11}$, $y_{12} = g_{12} + jb_{12}$, $y_{21} = g_{21} + jb_{21}$, and $y_{22} = g_{22} + jb_{22}$.

$$\begin{aligned} y_{11} &= g_{11} + jb_{11} \\ y_{12} &= g_{12} + jb_{12} \\ y_{21} &= g_{21} + jb_{21} \\ y_{22} &= g_{22} + jb_{22} \end{aligned} \qquad (1)$$

Any other convenient small-signal parameters (Z,H,ABCD) can also be used, since these parameters can be converted from one type to another. A transistor operated in its linear region can be described by a set of small-signal parameters. The bipolar 2N918 was used in the circuit whose y parameters for our requirement of operating frequencies is well categorised. The oscillator's AC equivalent circuit is shown in Figure 4.

We shall review some basic two-port operations:

Shunt connections – If an admittance Y1 and Y2 (Figure 5) is connected at the input or output of a two-port network (represented by its y parameters - y_{11}, y_{12}, y_{21}, y_{22}), the overall y parameters are determined as

$$[Y] = \begin{bmatrix} y_{11} + Y_1 & y_{12} \\ y_{21} & y_{22} + Y_2 \end{bmatrix} \qquad (2)$$

Series connections – Impedances Z1, Z2, Z3 connected in series (Figure 6) with a two port network (represented by its z parameters z_{11}, z_{12}, z_{21}, z_{22}) can be taken inside the black-box and

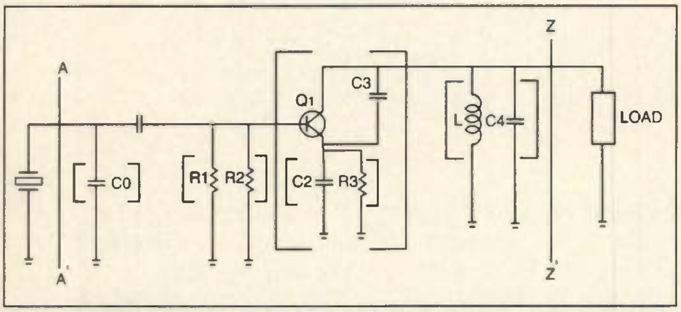

Figure 4. Grouping of series and shunt elements to arrive at an AC equivalent circuit for the crystal oscillator.

the overall z parameters will become

$$[Z]=\begin{bmatrix} z_{11}+Z_1+Z_3 & z_{12}+Z_3 \\ z_{21}+Z_3 & z_{22}+Z_2+Z_3 \end{bmatrix} \tag{3}$$

When a two-port is terminated at its output by an impedance Z_L, the input impedance is readily calculated as

$$Z_{in}=\frac{\Delta z+z_{11}Z_L}{z_{22}+Z_L} \tag{4}$$

where, $\Delta z = z_{11}z_{22} - z_{12}z_{21}$, ZL is the complex load impedance. Or, when the two-port is in terms of its y parameters:

$$Z_{in}=\frac{1+y_{22}Z_L}{y_{11}+\Delta y Z_L} \tag{5}$$

where $\Delta y = y_{11}y_{22} - y_{12}y_{21}$.

Circuit Reduction

We proceed in the following manner to reduce the circuit to a single black - box configuration flanked at its output - port by a complex load and by the crystal at its input port.

Step 1: The capacitor C3 which is placed in shunt across the collector and emitter (Figure 4) has to be absorbed into the active device two-port black box. For this operation the capacitive susceptance of C3 needs to be added to the imaginary component of y_{22}.

$$[Y]_{device+C3}= \tag{6}$$

$$\begin{bmatrix} g_{ie}+jb_{ie} & g_{re}+jb_{re} \\ g_{fe}+jb_{fe} & g_{oe}+jb_{oe}+j\omega C3 \end{bmatrix}$$

where g_{ie}, g_{re}, g_{fe}, g_{oe} are the real components of the y parameters of 2N918 at the chosen frequency and b_{ie}, b_{re}, b_{fe} and b_{oe} constitute the imaginary (susceptance) components.

Step 2: We now convert these y parameters to z parameters in order to add the series impedance of R3 I I C2

$$[Z]_{device+C3+(R3 \| C2)}= \tag{7}$$

$$\begin{bmatrix} r_{ie}+jx_{ie}+\dfrac{R3}{1+j\omega C2R3} & r_{re}+jx_{re}+\dfrac{R3}{1+j\omega C2R3} \\ r_{fe}+jx_{fe}+\dfrac{R3}{1+j\omega C2R3} & r_{oe}+jx_{oe}+\dfrac{R3}{1+j\omega C2R3} \end{bmatrix}$$

Step 3: Next, we convert the Z parameters to Y parameters. The admittance of R1 I I R2 at the input of the black box and that of L and C4 at the output is added to the y_{11} and y_{22} elements of the Y matrix.

Step 4: We again reconvert to Z matrix and add the reactance of C1 to the imaginary part of z_{11} of the new Z matrix.

Step 5: Again reconvert to Y matrix and accomodate the susceptance of C0 inside the matrix. The circuit now reduces to that shown in Figure 7.

Step 6: For the load to the right of Z-Z′, the input impedanceis calculated as

$$Z_{in}=\frac{1+y_{22}Z_L}{y_{11}-\Delta y Z_L} \tag{8}$$

where the y parameters are those of the final Y matrix.

Negative Resistance

A program was developed to reduce the oscillator circuit to the simplified form illustrated in Figure 7 and then calculate its input impedance. L and C2 values were chosen by trial for different frequencies and the input impedance calculated for capacitive variation provided by the tuning capacitors C4 and C0. All other component values remain unaltered with frequency. The y parameters of the bipolar 2N918 for different frequencies are given in Table 1.

In Table 2, the values of L and C2 selected for different oscillation frequencies are listed.

The data input to the program consists of the relevant frequency-dependent y parameters, the values of L and C2, the operating frequency, and the values of C4 and C0. All other component values are retained unchanged.

A load of 3.3 pF capacitance in series with a 10k resistance was taken for calculating the input impedance seen looking into 1-1′ (Figure 3). In Table 3, data of input impedance versus C4 and C0 values calculated for differ-

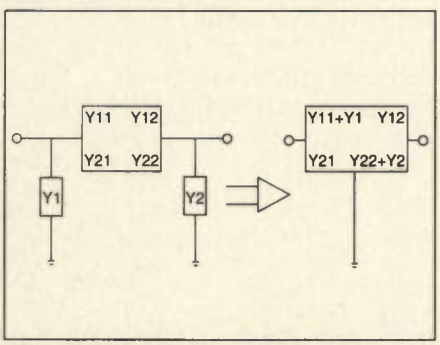

Figure 5. Result of adding shunt elements, reflected in Y-parameters.

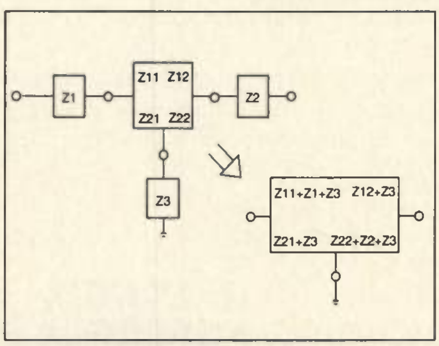

Figure 6. Result of adding series elements, reflected in Z-parameters.

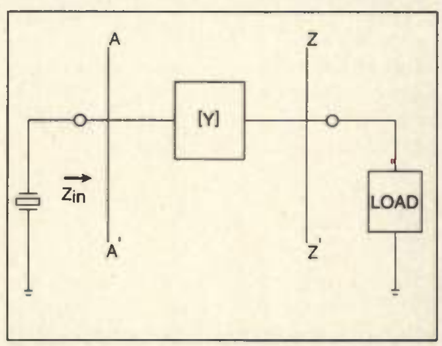

Figure 7. Two-port model of crystal oscillator

freq. (MHz)	gie mmho	bie	gre mmho	bre	gfe mmho	bfe	goe mmho	boe
5	1.45	1.0	–0.01	–0.08	95	–20	0.09	0.22
10	1.45	1.0	–0.01	–0.08	95	–20	0.09	0.22
20	2.5	1.5	–0.02	–0.1	80	–28	0.1	0.3
35	2.5	2.3	–0.02	–0.3	65	–33	0.1	0.5
45	3.0	3.0	–0.02	–0.4	57	–35	0.15	0.7
70	3.5	4.5	–0.03	–0.5	46	–38	0.2	1.0
100	4.8	5.2	–0.04	–0.8	38	–40	0.35	1.3
120	5.0	6.0	–0.04	–0.9	30	–40	0.4	1.6

Table 1. Complex admittance (Y-parameters) for the bipolar 2N918 transistor at various frequencies.

ent frequencies is available.

The oscillator circuit under consideration falls into the "negative resistance" class. Conditions for oscillation are found by evaluating the impedance at circuit plane 1-1′. The threshold of oscillation occurs when the impedance sum at plane 1-1′ is zero. In effect the two conditions for oscillation are:

1. The effective resistance of the crystal at resonance + resistive component of input impedance of the circuit facing the crystal unit = 0.

2. The reactance of the crystal + reactive component of input impedance of the circuit = 0.

Typical values of resistance of a crystal (for a given crystal type) may vary from about 60 ohms for VHF crystals to about 500 k ohms for audio-frequency crystals. For reliable oscillations, the negative resistance looking into the oscillator circuit must easily exceed the maximum specified resistance of the crystal.

The load capacitance specified for a parallel mode operation ranges from 10 pF to 90 pF. Typically, most crystals are specified to operate with 30 pF or 32 pF load capacitance. Therefore, a design criteria is that the input capacitance of the circuit facing the crystal unit should approximate-

C_0	C_4 = 1pF		C_4 = 2pF		C_4 = 3pF		C_4 = 4pF		C_4 = 5pF		C_4 = 6pF		C_4 = 7pF		C_4 = 8pF	
pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF
1	–346.8	32.2	–351.8	32.5	–356.7	32.8	–361.4	33.2	–366.1	33.5	–370.5	33.8	–374.8	34.0	–378.9	34.6
2	–325.7	33.0	–330.6	33.3	-335.4	33.6	–340.1	33.9	–344.6	34.2	–349.0	34.6	–353.3	35.0	–357.4	35.3
3	–306.3	33.8	–311.1	34.1	–315.7	34.4	–320.3	34.7	–324.8	35.0	–329.2	35.4	–333.4	35.7	–337.5	36.1
4	–288.5	34.6	–293.1	34.9	–297.7	35.2	–302.2	35.5	–306.5	35.8	–310.8	36.1	–315.0	36.5	–319.1	36.8
5	–272.1	35.5	–276.6	35.7	–281.0	36.0	–285.4	36.3	–289.7	36.6	–293.9	36.9	–298.0	37.2	–302.0	37.6
6	–256.9	36.3	–261.3	36.6	–265.6	36.8	–269.8	37.1	–274.1	37.4	–278.1	37.7	–282.2	38.1	–286.1	38.4
7	–242.9	37.2	–247.2	37.4	–251.3	37.7	–255.5	37.9	–259.5	38.2	–263.6	38.5	–267.5	38.8	–271.4	39.2
8	–229.9	38.1	–234.1	38.3	–238.1	38.5	–242.1	38.8	–246.1	39.1	–250.0	39.4	–253.8	39.7	–257.6	40.0
9	–217.9	38.9	–221.9	39.1	–225.8	39.4	–229.7	39.6	–233.6	39.9	–237.4	40.2	–241.2	40.5	–244.8	40.8
10	–206.8	39.8	–210.6	40.0	–214.4	40.3	–218.2	40.5	–221.9	40.8	–225.6	41.0	–229.3	41.3	–232.9	41.6
11	–196.4	40.7	–200.1	40.9	–203.8	41.1	–207.5	41.4	–211.1	41.6	–214.7	41.9	–218.3	42.2	–221.8	42.5
12	–186.8	41.6	–190.4	41.8	–193.9	42.0	–197.5	42.3	–201.0	42.5	–204.5	42.8	–207.9	43.0	–211.4	43.3

C_0	C_4 = 1pF		C_4 = 2pF		C_4 = 3pF		C_4 = 4pF		C_4 = 5pF		C_4 = 6pF		C_4 = 7pF		C_4 = 8pF	
pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF	R_{in} Ω	C_{in} pF
1	–249.5	23.7	–255.7	24.3	–261.2	24.9	–266.1	25.6	–270.3	26.4	–273.8	27.2	–276.5	28.1	–278.5	29.1
2	–229.1	24.5	–235.2	25.1	–240.9	25.6	–245.9	26.3	–250.4	27.1	–254.2	27.8	–257.4	28.7	–259.8	29.7
3	–210.8	25.3	–216.9	25.8	–222.6	26.4	–227.7	27.1	–232.4	27.8	–236.4	28.5	–239.9	29.4	–242.7	30.3
4	–194.6	26.1	–200.5	26.6	–206.1	27.2	–211.3	27.8	–216.0	28.5	–220.2	29.3	–223.9	30.1	–227.0	30.9
5	–180.0	26.9	–185.8	27.5	–191.3	28.0	–196.4	28.6	–201.2	29.3	–205.5	30.0	–209.3	30.8	–212.6	31.7
6	–166.8	27.8	–172.5	28.3	–177.9	28.8	–182.9	29.4	–187.7	30.1	–192.1	30.8	–195.9	31.5	–199.4	32.4
7	–155.0	28.7	–160.5	29.2	–165.7	29.7	–170.7	30.3	–175.4	30.9	–179.7	31.6	–183.7	32.3	–187.3	33.1
8	–144.3	29.5	–149.6	30.0	–154.7	30.5	–159.6	31.1	–164.2	31.7	–168.5	32.4	–172.5	33.1	–176.1	33.9
9	–134.6	30.4	–139.7	30.9	–144.7	31.4	–149.4	31.9	–153.9	32.5	–158.2	33.2	–162.2	33.9	–165.8	34.7
10	–125.8	31.3	–130.7	31.8	–135.5	32.2	–140.1	32.8	–144.5	33.4	–148.7	34.0	–152.7	34.7	–156.3	35.4
11	–117.8	32.2	–122.5	32.7	–127.2	33.2	–131.6	33.7	–135.9	34.2	–140.1	34.8	–143.9	35.5	–147.6	36.3
12	–110.5	33.1	–115.0	33.6	–119.5	34.1	–123.8	34.5	–128.0	35.1	–132.0	35.7	–135.8	36.4	–139.5	37.1

Table 3. Impedance seen by crystal looking into the rest of the wideband oscillator circuit at various values of C0 and C4. Each table is for a seperate operating frequency. From top to bottom, 6.4 MHz, 12.0 MHz.

freq. MHz	L µH	C2 pF
6.4	5.6	4700
12.0	3.4	4700
20.0	1.98	470
34.29	0.78	470
45.454	0.78	47
73.0	0.39	47
104.0	0.16	47
120.0	0.1	47

Table 2. Component values for crystal oscillator at different frequencies.

ly equal the specified crystal load capacitance. This implies that the crystal will operate in its inductive reactance region and resonate with the load capacitance.

Results

We see from the data shown in Table 3 that at all frequencies of interest, the negative resistance is greater than the 60 ohm maximum resistance of the VHF crystal when input (load) capacitance is in the vicinity of 30 pF. Reliable oscillations were verified at all these frequencies. The power output of the crystal oscillator measured at various frequencies was between –0.5 dBm to +3.4 dBm. There was a tendency for the circuit to oscillate at the second harmonic for crystal frequencies of 6.4 MHz and 12.0 MHz. This problem was overcome by increasing the capacitance of C5 from 3.3 pF to 68 pF at these frequencies.

The main purpose of providing the capacitor C0 across the crystal is to vary by a few ppm the frequency of

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–544.1	18.1	–555.2	19.4	–564.3	20.9	–570.9	22.8	–574.5	25.4	–574.6	28.7	–570.8	33.3	–562.7	39.6
2	–486.5	17.7	–499.7	18.7	–511.7	19.9	–521.9	21.4	–529.7	23.4	–534.6	25.9	–536.1	29.3	–533.6	34.0
3	–434.1	17.6	–448.5	18.4	–462.1	19.4	–474.6	20.6	–485.4	22.2	–494.0	24.2	–499.8	26.8	–502.1	30.4
4	–387.3	17.7	–401.9	18.4	–416.4	19.2	–430.2	20.2	–442.9	21.5	–454.1	23.1	–463.1	25.2	–469.3	28.1
5	–345.8	18.0	–360.3	18.5	–374.9	19.2	–389.3	20.0	–403.1	21.1	–415.9	22.5	–427.3	24.2	–436.4	26.5
6	–309.3	18.4	–323.3	18.8	–337.6	19.4	–352.1	20.1	–366.4	21.0	–380.2	22.1	–393.0	23.6	–404.2	25.5
7	–277.4	18.9	–290.7	19.3	–304.4	19.7	–318.6	20.3	–332.8	21.1	–347.0	22.0	–360.7	23.3	–373.4	24.9
8	–249.4	19.4	–261.9	19.3	–274.9	20.2	–288.6	20.7	–302.5	21.3	–316.7	22.1	–330.8	23.2	–344.3	24.6
9	–224.9	20.1	–236.6	20.3	–248.8	20.7	–261.8	21.1	–275.3	21.6	–289.1	22.4	–303.2	23.3	–317.1	24.4
10	–203.5	20.7	–214.3	20.9	–225.8	21.3	–237.9	21.6	–250.8	22.1	–264.2	22.7	–278.0	23.5	–292.0	24.5
11	–184.6	21.4	–194.6	21.3	–205.3	21.9	–216.8	22.2	–228.9	22.6	–241.7	23.1	–255.1	23.8	–268.9	24.7
12	–168.1	22.2	–177.3	22.3	–187.2	22.5	–197.9	22.8	–209.3	23.2	–221.5	23.6	–234.3	24.2	–247.7	24.9

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–184.6	33.7	–182.2	36.5	–178.9	39.8	–174.8	43.8	–169.8	48.6	–163.9	54.4	–157.2	61.5	–149.6	70.2
2	–173.9	33.0	–172.4	35.5	–170.1	38.6	–167.0	42.2	–162.9	46.6	–158.0	51.9	–152.2	58.4	–145.4	66.4
3	–163.7	32.5	–162.9	34.9	–161.5	37.7	–159.2	41.0	–156.1	45.1	–152.0	49.9	–147.0	55.9	–141.1	63.3
4	–153.9	32.2	–153.8	34.4	–153.1	37.0	–151.6	40.1	–149.2	43.8	–146.0	48.3	–141.8	53.8	–136.7	60.7
5	–144.6	32.1	–145.2	34.2	–145.1	36.6	–144.2	39.4	–142.6	42.9	–140.1	47.1	–136.6	52.2	–132.3	58.6
6	–135.9	32.2	–136.9	34.0	–137.3	36.3	–137.1	38.9	–136.1	42.2	–134.2	46.1	–131.5	50.9	–127.8	56.8
7	–127.7	32.3	–129.1	34.1	–129.9	36.1	–130.2	38.6	–129.7	41.7	–128.5	45.3	–126.5	49.8	–123.4	55.4
8	–120.0	32.5	–121.7	34.2	–122.9	36.1	–123.6	38.5	–123.6	41.3	–123.0	44.8	–121.5	49.0	–119.1	54.3
9	–112.8	32.8	–114.7	34.3	–116.3	36.2	–117.3	38.4	–117.8	41.1	–117.6	44.4	–116.6	48.4	–114.7	53.3
10	–106.2	33.2	–108.3	34.6	–110.0	36.4	–111.4	38.5	–112.2	41.0	–112.4	44.1	–111.9	47.9	–110.5	52.6
11	–99.9	33.6	–102.2	34.9	–104.1	36.6	–105.7	38.6	–106.8	41.0	–107.4	44.0	–107.3	47.6	–106.4	52.1
12	–94.1	34.1	–96.5	35.3	–98.6	36.9	–100.4	38.8	–101.7	41.1	–102.6	43.9	–102.9	47.3	–102.4	51.6

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–1107.1	*	–962.9	*	–807.3	*	–653.2	*	–511.5	*	–386.9	*	–282.9	*	–198.4	*
2	–1220.8	70.2	–1151.0	*	–1023.5	*	–855.1	*	–673.0	*	–501.8	*	–356.4	*	–240.8	*
3	–1067.8	8.3	–1123.7	14.1	–1117.9	98.8	–1025.9	*	–855.7	*	–649.3	*	–454.3	*	–296.6	*
4	–792.8	5.8	–902.9	6.3	–1003.2	9.8	–1050.1	25.3	–989.8	*	–811.9	*	–579.7	*	–370.2	*
5	–555.6	5.6	–654.6	5.3	–775.3	6.5	–902.7	8.7	–984.1	20.2	–932.1	*	–723.6	*	–465.8	*
6	–390.9	5.9	–463.7	5.9	–561.9	6.1	–690.9	6.6	–838.8	8.8	–935.4	24.4	–849.3	*	–583.8	*
7	–282.2	6.6	–333.2	6.4	–404.4	6.3	–505.8	6.3	–647.6	6.9	–815.6	9.8	–895.2	79.1	–711.9	*
8	–210.0	7.3	–245.8	7.1	–296.2	6.8	–369.9	6.6	–481.0	6.7	–645.1	7.5	–828.7	13.5	–814.7	*
9	–160.7	8.1	–186.4	7.3	–222.4	7.5	–275.2	7.2	–356.8	6.9	–488.3	7.0	–688.4	8.7	–842.3	50.4
10	–126.1	9.0	–145.0	8.6	–171.2	8.3	–209.4	7.9	–268.6	7.5	–366.9	7.2	–537.3	7.5	–775.1	13.5
11	–101.1	9.9	–115.3	9.5	–134.8	9.1	–163.0	8.7	–206.3	8.2	–278.5	7.7	–409.9	7.4	–648.2	9.1
12	–82.5	10.8	–93.4	10.4	–108.3	10.0	–129.5	9.5	–161.8	8.9	–215.0	8.3	–313.1	7.7	–512.2	7.9

Table 3 continued. From top to bottom, 20.0 MHz, 34.29 MHz, 45.454 MHz.

Quartz Crystal Specifications

Many textbooks have tutorial material on piezoelectricity and the theory of quartz crystal operation. Rather than duplicate that well-researched material, this note covers something rarely found in textbooks — how to specify a quartz crystal.

There are four main parameters that control the characteristics of a crystal, as noted in the equivalent circuit for Figure A. These parameters are:

- C_1 The motional capacitance
- L_1 The motional inductance
- R_1 The equivalent series resistance (ESR)
- C_0 The parallel capacitance resulting from the electrodes and crystal packaging
- C_L External load capacitance of the circuit

C_1 and L_1 are interdependent, since they determine the resonant frequency of the crystal. If we know one of the parameters, we can readily compute the other if we know the series resonant frequency.

R_1 is the resistance determined by the motional (piezoelectric) behavior of the crystal. If it is too high, the crystal may not start oscillation. High ESR can mean poor crystal design, a defective crystal, or contamination in the manufacturing. Typical ESR ranges for AT-cut crystals at various frequencies and modes are noted in Table 1.

It is important to note that, although these are "equivalent" values, not actual resistors, capacitors and inductors, they behave exactly like those components in a circuit. Simulation of circuit behavior using computer modeling is readily accomplished using these values.

C_0 is a physical capacitor, created by the electrodes plated onto the crystal surface, along with some additional capacitance from the package. Generally, larger C_0 contributes to better pullability, which may be important in a phase-locked oscillator. Typical AT-cut crystals have C_0 of 7 pF or less. High pullability requirements may include a specification for 9 or 10 pF. Too large a value, however, may amplify spurious responses and even cause the crystal to jump to a different mode. This jump is most likely to occur at oscillation start-up.

If it is important to obtain a crystal with the minimum effects from oscillator circuit parameters, C_0 might be specified as low as 2 or 3 pF. The reduced external control over frequency also means greater stability in the presence of changes due to temperature or component variations. Small C_0 can also improve circuit stability by reducing the potential for unwanted oscillations caused by C_0 resonating with stray inductance.

For stability and pullability, C_1 is also a factor. The ratio of C_0/C_1 is a better indicator that C_0 alone in determining crystal "stiffness" in frequency.

Finally, C_L is the load capacitance of the user's circuit. The crystal must operate at the right frequency in the intended circuit, so this value needs to be included in the crystal purchase specification. Either the crystal manufacturer must make the device using the customer-supplied value of C_L, or the customer must adapt the circuit to accommodate a crystal with a standard value of C_L.

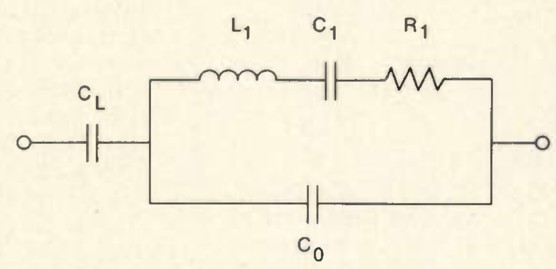

Figure A. Equivalent circuit of a quartz crystal, showing the four crystal parameters plus the load capacitance.

Mechanical and environmental specifications are also needed to select or purchase the desired crystal. Mechanical parameters include such things as case type, hermetic packaging, and physical dimensions. The case might be a standard HC-6/U or HC-49/U, or it might be a ceramic or plastic surface-mount package. The mechanical specifications must be consistent with the electrical parameters; e.g., does the specified case use electrodes that permit the required C_0?

Environmental requirements are similar. Vibration, shock, and solderability are among the things that might be included in a crystal specification. Can they be achieved with the desired packaging? What testing is required to assure performance as required?

Summary

Crystal specifications can be summarized as follows:

- Frequency
- Fundamental or overtone mode
- Package
- Frequency at ambient, and over temperature range
- Load capacitance or series resonance
- Maximum ESR
- Maximum or specific C_0
- Drive level, test level and maximum
- Aging requirements
- Storage temperature
- Environmental specifications

HC-6/U holder, 1-10 MHz	ESR decreases with frequency from 500Ω to 50Ω or less
HC-49/U holder, 4-25 MHz	ESR decreases with frequency from 150Ω to 20Ω or less
HC-49/U holder, 3rd overtone	ESR in the range of 60Ω
HC-49/U holder, 5th overtone	ESR in the range of 75Ω
HC-49/U holder, 7th overtone	ESR in the range of 125Ω

Table 1. Typical ESR values for AT-cut crystals in standard metal packages.

the oscillator. The effect of C0 on input (load) capacitance (Table 3) is to be broadly interpreted bearing in mind the fact that a transistor (to the extent possible) tends to automatically adjust its operating impedance to sustain oscillations. Hence the effect of C0 variation on input impedance will not be as drastic as it appears from the calculated data.

Conclusion

At the very least, the article provides an insight into the requirements for oscillations. The analysis provided takes away the "conformal" approach to crystal oscillator design. It also provides a good starting point for choice of range of components (L,C) values for over a decade change of frequency.

It is possible to study the contribution of individual circuit elements to the generation of negative resistance in the circuit. It was found that the value of C2 (which forms the series feedback element) plays a major role in determining the magnitude of negative resistance. For certain combinations of L, C2, C4 and C0, the input reactance is inductive (predominantly for 45.454 MHz and 73.0 MHz). This is a condition that violates the oscillation criteria. This can be overcome to some extent by reducing the value of R3 (taking care to minimize the effect on DC quiescent conditions).

At any particular frequency of interest, one can select component values (Cl,C5,R3,C3 etc.) for optimum performance by ensuring:

1. The negative resistance is greater than the equivalent crystal resistance.
2. The input capacitance is near the crystal load capacitance value of 30 pF
3. Variation in input reactance for a small change in C0 is not drastic (which is not the case in Table 3 at some frequencies).

The analysis does not provide for estimating the power output of the crystal oscillator.

Many design topologies of crystal oscillators whose performance is assured are available. However, the topology of the circuit analysed represents a versatile arrangement whose performance over a wide range of frequencies gives good results and conforms to theoretical expectations.

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–383.4	*	–338.0	*	–281.5	*	–217.1	*	–150.6	*	–88.3	*	–35.2	*	5.9	*
2	–422.1	*	–388.9	*	–335.6	*	–264.4	*	–183.7	*	–105.7	*	–40.6	*	7.1	*
3	–432.5	102.4	–423.1	*	–387.1	*	–319.0	*	–225.9	*	–128.4	*	–47.3	*	8.6	*
4	–409.8	21.2	–427.8	60.9	–422.7	*	–375.1	*	–278.5	*	–158.6	*	–55.9	*	10.4	*
5	–362.9	13.2	–400.6	19.1	–429.0	67.2	–420.5	*	–340.2	*	–199.1	*	–67.4	*	12.7	*
6	–306.7	10.8	–351.8	12.7	–403.0	19.5	–439.3	733.3	–403.5	*	–253.5	*	–82.9	*	15.6	*
7	–252.6	9.9	–296.0	10.6	–354.5	12.8	–423.2	24.3	–452.2	*	–324.7	*	–104.8	*	19.3	*
8	–206.1	9.8	–243.5	9.9	–298.4	10.6	–378.4	13.7	–466.6	88.5	–411.1	*	–136.7	*	24.2	*
9	–168.3	10.1	–198.8	9.9	–245.3	9.9	–320.7	10.8	–439.0	18.2	–497.4	*	–185.5	*	30.9	*
10	–138.2	10.5	–162.5	10.2	–200.0	9.8	–263.6	9.8	–381.5	11.5	–549.3	*	–263.8	*	40.2	*
11	–114.6	11.1	–133.7	10.6	–163.3	10.1	–213.9	9.6	–314.8	9.5	–534.5	19.9	–395.1	*	53.5	*
12	–95.9	11.8	–111.0	11.2	–134.1	10.6	–173.5	9.8	–253.1	9.0	–461.0	10.0	–610.7	*	73.5	*

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–196.8	59.2	–194.3	213.9	–188.1	*	–176.9	*	–159.4	*	–134.9	*	–103.8	*	–68.4	*
2	–187.6	31.0	–189.8	48.9	–188.9	155.5	–183.3	*	–170.6	*	–148.6	*	–116.9	*	–77.8	*
3	–173.8	22.3	–179.8	29.0	–184.1	47.0	–184.6	204.2	–178.3	*	–161.4	*	–131.2	*	–88.8	*
4	–157.4	18.4	–166.1	21.8	–174.3	29.0	–180.5	52.1	–181.5	*	–172.0	*	–146.0	*	–101.7	*
5	–140.3	16.5	–150.3	18.4	–161.1	22.2	–171.7	31.3	–179.5	74.4	–178.8	*	–160.4	*	–116.6	*
6	–123.8	15.5	–134.1	16.7	–146.1	18.9	–159.5	23.5	–172.8	37.7	–181.0	429.2	–172.9	*	–133.4	*
7	–108.6	15.2	–118.6	15.9	–130.7	17.2	–145.4	19.8	–162.2	26.5	–178.1	61.5	–182.2	*	–151.8	*
8	–95.1	15.1	–104.3	15.5	–115.9	16.3	–130.7	17.8	–149.2	21.5	–170.5	34.5	–186.7	*	–170.6	*
9	–83.3	15.3	–91.7	15.5	–102.4	15.9	–116.4	16.8	–135.1	18.9	–159.3	25.2	–185.6	83.8	–188.2	*
10	–73.2	15.6	–80.6	15.7	–90.2	15.9	–103.2	16.4	–121.0	17.5	–146.0	20.8	–179.1	38.3	–202.1	*
11	–64.5	16.1	–71.0	16.1	–79.6	16.1	–91.2	16.3	–107.6	16.8	–131.9	18.5	–168.1	26.1	–209.8	*
12	–57.0	16.7	–62.7	16.5	–70.3	16.4	–80.6	16.4	–95.4	16.5	–117.9	17.3	–154.3	20.8	–209.6	84.0

C_0 pF	C_4 = 1pF R_{in} Ω	C_{in} pF	C_4 = 2pF R_{in} Ω	C_{in} pF	C_4 = 3pF R_{in} Ω	C_{in} pF	C_4 = 4pF R_{in} Ω	C_{in} pF	C_4 = 5pF R_{in} Ω	C_{in} pF	C_4 = 6pF R_{in} Ω	C_{in} pF	C_4 = 7pF R_{in} Ω	C_{in} pF	C_4 = 8pF R_{in} Ω	C_{in} pF
1	–116.7	25.5	–118.8	29.4	–120.5	36.0	–121.7	48.8	–121.8	84.1	–120.3	525.9	–116.3	*	–108.5	*
2	–107.3	22.4	–110.3	24.9	–113.3	28.8	–116.1	35.7	–118.1	50.2	–119.1	99.0	–117.8	*	–112.8	*
3	–97.7	20.6	–101.3	22.3	–105.1	24.9	–109.1	29.1	–112.8	36.9	–115.9	56.0	–117.4	160.7	–115.7	*
4	–88.4	19.5	–92.3	20.8	–96.6	22.6	–101.3	25.4	–106.3	30.2	–111.1	40.3	–115.2	71.8	–116.9	*
5	–79.7	19.1	–83.7	19.9	–88.2	21.2	–93.3	23.2	–99.0	26.4	–105.2	32.4	–111.3	47.6	–116.3	135.7
6	–71.7	18.8	–75.6	19.5	–80.1	20.4	–85.3	21.8	–91.4	24.1	–98.4	28.0	–106.1	36.6	–113.8	57.1
7	–64.5	18.9	–68.2	19.4	–72.5	20.1	–77.7	21.1	–83.9	22.6	–91.3	25.3	–100.0	30.7	–109.8	45.8
8	–58.0	19.1	–61.5	19.4	–65.6	19.9	–70.6	20.6	–76.6	21.8	–84.1	23.6	–93.3	27.2	–104.6	35.9
9	–52.3	19.5	–55.5	19.7	–59.4	20.1	–64.1	20.5	–69.8	21.3	–77.1	22.6	–86.4	25.0	–98.4	30.3
10	–47.2	19.9	–50.2	20.0	–53.7	20.3	–58.1	20.6	–63.5	21.2	–70.5	22.0	–79.6	23.6	–91.8	27.0
11	–42.7	20.0	–45.4	20.5	–48.7	20.6	–52.7	20.8	–57.8	21.2	–64.3	21.7	–73.0	22.8	–85.0	24.9
12	–38.7	21.0	–41.2	21.0	–44.2	21.1	–47.9	21.2	–52.6	21.4	–58.6	21.7	–66.7	22.3	–78.2	23.6

Table 3 continued. Impedance seen by crystal looking into the rest of the wide-band oscillator circuit at various values of C0 and C4. Each table is for a seperate operating frequency. From top to bottom, 73 MHz, 104.0 MHz, 120.0 MHz.

Reference

1. M.E, Frerking, *Crystal oscillator design and temperature compensation*, Van Nostrand, 1978.

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R. Partha received BE and ME degrees in Electronics from Bangalore University in 1982 and 1991, respectively. He has worked in the R&D department of ITI Ltd. since 1983. While at ITI, he has been responsible for the desihn and development of microwave oscilators. He has conducted several experiments on EMI/EMC requirements of radio systems and has been involved in the engineering of digital microwave radio equipment.

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Using a Vector Network Analyzer to Make Time-Domain Transmission and Reflection Measurements

By Rob Frohne, Ph.D.
Walla Walla College

Time-domain reflection and transmission (TDR/TDT) techniques are useful for determining exactly where in a transmission line reflections are occurring, especially in broadband transmission systems with multiple reflections [1,2]. Usually a time domain reflectometer or the combination of a digital oscilloscope [3] and a pulse generator is used to make these measurements. This paper explains how to transform frequency domain data collected with a vector network analyzer to obtain this time domain information. I also present actual results obtained with a Hewlett-Packard HP 4195A vector network analyzer.

A time domain reflectometer usually consists of a pulse generator [4] and a storage oscilloscope. They are connected to the source end of the transmission system under test as seen in Figure 1. The pulse generator sends a pulse of unit amplitude down the line; any change in impedance of the transmission line encountered by the pulse creates a reflected voltage that travels back toward the source. The sum of both voltages is monitored on the oscilloscope. The time measured on the oscilloscope between the original pulse and the reflection is the time it takes a signal to traverse twice the distance to where the reflection occurred. If the signal velocity in the line is known, it is easy to determine the distance to the cause of the reflection.

This distance is the signal velocity multiplied by half the time difference between the incident voltage pulse and the reflected voltage as measured on the oscilloscope. If the incident pulse is subtracted from the function displayed on the oscilloscope, the result is the time-domain reflection coefficient. It is also the inverse Fourier transform of the complex reflection coefficient (S_{11}) normally displayed on a vector network analyzer. Time-domain transmission measurements are made in a similar way. For these measurements the oscilloscope is placed at the load end of the transmission line instead of the source end.

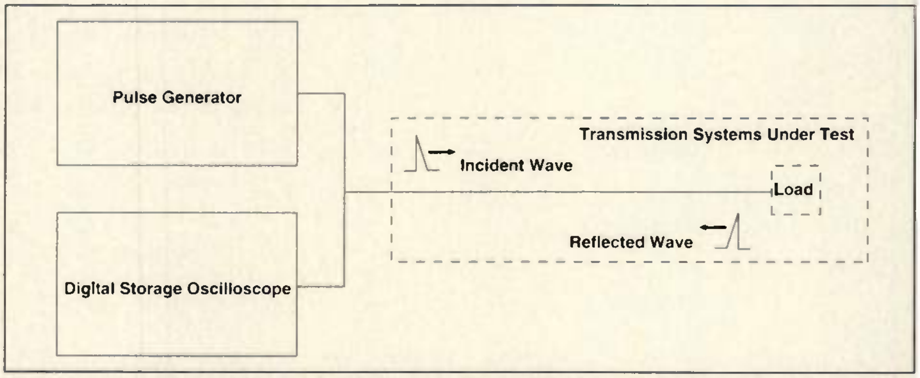

Figure 1. Typical setup for performing time-domain measurements on a transmission system using a pulse generator and oscilloscope.

The quantity measured on the oscilloscope is called the time domain transmission coefficient, and it is the inverse Fourier transform of the complex transmission coefficient (S_{21}) which can be also measured with a vector network analyzer. The method of this paper works equally well with either TDR or TDT measurements; however, the primary emphasis is on TDR measurements, and all experimental measurements presented are TDR measurements.

The method described here uses the inverse fast Fourier transform (IFFT) to obtain the time domain transmission or reflection coefficients from the measured complex frequency domain transmission or reflection coefficients. The data is transferred from the vector network analyzer using GPIB, or any convenient method, to a computer having software to do an IFFT on the data and display the result. See Appendix B for a method of computing the IFFT using an FFT subroutine.

There are so many different vector network analyzers and software packages with these capabilities that I will not describe our data acquisition and computing environment here other than to say I used a Hewlett Packard HP 4195A vector network analyzer and a PC compatible computer running MATLAB.

The fast Fourier transform (FFT) and the IFFT are fast algorithms for computing the discrete Fourier (DFT) and inverse discrete Fourier transforms (IDFT). The DFT and IDFT are numerical methods for approximating the Fourier transform and inverse Fourier transform. To interpret

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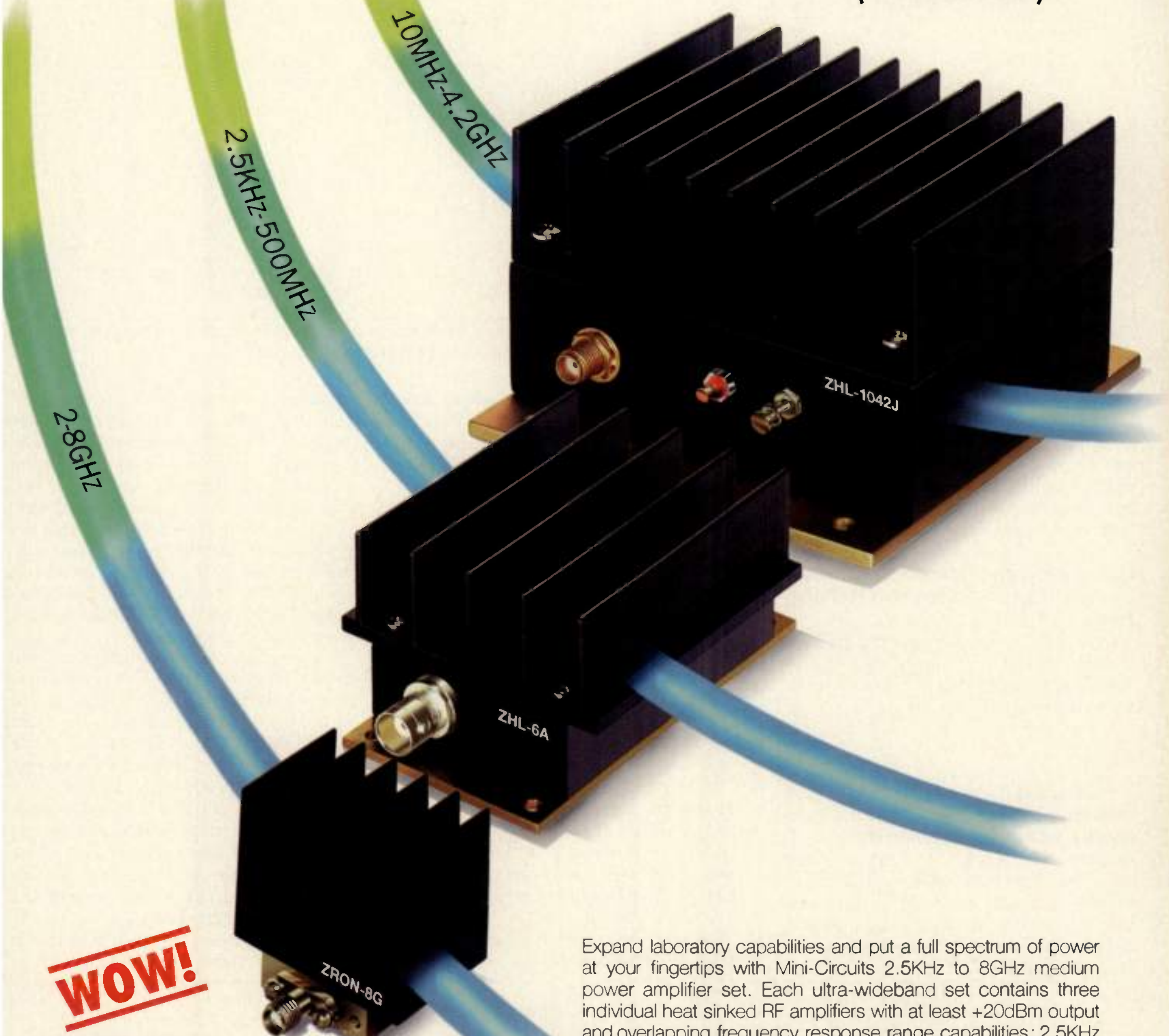

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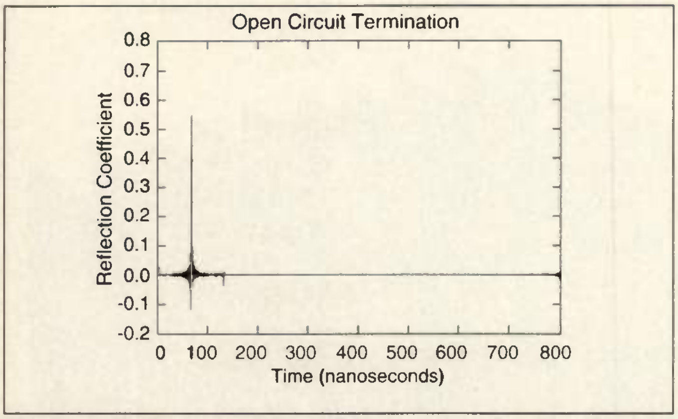

Figure 2. Reflection observed from open circuit at far end of a 6.43 meter transmission line.

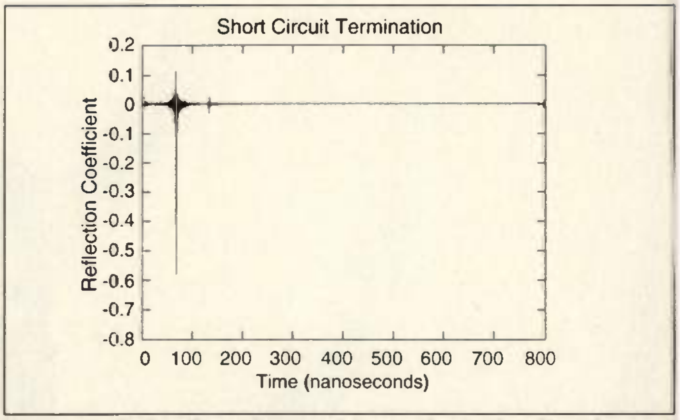

Figure 3. Reflection observed from short circuit at far end of a 6.43 meter transmission line.

results obtained by applying the IFFT to the data, the nature of these discrete approximations must be accounted for. I discuss these theoretical notions below. Finally, I present some sample experimental results obtained from our setup.

Computing and Interpreting Time Domain Transmission and Reflection Coefficients

One half the reciprocal of the highest measurement frequency, f_h, is the smallest time increment discernable with this method.

$$T = \frac{1}{2f_h} \qquad (1)$$

This time, T, is the time interval between points on the plot of the time domain reflection or transmission coefficient. The total amount of time viewed is this time increment, T, multiplied by 2M–2, where M is the number of positive frequency data points taken. To increase the observation time, increase M. It is recommended that M be made large enough so that all significant reflections arrive back at the source within (2M–2)T seconds. This avoids aliasing which causes reflections occurring later than (2M–2)T to appear as if they really occurred before (2M–2)T. If the polar plot of the complex frequency domain data appears very smooth, aliasing probably is not a problem.

An important point to bear in mind when interpreting the results from the IFFT is that this numerical approximation assumes that both time and frequency domain functions are periodic. The period of the time domain data is (2M–2)T seconds. Think of the time domain data obtained by this method as coming from a generator sending out a pulse every (2M–2)T seconds. The result of this periodicity in the frequency domain is that negative frequency components come directly after positive frequency components as shown in Table 1.

Yet another thing to be aware of is leakage, also known as sidelobes. Leakage is the name given to the IFFT data that spills over into adjacent time intervals. It is due to truncation of the frequency domain function (chopping it off at the highest frequency measurable on the vector network analyzer) and may sometimes be reduced by applying a Hanning or Hamming window function to the data [5]; however, I found that these window functions seriously shifted the results away from theoretical predictions.

For example, short circuit and open circuit terminations look very similar after applying either the Hanning or Hamming window functions to each. In addition, these window functions did very little to decrease the leakage. Therefore, windowing of the data before taking the IFFT is not recommended. One place leakage is apparent is at the end of a sample. The reflection, from an imperfect impedance match at the source end of the transmission system under test, leaks into the previous period, making it appear that there is a reflection arriv-

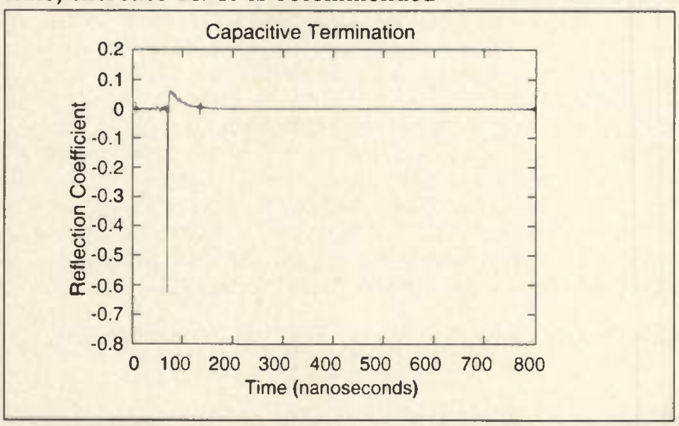

Figure 4. Reflection observed from a capacitively terminated (470 pF), 6.43 meter transmission line.

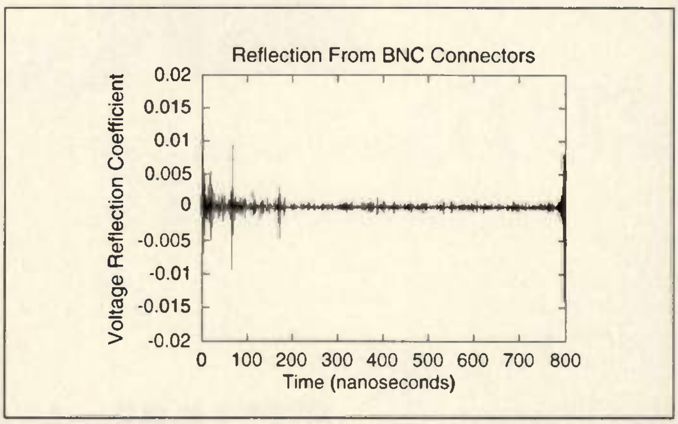

Figure 5. Reflections from 6.43 m and 10.3 m pieces of RG-58/U connected via a BNC connector and terminated in 50 Ω.

ing at 2MT seconds even if there actually is none. This is evident in all of the sample experimental results (Figures 2 to 5).

Since the time domain reflection and transmission coefficients are both real quantities, one can deduce from the positive frequency components of the complex reflection or transmission coefficients what the negative frequency components must be. The mathematical details are given in Appendix A. The result,

$$H(-n) = H^*(n) \qquad (2)$$

leads to this simple procedure.

Set the start frequency of the network analyzer sweep to DC and the stop frequency to f_h. The frequency range of many network analyzers doesn't extend to DC. I used the 10 Hz frequency result, deleting the imaginary part of the data. You may need to employ your own ingenuity.

Most FFT/IFFT algorithms require the number of data points to be a power of two (2^m where m is a non-negative integer). To meet this requirement, collect an odd number, $M = (2^m + 1)$, of data points. Insure that the first and last data points are entirely real numbers by deleting any imaginary parts. Take the complex conjugate of each of the M data points from the analyzer, reverse the order of this sequence of data, delete the first and last numbers and append it to the end of the original data sequence of M data points from the network analyzer to yield $2M-2 = 2^{m+1}$ total points.

This is the data on which to perform the IFFT. For example, see Table 1. The network analyzer gives the positive frequency data (above the double line); the data for negative frequencies (below the double line) is derived from the positive frequency data as described above. The result of the IFFT is then plotted to make its interpretation easier.

Experimental Results

Reflection measurements were done with terminations for which I knew the theoretical reflection coefficients. They were the open circuit, the short circuit, the capacitive load, the matched load and others. The HP 4195A I used has an upper frequency limit of 500 MHz. This upper frequency limit results in a time resolution of one nanosecond and a spacial resolution of the velocity factor of the cable multiplied by 15 centimeters, which is about 10 centimeters in RG-58/u. I set M to 401 for the following tests. (The IDFT algorithm in MATLAB didn't require the number of points to be a power of two, even though this is commonly the case, and the computations would have been faster if I had chosen it so.) The observation time was 800 nanoseconds. No window functions were used

Open Circuit Termination

A piece of RG-58/U, 6.43 meters long, with 50 ohm male BNC connectors on either end was connected to the network analyzer. The load end was left open-circuited. The results of the analysis are shown in Figure 2. The boundary condition at an open circuit requires that the current be zero making the voltage reflection coefficient equal to one. Cable loss and leakage are reasons for the pulse being 0.6 instead of one. The ringing is a result of leakage or a high frequency resonance or both. Knowing the termination helps identify it as leakage in this case; in others it might not be so easy. A quick calculation shows the signal velocity in the cable to be 0.65 the speed of light in a vacuum, which is close to the 0.66 number specified by the manufacturer. Note that there is a small second reflection coming from the first reflection bouncing off the source and then off the load again.

Short Circuit

The load end of the same cable was connected to a BNC barrel which was in turn connected to a BNC short circuit. See Figure 3 for the results of this experiment. The boundary condition at a short circuit requires the voltage to be zero. This makes the reflection coefficient –1. Again cable loss, leakage, and the second reflection are evident. The velocity factor can be calculated easily from this measurement also, and it agrees with that obtained from the open circuit termination measurement.

Capacitive Termination

A 470 picofarad capacitor was used as the load termination for the 6.43 meter cable. The results are shown in Figure 4. Originally the capacitor is uncharged and appears like a short circuit causing the initial –1 reflection. The capacitor is charged by both the incident and reflected current pulses simultaneously at the instant the incident pulse arrives. It subsequently discharges into the transmission line yielding the exponential decay. Note that this exponential decay has a time constant of about Z_0C as expected. Care was taken in this measurement to make the leads short on the capacitor. With standard one-inch leads on the capacitor, high-frequency resonance behavior was very prevalent and looked similar to the leakage of the short- and open-circuit terminations.

BNC Connectors

An effort was made to determine how small a disturbance in the impedance of the line could be detected. BNC connectors were selected as disturbances. The 6.43 meter cable was connected to a 10.30 meter piece or RG-58/U with a barrel connector. This second cable was terminated in a 50-ohm load made up of a barrel connected to a standard male 50-ohm BNC termination. The small disturbances from this splice and from the 50-ohm termination are easily seen in Figure 5. This demonstrates that the method is a practical way of investigating even very small reflections. It is also a testimony to the accuracy of the HP 4195A.

Conclusions

I have described a practical way to use a vector network analyzer and computer to make accurate TDR/TDT measurements. I have explained the IFFT technique used and included some hints on interpreting the results. I have presented sample measurements that illustrate the kind of results which may be obtained using the HP 4195A as well as some of the effects coming from the IFFT.

Acknowledgements

I am very grateful to Adventist World Radio Asia for allowing me the privilege of working with their HP 4195A vector network analyzer last summer. *RF*

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4. Ideally an impulse function, δ(t), generator is desired. Sometimes a step function generator is used instead because it is easier to construct. The response to a step function, g(t), is related to the impulse response, h(t), by

$$g(t) = \int_0^t h(\tau)d\tau \tag{3}$$

5. E. Oran Brigham, *The Fast Fourier Transform and Its Applications*, Prentice Hall, 1988.

Appendix A

Computing the Negative Frequency Components of Reflection and Transmission Coefficients

The DFT, H(n), of h(k) may be written in terms of its even and odd parts:

$$\begin{aligned} H(n) &= \sum_{k=0}^{N-1} h(k)e^{-\frac{i2\pi nk}{N}} \qquad \text{(A1)} \\ &= \sum_{k=0}^{N-1} h(k)\cos\left(\frac{2\pi nk}{N}\right) \\ &\quad -i\sum_{k=0}^{N-1} h(k)\sin\left(\frac{2\pi nk}{N}\right) \\ &= H_e(n) + iH_o(n) \end{aligned}$$

where He(n) is the even part of H(n) and Ho(n) is the odd part of H(n). Since h(k) is a real function

$$\begin{aligned} H(-n) &= H_e(n) + iH_o(-n) \qquad \text{(A2)} \\ &= H_e(n) - iH_o(n) \\ &= H^*(n) \end{aligned}$$

where H* (n) is the complex conjugate of H(n).

Appendix B

Computing the IFFT using an FFT Subroutine

This procedure is based on the relations:

$$h(k) = \frac{1}{N}\sum_{n=0}^{N-1} H(n)e^{\frac{i2\pi nk}{N}} \qquad \text{(B1)}$$

$$h^*(k) = \frac{1}{N}\sum_{n=0}^{N-1} H^*(n)e^{-\frac{i2\pi nk}{N}} \qquad \text{(B2)}$$

Since h(k) is real

The complex conjugate of the time sequence, h*(k), is recognized as 1/N times the DFT of the sequence H*(n). So to form the IFFT of a sequence H(n) whose IFFT, h(k), is real, take the complex conjugate of the sequence H(n), divide by N and then perform the FFT of H*(n)/N to get h(k).

About the Author

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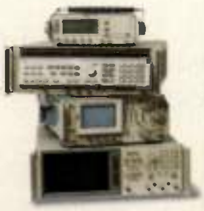

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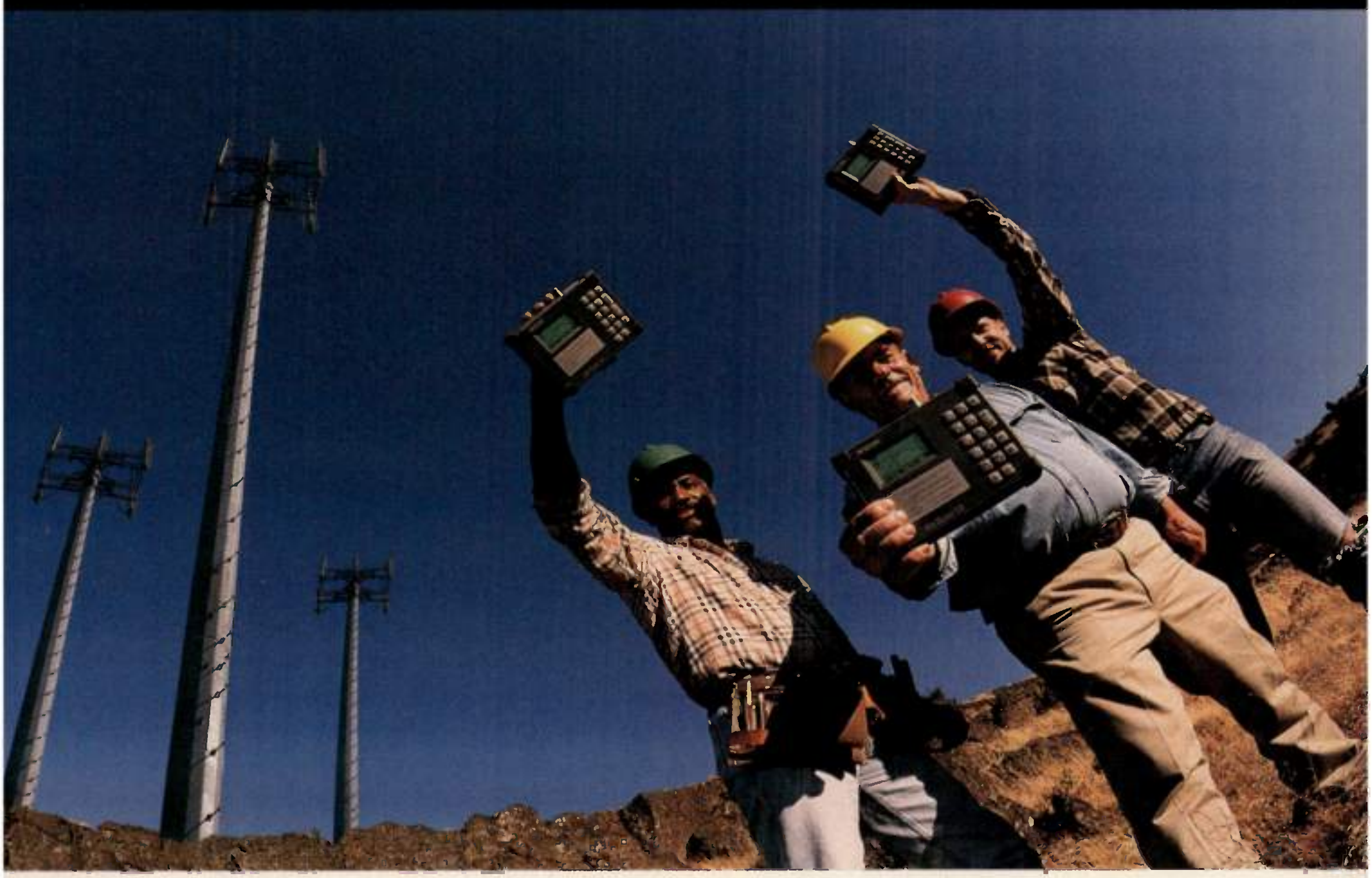

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Large-Volume Sales Prove GaAs RFICs Have Finally Arrived

This month's Product Forum covers the GaAs integrated circuit market. Several manufacturers offer their opinion regarding the market and technology trends affecting this market segment.

ITT GTC RF IC Products

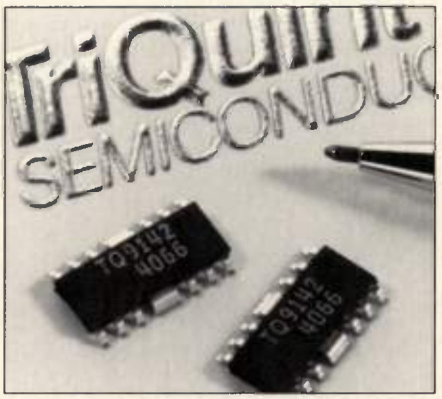
ITT GTC serves the rapidly growing wireless industry through RF IC product sales to OEMs and wafer sales to Alpha Industries and RF Micro Devices. Since we shipped our first RF wafer in March 1990 and our first RF IC products were introduced in February 1994, this product line has become our largest source of sales. We have responded to this growing demand by increasing our capacity in September 1995 via a $400,000 expansion to our clean room and implementing a four-shift, 24 hour a day, seven day a week continuous operation in our wafer fab.

ITT GTC predicts RF ICs will become more popular as designs of hand held consumer products find that their time to market can be reduced by eliminating the efforts needed to design and stabilize discrete circuit implementations. Our RF IC power amplifier products offer significant savings over hybrid modules and have been selected in many cost reduction redesigns

Anadigics

The market for GaAs ICs is fast approaching $1B and is expected to grow to nearly $2B by the year 2000. GaAs ICs are no longer the technology of the future and are widely used today in satellite and cable TV, cellular, GPS, and telecom/datacom fiber-optic links. ANADIGICS is actively supplying high volumes (>1.5M per month) of GaAs ICs to most of these markets.

The continued growth of the wireless-terminals markets, coupled with the trend towards lower voltage, higher frequencies small size/increased portability, and digital standards should provide tremendous growth opportunities for GaAs ICs since these all play to the strengths of GaAs ICs. ANADIGICS is already a proven supplier of GaAs ICs to the cellular phone market, having already shipped more than 2 million ICs.



Housed in plastic packaging and selling for under $5.00 each, GaAs ICs like this 1 W power amplifier from TriQuint Semiconductor are being designed into wireless devices destined for the cost-conscious consumer market.

Today, GaAs IC manufacturers are fully aware of the need to make their products cost effective and user friendly. ANADIGICS has recently released a single-supply GSM power-amplifier IC which provides the ease-of-use of a hybrid power-module, but with better performance, and at a price which is competitive with low-cost discrete solutions.

Oki Semiconductor

The Personal Communications Services (PCS) market will hit the ground running in 1996. PCS will increase the demand for high-performance, power-efficient GaAs RF products in 1996. Moreover, Oki Semiconductor expects output of PCS handheld units to reach 30,000 units per month by the end of the first quarter, 1996. The market for PCS applications will consume more than 20 million GaAs RF components by 1997. Oki expects these trends to continue through the remainder of the decade.

Growth of the PCS market will be driven by a need for longer talk times and longer standby times for end users, and increased miniaturization. High-efficiency, high-performance, low-power, low-cost and high-integration are inherent in Oki's design and manufacturing philosophy.

Oki recently introduced the first complete 3V solutions for PCS. Its new KGF1606 and KGF1608 power amplifiers, and its KGF1262 driver amplifier, operating from 850 MHz to 2.4 GHz, represent the latest additions to Oki's existing high-performance, highly integrated 3V GaAs RF solutions for PCS. Oki will follow up these initial 3V product offerings with several new power-efficient products throughout 1996 and beyond.

TriQuint Semiconductor

Wireless markets are growing wildly. Wireless telephones, both mobile and cordless, are changing people's expectations about how they live their lives. If so, a whole new industry is developing, with its own business cycles, just as did computers, television, and even the telephone itself. It is quite likely that the next down-turn in the "electronics industry" will not affect wireless telephone suppliers.

Commercial GaAs has both performance and price to supply RFICs for LNAs, mixers, and PAs. Many engineers wisely use a technology in its natural place, without listening to the "technology ideologues". TriQuint has "commercialized" GaAs: low cost, in plastic, reliable and repeatable.

TriQuint supplies to wireless telephony in two ways: 1. with catalog products optimized for those frequency ranges, and 2. with manufacturing and manufacturing engineering services for people wanting to design their own RFICs. In both cases, TriQuint is a volume supplier – production-oriented and commercial. *RF*

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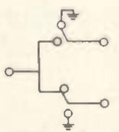

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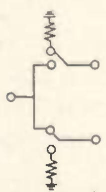

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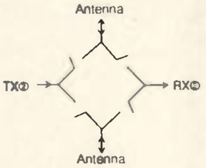

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F 174 Rev A

INFO/CARD 57

RF DESIGN SEMINAR SERIES

Call for Papers

RF Design Seminar Series
April 24-26, 1996 — Las Vegas, Nevada

Papers are invited for the second RF Design Seminar Series event, to be held in conjunction with the giant International Wireless Communications Expo (IWCE). If you have been looking for an opportunity to attend the premier mobile radio, cellular and PCS trade show, and you have a valuable engineering contribution for our program (especially in the area of mobile communications) this is the place!

Suggested Topics

Technical presentations on any RF topic are encouraged, with special attention given to papers on recent engineering developments in components and techniques for applications of current interest:

Cellular • PCS • ESMR,
WLAN • unlicensed systems,
RFID • IVHS • LEO
Digital Modulation • Antennas & Propagation
Communications System Design

Proposals should indicate whether the paper will require one-half hour or one hour for presentation, including a question-and-answer period. Papers may cover engineering design or analysis, testing, development case histories, or tutorial material.

Presenter Benefits

All speakers and poster session participants receive free admission to the technical papers program, exhibits and a copy of the Proceedings. In addition, all presenters will be given discounts on class fees for the short courses offered at this event. Your contribution to the program is appreciated!

Send a one or two paragraph abstract by January 8, 1996 to:

Gary Breed, Editor
RF Design
6300 S. Syracuse Way
Suite 650
Englewood, CO 80111
Tel: (303) 220-0600
Fax: (303) 267-0234

Future Seminar:
Wakefield, MA — October 21-23, 1996

The RF Design Seminar Series — A Unique Learning Environment for RF Engineers

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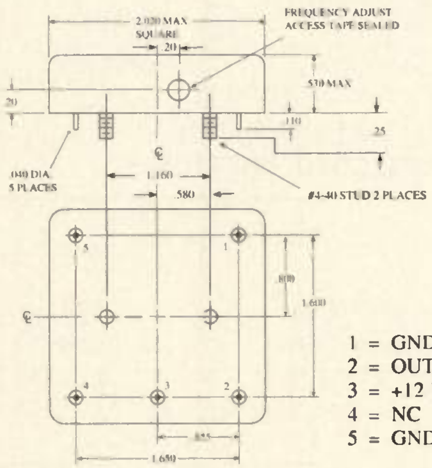
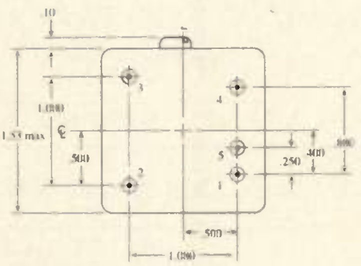


1 = GND. CASE
2 = OUTPUT
3 = +12 VDC
4 = NC
5 = GND

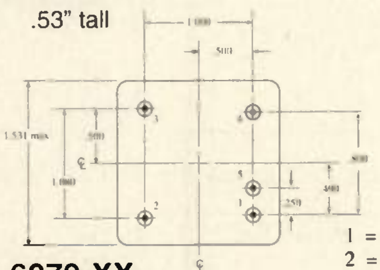
6024-XX



1 = OUTPUT
2 = + 12 VDC
3 = CASE
4 = CASE
5 = GND. CASE

Pin Dia. = .030

6099-XX
.53" tall



6079-XX
.53" tall

1 = OUTPUT
2 = +12VDC
3 = GND. CASE
4 = VCO
5 = GND. CASE

Pin Dia. = .030

6024-XX 6099-XX 10.0 MHz SINEWAVE

STABILITY OPTIONS		6024 - XX	6099-XX
-01	0° to +70°C	±0.1 PPM	±0.2 PPM
-02	0° to +70°C	±0.3 PPM	±0.5 PPM
-03	0° to +70°C	±0.5 PPM	±1.0 PPM
-04	-40° to +85°C	±1.0 PPM	±1.0 PPM
-05	-55° to +85°C	±1.0 PPM	±1.5 PPM
-XX	CALL FOR OTHER OPTIONS		

ALAN VARIANCE:

-01	±1 x 10^{-10} at tau = 1 second
-02 thru -05	±2 x 10^{-10} at tau = 1 second

AGING:

-01 thru -02	<0.2 PPM/year <1.0 PPM/10 years	< 0.25 PPM/year < 1.5 PPM/10 years
-03 thru -05	<0.5 PPM/year ≤2.0 PPM/10 years	< 0.5 PPM/year < 2.5 PPM/10years

PHASE NOISE:

-100 dBc at	10 Hz
-130 dBc	100 Hz
-150 dBc	1.0 KHz
-155 dBc	>10.0 KHz

+12.0 VDC ±5% Input   +6.5 to +10 dBm Output into 50Ω

6079 - XX 10.0 MHz HCMOS

STABILITY OPTIONS		AGING/YEAR	10 YEARS
6079 -01	0° to +70°C	±0.2 PPM	±1.5 PPM
6079 -02	0° to +70°C	±0.5 PPM	±1.5 PPM
6079 -03	0° to +70°C	±1.0 PPM	±2.0 PPM
6079 -04	-40° to +85°C	±1.0 PPM	±2.5 PPM
6079 -05	-55° to +85°C	±1.0 PPM	±2.5 PPM
6079 -XX	CALL FOR OTHER OPTIONS		

SHORT TERM and ALAN VARIANCE PER ABOVE

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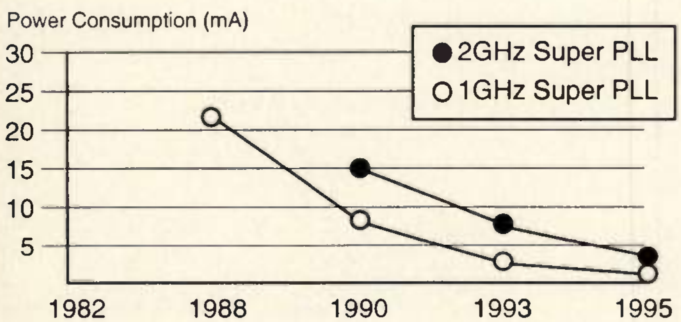

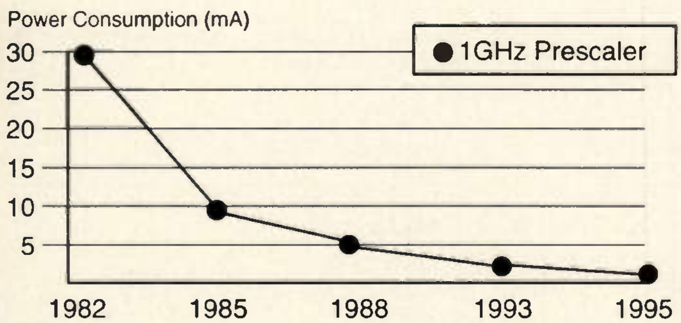

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AMPS, CT–2, GSM, CDPD, ARDIS, MOBITEX, W/LAN

Single Modulus	MB511
Dual Modulus, Low Current	MB501L
Dual Modulus, Low Voltage	MB501LV
Dual Modulus, Super Low Current	MB501SL
Dual Modulus, Power Saving	MB509

PRESCALER ABOVE 1GHz

Single Modulus – w/LAN – 2.4GHz	MB506
Single Modulus – 1.6GHz	MB505–16
Dual Modulus – 2.3GHz	MB508
Dual Modulus – 1.6GHz	MB507
Dual Modulus – 2.7GHz	MB510
Dual Modulus – 2.0GHz	MB517

PRESCALER BELOW .5GHz

Dual Modulus	MB504
Dual Modulus, Low Current	MB504L
Dual Modulus, Low Voltage	MB504LV

1GHz SUPER ANALOG DEVICES
GSM, CT–2, AMPS, CDPD, UHF TUNER

Prescaler & VCO	MB551
Mixer	MB531
Double Functions : LNA/Mixer : Dual AMPs	MB54501 MB54502
High Power Amp	MB54503
I/Q Modulator	MB54609
Demodulator	MB537

1GHz–2GHz SUPER ANALOG DEVICES PCN/PCS

Low Noise Amp	MB539
I/Q Modulator	MB54619A

2.5GHz SUPER PLL (Single Chip PLL & Prescaler

Single Divider	MB1508 MB1518
Small Package (SSOP)	MB1515
Low Current	MB1517 MB15E06

2.0GHZ SUPER PLL (Single Chip PLL &Prescaler

Super Low Current & Analog Switch	MB1507
Small Package (SSOP)	MB1506

Preferred New Designs

For Digital Radio Systems	MB1517
Low Current	MB1517 MB15E05

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5GHZ SUPER PLL (Single Chip PLL & Prescaler)

Low Current & Wide Operating Voltage	MB1504 MB1504L MB1504H
Super Low Current & Analog Switch	MB1505
Dual PLLs & Wide Operating Voltage	MB15A19 MB1519 MB1514 MB1509

GHZ SUPER PLL (Single Chip PLL & Prescaler)

MPS, CT–2, GSM, CDPD, ARDIS, MOBITEX

Low Current & Wide Operating Voltage	MB1501 MB1501L MB1501H
Super Low Current & Analog Switch	MB1502 MB1502H MB1503
Dual PLLs & Wide Operating Voltage	MB1510
Small Package (SSOP)	MB1511 MB1512

Preferred New Designs

For Digital Radio Systems	MB1516A MB15A16
For General Purpose	MB15A01 MB15A02
Dual PLLs	MB15B01 MB15B03 MB15B11 MB15B13

SAW Filters

Part Number	Standard	Use
F5CB–836M50–G201	AMPS–136/1S–95	Tx
F5CB–881M50–G201	AMPS–136/1S–95	Rx
F5CB–881M50–G211	AMPS–136/1S–95	Rx
F5CB–888M50–G201	ETACS	Tx
F5CB–933M50–G202	ETACS	Rx
F5CB–933M50–G212	ETACS	Rx
F5CB–902M50–G201	NMT/GSM	Tx
F5CB–947M50G–201	NMT/GSM	Rx
F5CB–947M50–G211	NMT/GSM	Rx
F5CB–911M50–G201	NTACS	Tx

SAW Filters continued

Part Number	Standard	Use
F5CB–933M50–G201	NTT	Tx
F5CB–878M50–G201	NTT	Rx
F5CB–836M50–L2AA	AMPS/IS–136/IS–95	Tx
F5CB–836M50–L2AZ	AMPS/IS–136/IS–95	Tx
F5CB–888M50G201	AMPS/IS–136/IS–95	Tx
F5CB–902M50G201	AMPS/IS–136/IS–95	Rx
F5CC–933M50–L2BA	NTT	Tx
F5CC–878M50–L2CA	NTT	Rx
F5CC–888M50–L2CA	ETACS	Tx
F5CC–933M50–L2CB	ETACS	Rx
F5CC–911M50–L2DA	NTACS	Tx
F5CC–856M00–L2DB	NTACS	Rx
F5CC–902M50–L2EA	NMT/GSM	Tx
F5CC–902M50–L2EZ	NMT/GSM	Tx
F5CC–947M50–L2EB	NMT/GSM	Rx
F5CC–947M50–L2EY	NMT/GSM	Rx
F5CC–947M50–L2EX	NMT/GSM	Rx
F5CC–897M50–L2KA	E–GSM	Tx
F5CC–942M50–L2KB	E–GSM	Rx
F5CC–942M50–L2KY	E–GSM	Rx
F5CC–950M00–L2FA	PDC	Tx
F5CC–820M00–L2FB	PDC	Rx
F5CC–915M00–L2JA	900 MHz ISM	Tx/Rx
F5CC–915M00–L2JZ	900 MHz ISM	Tx/Rx
F5CC–935M00–L2LA	2–Way Pager	Tx/Rx
F6CC–1G4410–L2ZA	PDC 1.5GHz	Tx
F6CC–1G4890–L2ZB	PDC 1.5GHz	Rx
F6CC–1G6190–L2ZN	PDC 1.5GHz	Lo
F5CE–1G7475–L2YA	DCS 1800	Tx
F6CE–1G8425–L2YB	DCS 1800	Rx
F6CE–1G8800–L2XA	PCS(US)	Tx
F6CE–1G9600–L2XB	PCS(US)	Rx
F6CE–2G4500–L2WA	WLAN(US)	

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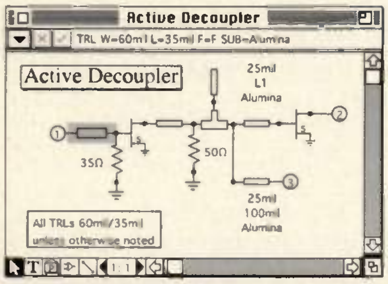
DragonWave 7 Key Features

Powerful features won't save you time, unless they're easy to use.

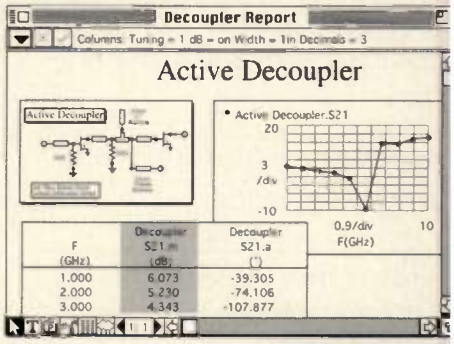


Circuits

It's as easy as choosing a symbol from the palette and clicking in the window.
Interconnections are made by dragging from one node to another.
Arbitrarily complex topologies with up to 99 external nodes — unlimited internal nodes.
Supports full Macintosh interface: cut, copy, paste, clear, and undo. Even option-drag.
Rotate groups of elements and retain all interconnections.
Set parameters for more than one element at a time.
Name each element; then show names and parameters on schematic.
Any circuit can be a subcircuit — with user-defined parameters!
Open multiple circuits. Five levels of zooming. Mix in text and pictures. More...

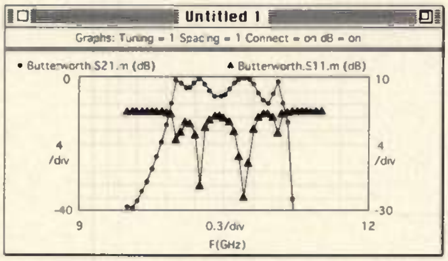
Integrated Reports

Reports contain text, pictures, schematics, tables, and plots — exceptional data sheets
All calculations update automatically when you modify the circuits
Save reports and open them as templates: substitute new circuits for originals
Each object in the report remains fully editable
Tables and plots can:
- show complicated expressions combining calculations from different circuits
- show calculations as a function of any one OR TWO user-defined variables
- show calculations with different sweeps. Sweeps can be log or linear
- be tuned (i.e. leave a copy graph or column each time you change a parameter)
- store their formats as data sheets which can be reused with different circuits



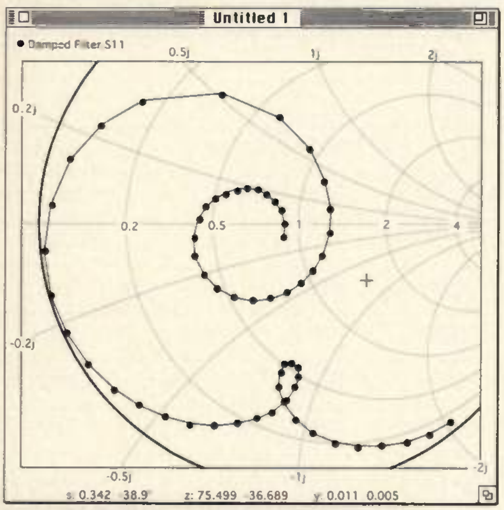
Data Libraries

Create data elements with 1 to 32 ports
Data can be a function of any variable or equation
Store data in intuitive, nested-folder libraries
Convert between grounded port configurations



Plots

Smith charts, XY plots, and polar plots
Zoom in by dragging a rectangle
Shows coordinates of cursor
Autoscale to show all graphs
Smith chart shows admittance circles



Calculations

Full nodal noise analysis. Matrix reduction for maximum speed
Each part of a circuit is recalculated ONLY when necessary — save up to 99% on time
Calculates S, Y, Z, spot noise, stability, group delay, VSWR, input impedances, ...
Or make your own using DragonWave's output equations
Robust gradient and random optimizers
Optimize any number of variables, elements, substrates
Goals can be any calculation, including output equations over sweeps of any variable

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Element and substrate parameters can be constants, variables or expressions
Includes library of real and complex functions
Use our data function to look up parameters as a function of any value

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Complete library of lumped and distributed models
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Tegal Corporation is worldwide leader in the development and manufacture of plasma etch systems for the semiconductor industry and winner of Semiconductor International's 1994 Editor's Choice for Best Product. Tegal is located just north of San Francisco in beautiful Petaluma, CA.

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Tegal offers an excellent working conditions. This is an excellent opportunity for the right candidate to join a challenging, progressive and innovative company. For consideration, please send your resume along with salary history to: Tegal Corporation, Attn: PJL, P.O. Box 6020, Petaluma, CA 94953-6020. Fax (707)765-9311. We are an Equal Opportunity Employer.

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Albuquerque, New Mexico 87110

IOWA MIDWEST

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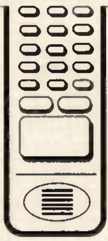

...YOUR CAREER

RF DESIGN GPS: The successful candidate must have a B.S.E.E. with a minimum 12 years of experience in the design of Lband LNAs, Mixers, VCOs, and Microstrip Matching circuits. Knowledge of spread spectrum and modulation/demodulation schemes highly desirable. M.S.E.E. and/or VHF/UHF background a plus.

Pacific Rim Marketing Specialists: Knowledge of cellular systems. Understanding of market forces in cellular (consumer). Needed skills include: writing business plans, formulation fundamental business strategies, coordinating advertising.

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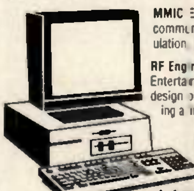
Cellular Engineers: Design/Develop RF and analog circuits for high capacity cellular systems. Requires minimum of 2 years experience in any of the following: DSP, ASIC Design, CAE Development, Digital Modulation, Digital Mobile Communications, Channel Equalizers, Transmitter-Receiver-Synthesizer or Audio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

Wireless Engineers
RF Design Engineers: Design of Si RF-ICs for wireless communication applications (AMPS, DAMPS, GSM, DECT, POS). Si RF-IXC design experience in the 400-2400 Mhz; fast RF PLL synthesizer design experience; RF receiver/transmitter/design experience using Si bipolar and MOS technologies
RF Small Signal and RF Power AMP System Engineers: Requires detailed technical knowledge of cellular and PCS systems with experience designing RF XMTRS and RCVRS. Need 5+ years' related experience in RF.

Design Engineer Communications ICs: Requires B.S.E.E. (M.S.E.E. preferred) and 5+ years experience. Individual will be responsible for leading the design and characterization of high frequency transceiver ICs for wireless communications applications. Design includes circuit integration of baseband, converter and RF/IF circuitry.



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

RF Engineer: Design RF portions of digital video home terminals (set top boxes) in new Video Entertainment Systems now under development. The engineer will be responsible for the design of the RF receivers (tuners)/transmitters. The engineer will join a growing team developing a line of low-cost, high volume terminal for a variety of interactive video services. 5-900 Mhz.

RF/MODEM ENGINEER: Requires BSEE/MSEE and 8+ years' experience with responsibility for the design of cable modems. Experience with QPSK and 64 QAM modems, digital modulators and demodulators, high-volume consumer products

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(Position #AR 3120)

The Continuous Electron Beam Accelerator Facility is seeking a senior electrical engineer for a position in the Radio Frequency group. The group is responsible for the design and maintenance of the linear accelerator RF control system that includes low power receiver technology and high power transmitter technology. The person will be responsible for the design, development and implementation of various subsystems of the RF system. Designs may include RF and microwave systems for both control and diagnostics. Incumbent will develop system specifications based on requirements, documentation, CEBAF and industry standards. Individual will provide job direction to junior engineers and technicians and communicate with accelerator physicists and other engineers to improve performance of the RF system. Individual will work to insure that designs and requirements comply within the guidelines of the CEBAF EH&S policies. Other duties may include test and measurement of the RF system, design of portable RF pulser, upgrade of existing RF control components, design of RF control system for an FEL driver, and design of receivers for accelerator diagnostics.

The minimum qualifications for this position are: BS Degree in Electrical Engineering (MS preferred) and 5 to 15 years of applicable experience and or an equivalent combination of education, experience and specific training. Incumbent must have a thorough background in RF and microwaves and have a working knowledge in at least two of the following areas: control systems, receiver design signal processing or high voltage. In addition, the individual must be able to communicate on a high level with accelerator physicists and engineers. Individual should be able to demonstrate continuous technical growth through, education, publications or patents.

The salary range for this position is $48,600 - $96,400. We are located near Colonial Williamsburg and the Chesapeake Bay. For prompt consideration, please send resume and salary history to: CEBAF, ATTN: Employment Manager, 12000 Jefferson Avenue, Newport News, VA 23606. Please specify position number and job title when applying.

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WIRELESS ENGINEERING OPPORTUNITIES with MOBILE SYSTEMS INTERNATIONAL

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

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

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

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

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Fax: (708)261-3028

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ENGINEERING

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RF/SENIOR RF ENGINEER

Will perform RF circuit and system design simulation up to 1 GHZ including PLL's, mixers, VCO's, modulators, demodulators, amplifiers and AGC systems. Strong communications theory background desired. Requires minimum BSEE (MSEE preferred) with experience in complex RF circuit and system design. Minimum of 5 years hands-on design experience or equivalent.

SENIOR LEVEL DIGITAL/SOFTWARE ENGINEER

Will perform system architecture design, digital design, and software design in embedded/real time systems. C language and Motorola processor experience desired. BSEE or MSEE and minimum 3 years experience.

SOFTWARE ENGINEER

Will perform system design and structured software design in embedded/real time systems. C language and Motorola processor experience desired. BSEE or MSEE and minimum 3 years experience.

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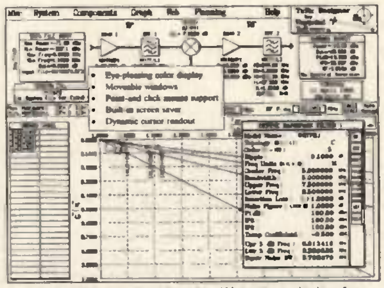

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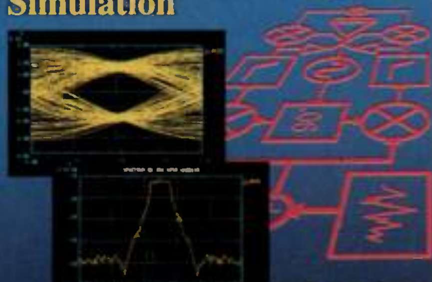

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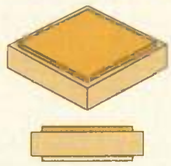

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licrosorb Technologies, Inc., 14A Airport Dr. Hopedale, MA 01747 .... (508)634-1900
antec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

nechoic Chambers

dvanced Electromagnetics, Inc., P.O. Box 711719, Santee, CA. 92072- 1719 .... (619) 449-9492
antec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

ntennas

ntenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (301) 937-8888
MCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

ntennas Above 30 MHz

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MCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

ntennas Masts

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urrent Probes

ischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
on Physics Corp., 11 Industrial Way, Atkinson NH 03811 .... (603) 893-6687

errite Absorber Tiles

antec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

TEM Cells

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ine Impedance

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ine Impedance Stabilization Networks

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ischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
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lear Field Probes

MCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

hielding Effectiveness Testers

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MC TEST EQUIPMENT - SUSCEPTIBILITY

ntennas

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EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Sheilded Fiber Optic Links

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ESD TEST EQUIPMENT

ESD Event Detectors

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Surface & Volume Resistivity Meters

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MATERIALS, HARDWARE AND PACKAGING

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Conductive Fiber/Fabric

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Gasketing Materials

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Laminates

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Sheilding Foils and Tapes

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Tripods

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Turntables

EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

SHIELD ROOMS AND CHAMBERS

Shielded Rooms EMI/RFI/Magnetic

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TEST LABORATORIES AND CONSULTANTS

TEST LABORATORIES

TUV Product Service, Inc., 1775 Old Hwy. 8, New Brighton, MN 55112 .... (800) 472-7999

CONSULTANTS

Kimmel Gerke Assoc. Ltd., 1544 N. Pascal, St. Paul, MN 55108 .... (612) 330-3728
EMC Design/Troubleshooting-Medical, Industrial, ITE, Vehicles & More-50+ years exp.

Coaxial Connector Catalog

A new catalog that features a broad line of 7/16 RF coaxial connectors for wireless communications applications is being offered by Tru-Connector Corp. The catalog features a full line of standard connectors in straight, right-angle, and between-series configurations that fit a host of popular cables from 0.041-inch to 0.685-inch dielectric diameters. Plugs, jacks, panel receptacles, and a wide variety of combination heads and adapters are included.
Tru-Connector Corp.
INFO/CARD #212

Switch Matrix Catalog

A 28-page color catalog from ST Olektron Systems outlines new switch matrix technology and other related components for switching RF, microwave and digital signals. These full fan-out, non-blocking switch matrices will allow users to connect a selected input to multiple outputs simultaneously without signal degradation.
ST Olektron Systems
INFO/CARD #211

Telecom ASICs and Assemblies

A new short form catalog is available from the Telecom Products Group of Stanford Telecom. The catalog provides technical information on the Telecom Products Group's entire portfolio of ASICs and board-level assemblies for demodulation and spread spectrum, frequency synthesis and forward error correction. The catalog is available free-of-charge.
Stanford Telecommunications, Inc.
INFO/CARD #210

Software Company On-Line

Compact Software has opened its own World Wide Web site. The Web site is a dedicated facility maintained by Compact, available 24-hours a day through a high-performance telecommunications link. The site offers basic corporate background and product information for Compact's line of RF and microwave CAD products. Compact's website is located at: http://www.comsoft.com.
Compact Software, Inc.
INFO/CARD #209

Crystal Oscillator Catalog

Q-Tech Corporation's 40-page catalog features a number of high-reliability hybrid products offered in standard DIP, TO, flat pack, and LCC packages. Products include standard hybrid crystal-controlled clock oscillators with TTL and CMOS outputs from 0.01 Hz to 160 MHz and ECL outputs from 1 to 200 MHz. Other products include Microcomputer-controlled hybrid sources, VCXOs, sine wave sources, and microprocessor drivers.
Q-TECH Corp.
INFO/CARD #208

Crystal & Oscillator Catalog

CTS Frequency Controls offers a 36-page catalog that lists CTS's lines of crystals, clock oscillators, and precision oscillators. The catalog also contains an introduction to CTS's manufacturing capabilities and contains a number of application notes. A list of sales offices is also included.
CTS Frequency Controls
INFO/CARD #207

Cable Assemblies Brochure

MICRO-COAX has released its latest UTiFLEX™ flexible cable assemblies brochure, which features the company's expanded family of flexible microwave cable assemblies. The 26-page brochure provides detailed charts, specifications, and photographs of the UTiFLEX cable assemblies, which include low-loss, ultra-low-loss, power, high-flexlife, high-isolation and miniature cable types.
MICRO-COAX
INFO/CARD #206

Cable/Connector Cross Reference

RF Industries' new easy-to-use cable-to-connector cross reference matches Belden, Alpha, and Times Microwave cables to a wide variety of RF Industries connectors. The cross reference is organized first by cable groups and second by the types of RF connectors available for these groups. The connectors are then divided into subgroups by type.
RF Industries, Ltd.
INFO/CARD #205

Electronic Cables Catalog

Belden Wire & Cable announces the availability of its New Generation Electronic Cables Catalog. The extensive lineup of multi-conductor, paired and coaxial cables shown in the 28-page publication have been re-engineered to deliver a large, economical and up-to-date selection of low voltage, electronic cables.
Belden Wire & Cable Co.
INFO/CARD #204

Antenna Monitor Data

Noise Com has released a data sheet on its ANVIL™ antenna VSWR and interference level monitor. The four-page data sheet details the applications, features, and specifications of the ANVIL monitor, which determines antenna problems. Charts and diagrams aid in the descriptions of the monitor's advanced technology features and functions.
Noise Com, Inc.
INFO/CARD #203

Cable and Connector Guide

Nemal Electronics has published a new edition of its Cable and Connector Selection Guide. The 48-page guide contains detailed technical specifications and illustrations of more than 1,000 cable, connector, and interconnect products. The guide also includes comprehensive performance data on a wide range of both commercial and military coaxial cables together with charts for quick selection of appropriate connectors and tooling.
Nemal Electronics International, Inc.
INFO/CARD #202

Radio Handbook

The *1996 ARRL Handbook* from the American Radio Relay League includes new projects, updated information, and for the first time, software. The 3.5-inch, 1.44 MB IBM compatible diskette includes an RF supplier database, a number of design programs, various utility programs, and the software side of several projects in the handbook. Retail price of the 1996 ARRL Handbook is $38.00.
American Radio Relay League
INFO/CARD #201

System Simulation Newsletter

Elanix offers *SystemView Times*, a newsletter providing product information, application tips and seminar information for users and potential users of the system simulation software, SystemView. The newsletter is offered free-of-charge.
Elanix, Inc.
INFO/CARD #200

Annual Standards Report

The American National Standards Institute (ANSI) offers its 1994 annual report. The report focuses on ANSI's revised strategic plan and on a number of new and significantly expanded programs. The report also includes financial information and a list of members.
American National Standards Institute
INFO/CARD #199

Spectrum Probe App Notes

Smith Design offers a 20-page pamphlet describing applications for the 255 and 107 Spectrum Probes™. The 0.12 to 2.5 MHz 255 Spectrum Probe and the 2.5 to 100 MHz 107 Spectrum Probe provide spectral analysis when used with an oscilloscope. The pamphlet describes the use of the IA5 and IA7 current measurement accessories for various current measurements and describes how the Spectrum Probe can be used for various servicing and EMI-tracking applications.
Smith Design
INFO/CARD #198

Noise Product Catalog

Micronetics Wireless' 24-page catalog contains specifications for their lines of noise modules, noise standards and noise instruments. A brief tutorial about noise is also included.
Micronetics Wireless
INFO/CARD #197

RF software

Schematic Editor

Ivex Design International has announced a newly revised version of WinDraft Schematics for Windows. Win Draft 1.2 now has True Type fonts as well as the ability to "copy" and "paste" from WinDraft to other applications. The new version also has the added ability to store component attributes in the library parts. This enables the user to build up libraries containing all the necessary information such as module footprint name, internal stock number, alternative part, SMD module name, etc. WinDraft is an ideal front-end for WinBoard PCB layout, also from Ivex. WinDraft sells for $495 and is available immediately.
Ivex Design International
INFO/CARD #195

Electronic Reference Utility

CyberCircuit is a Windows program that allows you to quickly find application circuits and other reference information. The program uses a powerful search engine to find hundreds of analog and digital circuits, formulas, tables, dimensions, pinouts and other information. All schematics are redrawn, not scanned. CyberCircuit is works under Windows 3.1 or greater and is available to the first 2,000 customers for $39.95 plus $4.95 S&H.
PTM
INFO/CARD #194

Analog Simulation

Avista Design Systems announces Avista Spectre/XL for Microsoft Windows 95. Avista Spectre/XL embeds circuit simulation inside Microsoft Excel. Avista Spectre/XL's combination of immediate access to all circuit values, and instant what-if analysis gives analog designers a uniquely flexible tool for evaluating, developing and optimizing circuit designs. The Windows 95 release of Spectre/XL runs up to 100 percent faster than the 16-bit Windows 3.1 version, and it supports translation of existing SPICE netlists to the Spectre format. Avista Spectre/XL for Windows 95 is priced at $795. The program requires Microsoft Excel 7.0 for Windows 95.
Avista Design Systems
INFO/CARD #193

Super-Spice for Windows

Compact Software has begun customer shipments of its Super-Spice 1.1 simulator for PCs running Microsoft Windows. Super-Spice addresses high-frequency design applications by combining microwave-quality active device models with accurate models of passive distributed devices. Super-Spice provides accurate simulation up to 10 GHz. Integrated with Super-Spice is Compact's Serenade schematic editor, which graphically captures designs for simulation. U.S. pricing begins at $4,995.
Compact Software
INFO/CARD #192

RF guide to editorial coverage

RF advertising index

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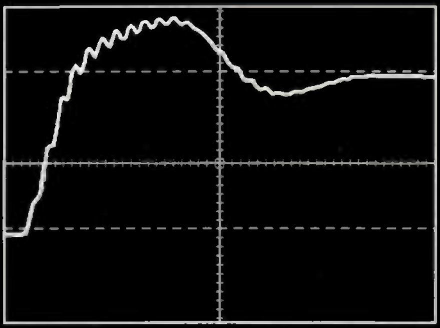

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F Input-Main PLL F Input-Aux PLL	1.1GHz	1.1GHz	1.2GHz	2.0GHz	2.5GHz	2.5GHz 510MHz	2.0GHz 510MHz	1.2GHz 510MHz	1.1GHz 1.1GHz	2.0GHz 1.1GHz	550MHz 550MHz
(typ) @3V owerdown (typ)	6mA N/A	6mA N/A	6mA 30μA	10mA 30μA	11mA 30μA	15mA 1μA	14mA 1μA	8mA 1μA	9mA 1μA	11mA 1μA	9mA 1μA

National Semiconductor

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