RF design

engineering principles and practices

June 1991

F. C. de Haan

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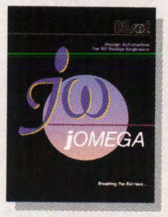

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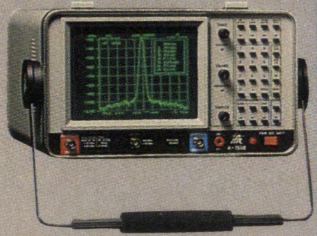

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DSO990	SPST	10-2000	1.5	62	25.0	14 Pin DIP	TTL
DSO850	SP2T	DC-2000	0.4	47	5.0	TO-5	0/-7
DSO813	SP2T	DC-2000	0.7	40	140.0	TO-5	TTL
DSO812	SP2T	10-1000	0.5	54	50.0	TO-8	TTL
DSO860	SP2T	10-1000	0.5	47	50.0	.380 sq	TTL
DSO602	SP2T	5-4000	1.3	65	26.0	14 Pin DIP	TTL
DSO842	SP2T	5-1500	1.0	75	50.0	14 Pin DIP	TTL
DSO864	SP4T	5-2000	1.3	49	28.0	16 Pin DIP	TTL
DSO874	SP4T	DC-2000	2.2	60	55.0	14 Pin DIP	TTL
DSO838	SP8T	5-1000	2.2	40	40.0	24 Pin DIP	TTL
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RF design

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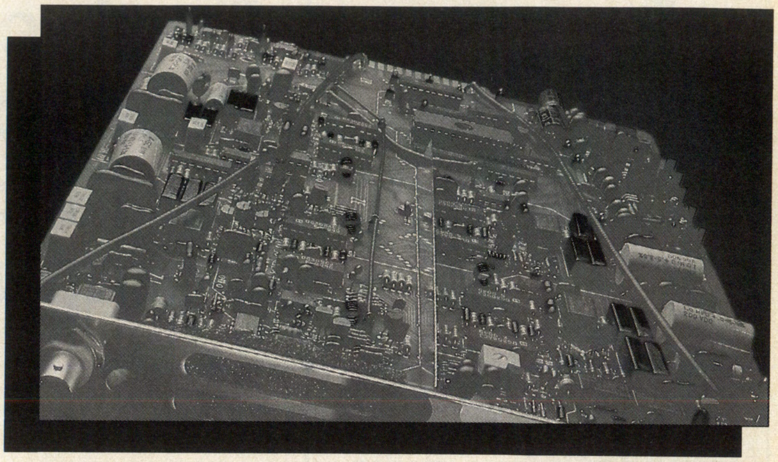

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RF editorial

Engineering Productivity Part III: Computers

By Gary A. Breed
Editor

Getting the maximum output from an engineer requires support. In my last editorial, I noted how new test instrument capabilities support RF engineers. This month, the focus is on software design tools and how they can contribute to greater productivity. Just as new philosophies in manufacturing represent a change in the way companies operate, design software is changing the way RF engineering is done.

At the high end are comprehensive design and simulation packages from Hewlett-Packard, EEsof, and Compact Software. Each offers complete design, analysis, modification, simulation, physical layout, and documentation of RF circuits. They have complex and accurate models which combine physical and electrical parameters and perform linear and non-linear analysis of the circuit. These packages actually allow an engineer to "build" a design in software, analyze its performance, modify its configuration, and optimize important parameters.

But, this power comes with a substantial price tag. To justify the cost, the benefits in engineering time, prototyping iterations, manufacturing assembly and test time all must be determined. Despite the apparent high cost, most major manufacturers are making the investment in large-scale RF CAE.

For companies which cannot justify this level of capital investment, other options are available from companies like Eagleware, ingSoft, DGS Associates, Tesoft, Webb Labs, and many others. Specific design programs for filter design, system analysis, oscillator design, low noise and power amplifier design are available at low cost. Modestly-priced circuit design, analysis and optimization packages offer good performance and accuracy for most engineering design assignments.

With these specialized lower cost products, an engineer can make up a collection of individual "problem solvers," but they do not make up a *system*. Parameters have to be translated or re-entered to move from one program to another, and documentation has to be collected by hand or in a separate text and graphics package. Still, these limitations are trivial compared to manual efforts!

Computers are already used extensively by RF engineers, but with widely varying degrees of utilization. Whether they play a major or minor role in design, they still add to an engineer's capabilities. As engineers and their managers realize how much improvement in productivity is achieved, usage will continue to grow rapidly.

Warning! There are two things to remember. First, it takes an investment of time as well as money to implement any degree of computer-aided design. Getting results takes training and familiarization. Secondly, we all need to remember that computers don't replace people. Computers cannot choose a good starting point for optimization, and they can't make very many decisions on practical component values and performance tradeoffs. Both of these factors remind us that the *engineer* is the single most important part of any design system — which is next month's subject.

Speaking of important engineers — don't miss the July issue, featuring the winners of our design and software contests!

RF design

a Cardiff publication — Established 1978

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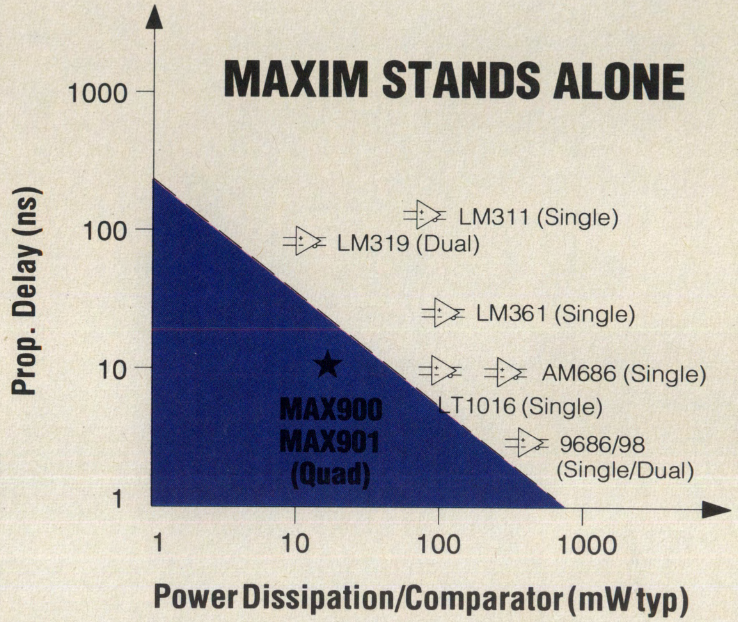

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MAX9687	2	ECL	1.4ns	Yes	DIP, SO	$5.12
MAX9690	1	ECL	1.3ns	No	DIP, SO	$3.29
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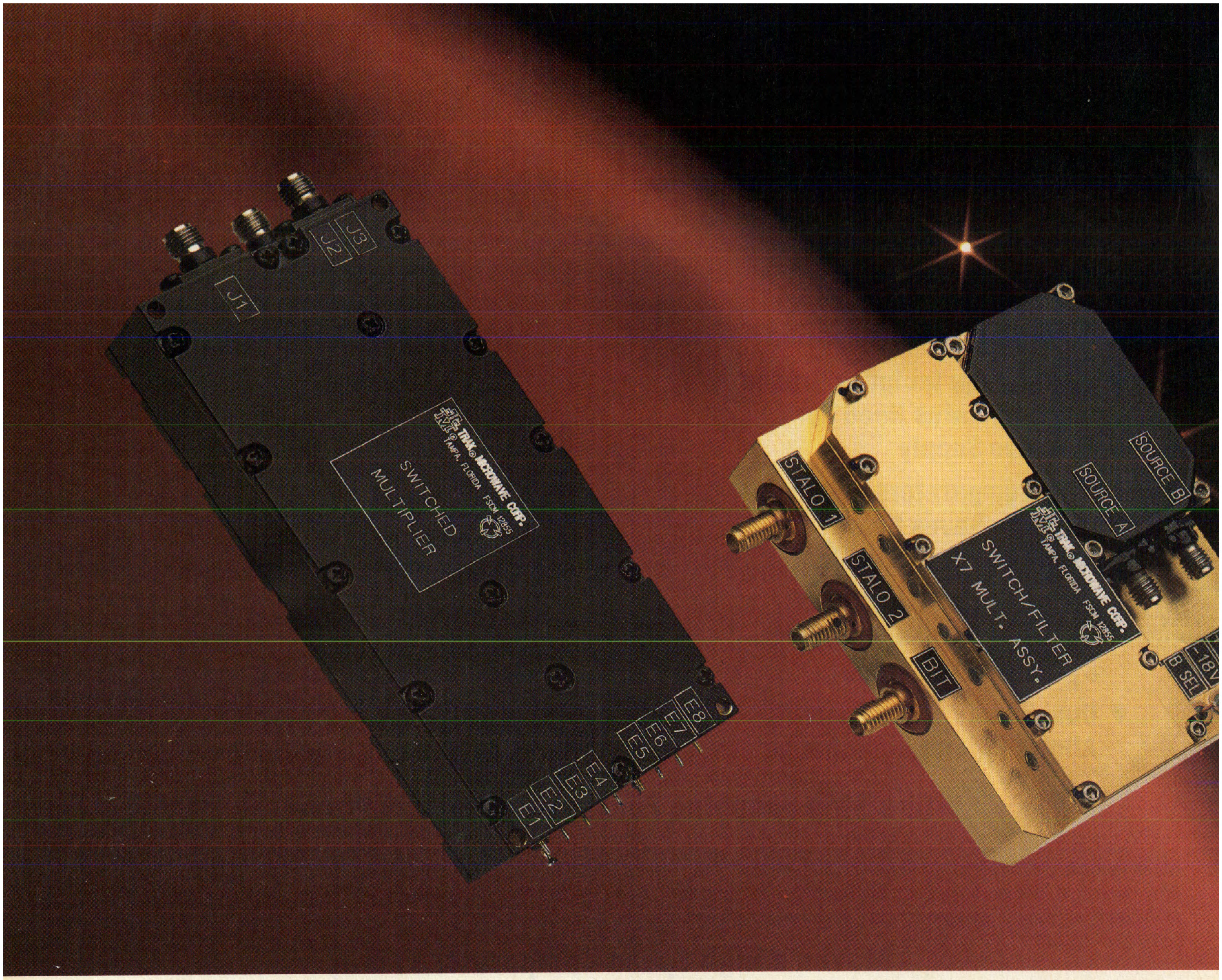

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INFO/CARD 9

RF letters

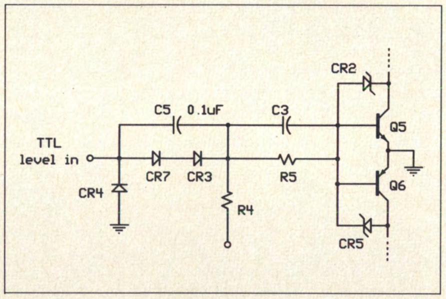
Letters should be addressed to: Editor, *RF Design,* 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111.

Quiet Switch Notes

Editor:

The article "A Lowband RF Quiet Switch" by Kevin Randall (July 1990) seems to solve many problems with low level RF switching. By putting a suitable resistor in series with the output to reduce power dissipation in the output transistor, the driver can be used to drive a diode switch. In trying the driver for such an application, I came across some difficulties which required minor modifications.

First, when the input is logic 0, i.e. 0.2 volts, transistor Q6 was not turning on due to insufficient base drive. This problem was overcome by putting another diode in series with CR3.



Modified input stage of the driver

Second, the ramp (or square if C4 is removed) output had a step discontinuity while passing through the ground state. This can be attributed to the fact that CR3 and new CR7 undergo a no-bias state. This problem was removed by putting a 0.1 uF capacitor in parallel with the CR3 and CR7. See the figure above for illustration of these modifications.

I would like to congratulate Mr. Randall for winning the RF Design Awards Contest and wish him well in the future.

Subrata Halder
Sameer, IIT Campus
Bombay, India

Crystal FM Transmitter Memories

Editor:

I recently discovered my misplaced February 1991 issue and read Mr. Xydis' interesting article, "A Novel, Wide Band Crystal Controlled FM Transmitter." He has done a nice job of implementing the circuit with inexpensive commercial ICs.

The article invoked memories of a similar, but much older circuit used in the AN/PRC-6 walkie-talkie. The audio and discriminator outputs were summed, driving a reactance modulator. The receiver is on while transmitting, keeping the transmitter 4.3 MHz (the intermediate frequency) above the receiver's crystal oscillator frequency.

Many thanks for producing an excellent and entertaining technical journal.

Ray Kaufman
Electronic Devices Inc.

PLL Feedback

Editor:

The "Parasitic Positive Feedback Frequency Acquisition in a PLL" by Dr. Cheah (April 1991 issue) is an interesting technique that actually is very old. It has been used in spectrum analyzer YIG PLLs for many years. The first use of it to my knowledge was in H-P's 8554L spectrum analyzer, introduced around 1969. It is an extremely clever technique and I have always wanted to know who invented it. *[Perhaps one of our readers can help — Editor.]*

Linley Gumm
Tektronix, Inc.

The Best Approach

Editor:

I'd like to add a comment to your editorial for the March 1991 issue ("A Balanced Approach"). You could have added that it's always a good idea to have more than one approach to solving any problem. It is especially useful when the two approaches are independent of one another, such as computer-aided versus black magic.

The area of RF design, where computer models of circuits can become highly complex, a crosscheck on the models' results using a proven rule of thumb can be an invaluable aid in troubleshooting. In today's intensely competitive world marketplace, you need as much help as possible to design systems that are reliable, accurate and economically manufacturable.

Paul P. Wollam
Oceanside, CA

Note: The 1991 contest winners will be featured in next month's issue of RF Design.

RF calendar

June

12-13 **Santa Clara Valley EMC '91: A Colloquium and Exhibition**
Santa Clara Convention Center, Santa Clara, CA
Information: Registration Chairman Ghery Pettit. Tel: (408) 285-2528.

23-26 **1991 IEEE International Communications Conference**
Denver, CO
Information: John Tary, Tri-State Generation. Tel: (303) 452-6111.

24-27 **Test Engineering Conference**
Georgia World Congress Center, Atlanta, GA
Information: Miller Freeman Expositions. Tel: (800) 223-7126 or (617) 232-3976.

25-27 **EMC Expo '91**
Walt Disney World Resort, Orlando, FL
Information: Ellen Lunsford, Registration. Tel: (703) 347-0030.

July

15-18 **Communication Networks West '91**
Moscone Center, San Francisco, CA
Information: Conference Sales, Tel: (800) 225-4698.

22-24 **Fifth International Conference on HF Radio: Systems and Techniques**
Edinburgh Conference Centre, Edinburgh UK
Information: Secretariat, Conference Services, IEE, Savoy Place, London WC2R OBL, UK. Tel: 071 240 1871 ext. 222.

August

13-15 **IEEE 1991 International Symposium on Electromagnetic Compatibility**
Cherry Hill, NJ
Information: IEEE International Symposium on EMC, PO Box 609, Lincroft, NJ 07738. Tel: (201) 386-2378.

18-21 **The 3rd International Symposium on Recent Advances in Microwave Technology**
Reno, NV
Information: Banmali Rawat, Chairman, Technical Program Committee, Electrical Engineering and Computer Science Department, University of Reno, Nevada, Reno, NV 89557-0030. Tel: (702) 784-6927. Fax: (702) 784-1300.

25-29 **Surface Mount International**
San Jose, CA
Information: Surface Mount International, 1050 Commonwealth Ave., Boston, MA 02215 or Miller Freeman Exhibitions, Tel: (800) 223-7126 or (617) 232-3976.

September

2-5 **Sixth International Conference on Digital Processing of Signals in Communications**
Loughborough, United Kingdom
Information: Secretariat, Conference Services, IEE, Savoy Place, London WC2R OBL, UK. Tel: 071 240 1871 ext. 222.

Numerical Techniques for RCS Computation and Scattering Center Approach to RCS Modeling
July 8-12, 1991, Monterey, CA
Information: Kelly Brown, SCEEE. Tel: (407) 892-6146.

Introduction to Modern Radar Technology
June 26-28, 1991, Washington, DC
Ionospheric Radio Propagation for System Planners
July 8-11, 1991, Washington, DC
Radio Frequency Spectrum Management
July 8-12, 1991, Washington, DC
Synchronization in Spread-Spectrum Systems
July 15-19, 1991, Washington, DC
Global Positioning System: Principles and Practice
August 12-14, 1991, Washington, DC
Grounding, Bonding, Shielding and Transient Protection
August 13-16, 1991, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Merril A. Ferber. Tel: (202) 994-8522 or (800) 424-9773.

New Broadcast Standards and Systems
July 21-26, 1991, Southampton, United Kingdom
Satellite Communication Systems
July 22-26, 1991, Guildford, United Kingdom
Electromagnetic Compatibility
September 15-20, 1991, Canterbury, United Kingdom
Microwave Measurements
September 22-27, 1991, Canterbury, United Kingdom
Information: The Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, UK.

Digital Signal Processing Workshop
July 16-18, 1991, Campbell, CA
September 11-13, 1991, Norwood, MA
Information: Analog Devices, DSP Applications Department, Maria Butler. Tel: (617) 461-3672.

Workshop for EMI Certificate Testing
June 19-20, 1991, Mariposa, CA
Seminar in EMI Software (EMCAD1)
August 21-22, 1991, Mariposa, CA
Seminar on the High Intensity Electromagnetic Radiated Fields (HIRF)
July 23-25, 1991, Mariposa, CA
Advanced HIRF Seminar for Commercial Flight Applications
September 24-26, 1991, Mariposa, CA
Information: CKC Laboratories, Registrar. Tel: (209) 966-5240. Fax: (209) 742-6133.

Understanding Data Communications and Computer Networks
June 24-25, 1991, Chicago, IL
Information: Quest. Tel: (908) 251-3217.

Libra/Academy
June 17-21, 1991, Baltimore, MD
June 17-21, 1991, Gilching, Germany
Information: EEsof. Tel: (818) 991-7530. Fax: (818) 991-7109.

Fiber Optical Communication Technology and Systems
August 26-30, 1991, Switzerland
Combined Digital Coding and Modulation Techniques
October 14-18, 1991, Spain
Modern Digital Modulation Techniques
October 14-18, 1991, Spain
Broadband Telecommunications
October 14-18, 1991, Spain
Information: CEI-Europe/Elsevier, Mrs. Tina Persson, Box 910, S-612 01 Finspong, Sweden. Tel: 46 (0) 122-17570. Fax: 46 (0) 122-14347.

Modern Power Conversion Design Techniques
July 15-19, 1991, Chicago, IL
Information: e/j Bloom Associates, Joy Bloom. Tel: (415) 492-8443. Fax: (415) 492-1239.

Electromagnetic Propagation
August 20-22, 1991, Syracuse, NY
ELINT Analysis
September 10-12, 1991, Syracuse, NY
ELINT Interception
September 17-19, 1991, Syracuse, NY
ELINT/EW Applications of Digital Signal Processing
September 17-19, 1991, Syracuse, NY
Integrated EW
September 24-25, 1991, Syracuse, NY
ELINT/EW Data Bases
September 24-26, 1991, Syracuse, NY
Information: Research Associates of Syracuse. Tel: (315) 455-7157.

Basic Network Measurements Using the 8510B Network Analyzer
June 18-20, 1991, Atlanta, GA
June 25-27, 1991, Los Angeles, CA
June 26-28, 1991, Boston, MA
July 29-31, 1991, Los Angeles, CA
July 29-31, 1991, Boston, MA
August 5-7, 1991, San Francisco, CA
Microwave Fundamentals
July 15-18, 1991, Los Angeles, CA
September 16-19, 1991, Los Angeles, CA
Designing for EMC
July 11-12, 1991, Atlanta, GA
August 22-23, 1991, New York, NY
September 24-25, 1991, Washington, DC
Information: Hewlett-Packard Company. Tel: (714) 999-6700.

Introduction to Telecommunications
June 25-28, 1991, Washington, DC
July 16-19, 1991 Los Angeles, CA
Digital Signal Processing: Techniques & Applications
June 18-21, 1991, Washington, DC
July 9-12, 1991, Boston, MA
Information: Learning Tree International. Tel: (800) 421-8166, (703) 893-3555, (203) 417-8888.

Introduction to EMI/RFI/EMC
June 24-25, 28, 1991, Orlando, FL
Grounding and Shielding
June 24, 27, 28, 1991, Orlando, FL
System Integration and Design for EMC
June 24, 25, 28, 1991, Orlando, FL
Information: Interference Control Technologies, Registrar. Tel: (703) 347-0030.

US West Opens Research Center

US West recently opened a new $42 million research and development center in Boulder, Colorado. The facility will house US West Advanced Technologies, the research and development arm of US West. The division's 600 employees work primarily in the information processing and telecommunications fields, developing and engineering new products, services and systems for US West's domestic and international subsidiaries and their customers.

Electromagnetics Bibliographies Available — NIST has issued two new bibliographies which list all publications (1970 to July 1990) by staff in two NIST divisions. *A Bibliography of the NIST Electromagnetic Fields Division Publications* (NISTIR 3945) and *Metrology for Electromagnetic Technology: A Bibliography of NIST Publications* (NISTIR 3946) are available from the National Technical Information Service, Springfield, VA 22161. Order NISTIR 3945 by PB #91-132241 for $23 prepaid and NISTIR 3946 by PB #91-132266 for $17 prepaid.

Beryllium Oxide Removed From Hazardous Materials List — The Defense Electronics Supply Center has issued a new statement concerning the health and safety effects of beryllium oxide ceramic substrates used in electronics packaging. Earlier, the agency had included beryllia on its hazardous materials list and suggested that alternate materials be developed for electronics applications. Its recent announcement states that "hazards occur only when the inhalation of fine airborne BeO dust particles are encountered during the basic manufacturing process, and not during the use of a finished electronic device." The agency's most recent statement concludes that, "BeO has been recognized as a completely safe product when handled in a solid beryllia ceramic form."

Bell Atlantic Adds Mobile Wireless Technology Lab — Bell Atlantic recently added a mobile unit to its Wireless Technology Laboratory. The van will be able to extend the lab's activities into the field. It is outfitted with a pneumatic mast for positioning antennas at heights up to 20 feet and will eventually have a complete array of test equipment including two computers for controlling test equipment and gathering and analyzing data, a spectrum analyzer, a synthesizer, and a vehicle position locating system using GPSS and/or LORAN technology to pinpoint the van's location. At present, it has two equipment racks, an operator position in front of each rack, and three cellular phones. The van's primary role will be research into advanced cellular and other wireless technologies.

IBC Call for Papers — The fourteenth International Broadcasting Convention, to be held July 3-7, 1992 in Amsterdam has issued a call for papers. Some of the topics to be covered are: advanced compatible and HDTV systems; analog and digital signal origination; analog and

digital audio and video recording; studio and network distribution; terrestrial transmission and reception; satellite systems, point-to-point and DBS; receiver and display technology and test and measurement technology. A summary of approximately 800 words is due by November 11, 1991. Mail summaries to Secretary, IBC Technical Programme Committee, IBC Convention Office, IEE, Savoy Place, London WC2R 0BL, United Kingdom.

ATE & Instrumentation Issues a Call for Papers — The ATE & Instrumentation Conference has announced a call for papers for its exhibition and conference, January 13-16, 1992, at the Disneyland Hotel in Anaheim, California. Individuals are invited to submit original, unpublished papers on any test related topic pertaining to the commercial, military, and aerospace environments. For information on presenting a paper contact Carol Hurely, Director of Technical Programs, Miller Freeman Expositions, 1050 Commonwealth Avenue, Boston, MA 02215-1135. Tel: (617) 232-3976. Fax: (617) 232-0854.

QuadTech Acquires GenRad Precision Instrument Line — QuadTech, a recently formed company, has announced the acquisition of the Precision Instrument Product Line from GenRad, Inc. The new company will assume all products, patents, manufacturing technologies, inventory and sales in process associated with the GenRad Instruments product line. QuadTech has leased approximately 35,000 square feet where it will move after completing modifications. In addition to acquiring the products, patents, and inventories of the product line, QuadTech has assumed outstanding product warranties and support agreements.

Pascall Subsidiary Formed — Pascall Electronics Limited has announced the formation of Pascall Microwave Limited. The company was established to develop a range of RF solid state power amplifiers in the 1 GHz to 20 GHz range. Pascall Microwave will manufacture and sell solid state power amplifiers and amplifier sub-systems to the professional and military sectors, with particular emphasis on the requirements of satellite earth stations. The company's address is Pascall Microwave Limited, Saxon House, Downside, Sunbury-on-Thames, Middlesex, TW16 6RY, England. Tel: (44) 081-979-0123.

HK Microwave Acquired by Dynatech — Dynatech Corporation recently announced the acquisition of HK Microwave, Inc., a privately-owned designer and manufacturer of microwave sources for the microwave and telecommunications industry. Terms of the deal were not disclosed.

Eaton Sells RF Power Amplifier Product Line — Eaton Corporation's Electronic Instrument Division has sold its laboratory RF power amplifier product line to American Microwave Technology. Terms of the acquisition were not revealed.

Antenna Company Established — Decibel Products has established Decibel Mobilcom Ltd. Mobilcom Ltd. will sell and service base antennas and systems equipment in the 30 to 2000 MHz range, including cellular and PCN frequencies. Their address is Decibel Mobilcom Ltd., Sandy Farms, Sands Road, Surrey, GU10 1PX, England. Tel: (44) 2518-3455.

Intepro and Instrument Division of Schaffner to Merge — Schaffner Instruments and Intepro Systems recently announced that they will merge. The range of systems and instruments coming from this combination will have Front Panel as well as GPIB-IEEE 488 programmability, VXI control and a Microsoft Windows 3.0 test Programming and Graphical User Interface. The Component Division of Schaffner EMC is unaffected by the merger. Existing Schaffner and Intepro sales and technical support engineers will remain unchanged, and coverage will be expanded in key territories with additional applications engineers.

Ball Corporation to Supply Airlink™ Antennas — Ball Corporation recently received an order from Saudi Arabian Airlines to supply the Airlink antenna system to 11 of its Boeing 747 aircraft. The contract will involve Ball's high-gain and low-gain antenna systems and will include training, service and installation assistance. The antenna will provide digital communications for aircraft crews and enable them to communicate, via satellite, virtually anywhere in the world.

Rebuilding Kuwait's Communications Infrastructure — Micro Communications Inc and Thomson-CSF have both received contracts for the rebuilding of communications systems in Kuwait due to damage sustained in the Gulf War. Micro Communications received a $3 million contract to design, supply and set-up an emergency FM-AM radio station, a Rapid Deployable Dual Channel TV Station and a Super Power TV transmitter, Antenna and tower that will serve as Kuwait's new TV station. Thomson-CSF has signed a contract to supply an emergency mobile television system to enable Kuwait television to produce and broadcast programs as soon as possible. The contract includes the supply of an outside broadcast van, a transportable TV studio, a 5 kW power transmitter and microwave links.

Thomson-CSF Wins Air Traffic Control Contract — Thomson-CSF has been awarded a contract for the upgrading and extension of the air traffic control system of the Yucatan peninsula. An approach control system, consisting of a radar station equipped with a primary radar TA 10 MTD, associated to a monopulse secondary radar RSM 970, and a control center AIRCAT 200, will be installed at the Cancun International Airport. The en-route control center of Merida will be equipped with a radar processing system associating the data originating from the stations located in Cancun, Merida and Veracruz.

HP Receives Order for Test Equipment — Hewlett-Packard recently announced that it has received a $10.5

million order to furnish its modular measurement system test equipment to General Electric Company. The HP test equipment will be used by GE in its first production series of the U.S. Navy Consolidated Automated Support System (CASS). CASS includes modular measurement system equipment from HP and other vendors, such as spectrum analyzers, network analyzers, spread-spectrum modulators, signal generators, synthesizers and power meters.

Motorola Bidding on Canadian Military Cellular System — According to a report in the March 25 edition of *Electronic News,* Motorola recently bid on a military version of its cellular radio terminal and base station network for the Canadian Iris battlefield communications net. This is one of Motorola's first attempts at entering the military cellular market. Motorola is competing against Racal for the cellular radio, called Single Channel Radio Access terminals. Should they be awarded the contract, more than 300 terminals would be bought, with much of the equipment being built in Canada.

Harris Wins Contract for HF Radio Systems — Harris RF Communications has received multiple contracts from the Southwest Power Pool members to provide automated HF radio systems for emergency backup communications for power control centers and other utility sites, within the utilities area. The network will employ a variety of base station, mobile and ruggedized transportable radios for installation at more than 50 sites throughout the south central United States region.

Motorola and Unitrode Announce Joint Venture — Motorola's Semiconductor Products Sector and Unitrode Corporation have announced a technology partnership agreement to jointly develop a proprietary technique to be used in the manufacture of direct wafer bonded silicon wafers. Direct wafer bonding significantly reduces the material cost for high voltage devices by eliminating the thick epi layer. Bonded wafer technology also improves device performance and increases design flexibility, speed and packing density for bipolar devices.

Watkins-Johnson Wins Receiver Contract — Watkins-Johnson Company has been awarded a $3 million contract by ESL, Inc., a subsidiary of TRW. The contract calls for delivery of WJ-8604 Miniceptor VHF/UHF Receivers for upgrading an existing major Department of Defense program.

AEL Awarded Navy Contract — AEL Defense Corporation has been awarded a $9.2 million contract for the production of Type-18 Periscope Mounted Automatic Direction Finding systems. The system includes such equipment as antenna subsystems, radio frequency receiving devices, a digital processor and a display. Delivery of the first full production system is scheduled for July, 1992, with production continuing until July, 1995.

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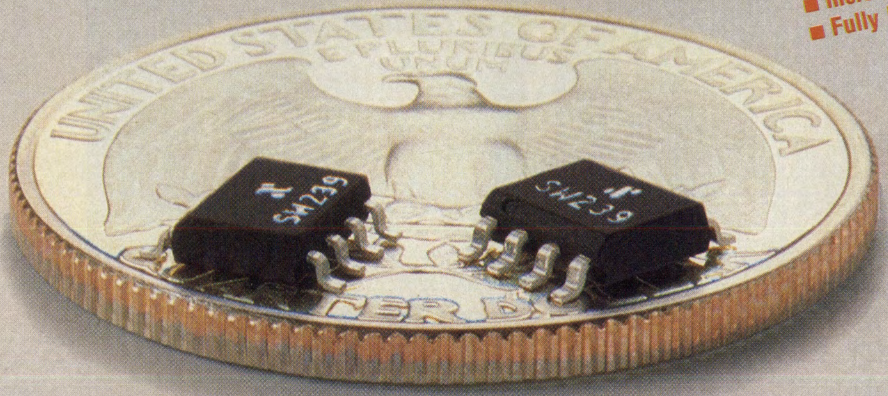

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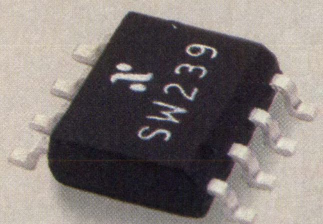

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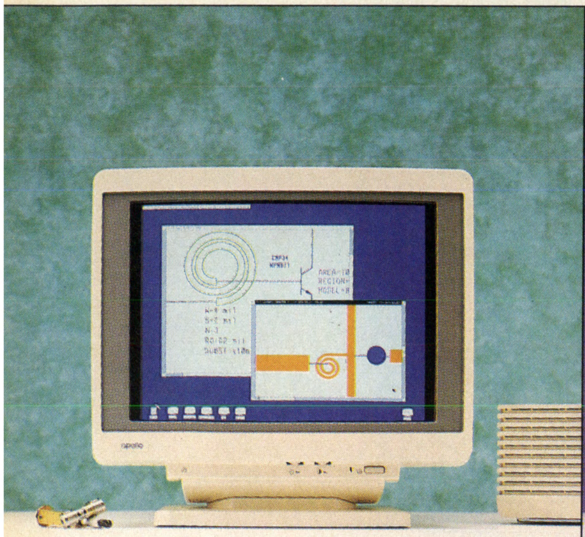
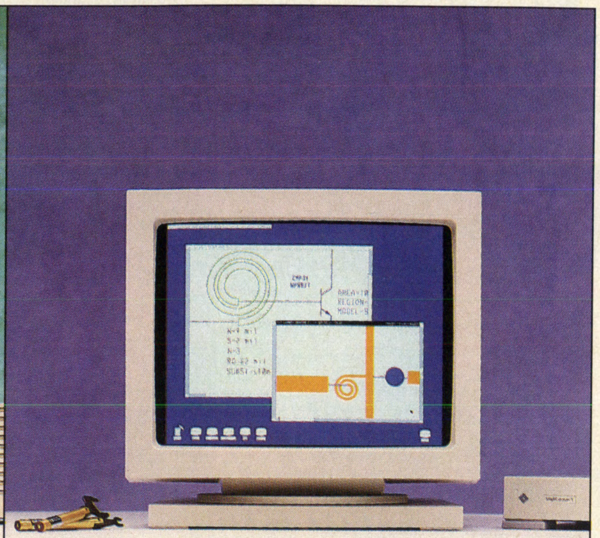
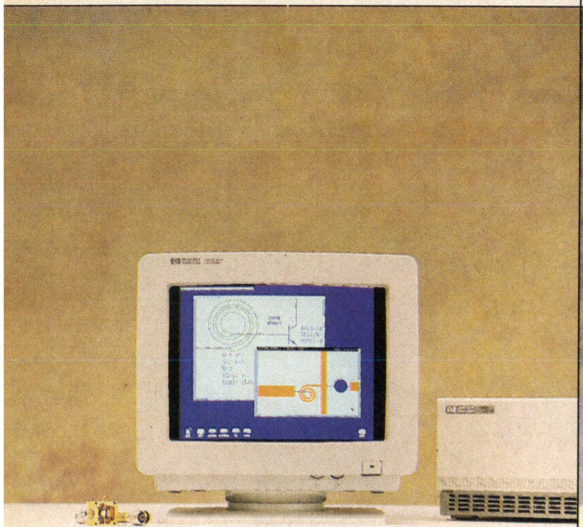


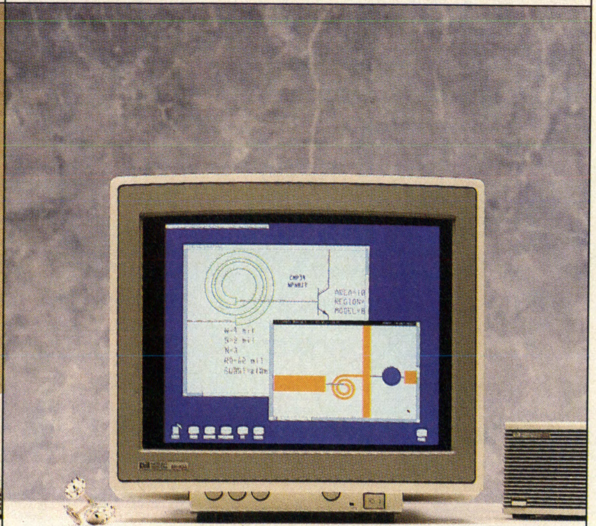
HP high-frequency CAE runs on Apollo.



HP high-frequency CAE runs on Sun.



HP high-frequency CAE runs on 386 PCs.



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Please see us at the MTT-S Show, Booth #730.

Embedded Intelligence Adds Power to RF Products

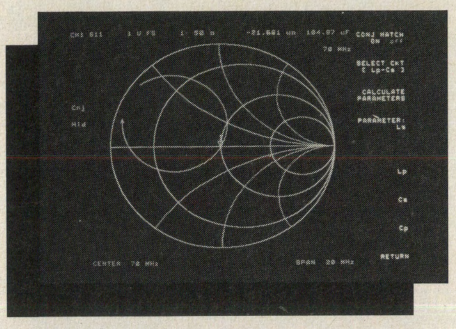
By Gary A. Breed
Editor

Recent issues of *RF Design* have included articles on new instruments capabilities, spread spectrum systems, a microprocessor-controlled antenna tuner, and the VXIbus for instrument control. If you add digital communications to the list, these topics have easily been the leading areas of interest for RF engineers over the past two years. Computing functions have become standard in many RF systems.

The process began when analog control functions and many manual adjustments were implemented digitally, using either discrete digital ICs or microprocessor controllers. In a receiver, for example, AGC parameters and IF bandwidths could be programmed for the various operating modes. Frequency synthesizer data, frequency displays, and frequency/mode memories were made programmable. Monitoring functions in both receivers and transmitters were implemented in controllers programmed to respond to overloads, high VSWR, temperature sensors and current monitors. Now, virtually every piece of commercial and military radio equipment has a microprocessor inside.

One of the most common places to find computing power is in instrumentation. Again, control is the first application. The development of the GPIB/IEEE-488 interface was required when instrument manufacturers implemented digital control in addition to manual operation. More recently, the VXIbus has been developed for modular instruments, principally through the efforts of Racal-Dana and Hewlett-Packard.

Recent applications often include real-time computing. In instrumentation, we have IF or baseband analog-to-digital conversion and digital signal processing (DSP). "With IFs becoming increasingly digital, new instruments can benefit from the power of digital signal processing," says Hewlett-Packard's Manfred Bartz in his article "New Trends in Analyzer Technology Provide Faster Measurements for Narrowband Applications." Fast Fourier Transforms allow precision narrowband analysis that was,



until recently, nearly impossible. Other processing functions include comparisons with stored waveforms, error correction, self-calibration, and conversion of measurements into mathematical models for further analysis. Every major instrument manufacturer is now incorporating computing power for control and analysis in their products.

The "digital radio" has become a reality. Related to computation and DSP is analog-to-digital conversion. High-speed digitization (usually after preamplification and bandpass filtering) allows an RF signal to be digitally filtered, manipulated, and demodulated. In applications like radar, sonar, or synchronized communications where the baseband or IF signal requires analysis, the ability to digitize with the fewest intermediate levels of signal processing improves performance. For several years, VLF and ELF communications equipment has used front-end digitization and digital signal processing to recover data from signals that are often below the ambient noise level.

The communication of digital information is the fastest growing RF application area, often requiring on-board intelligence. Encoding and decoding data for spread spectrum transmission and reception is one unique requirement. Error detection and message buffering are other jobs requiring digital and RF circuitry in tandem. Data-over-voice, packet data systems, and other unique applications require management of timing, message queuing, and communications protocols.

Impact on RF Engineering

The engineering requirements for systems which include complex RF and digital components are placing new demands on RF and digital engineers alike. First, for control systems the difficulties are really quite small, since the requirements for control of RF functions are well defined. For digital signal processing, some special engineering skills are needed. The RF/analog functions that must be carried out have to be translated into digital algorithms. If the processing function is accurately defined by the RF specialist and the digital algorithm correctly developed, a digital specialist can complete the job of programming the DSP circuitry.

Unique problems occur in digital transmission systems, which require a new combination of engineering skills. The digital and analog processes are not independent. Variations in phase and amplitude in the analog signal path have significant effects on the integrity of the digital signal, so the RF engineer has to the effects of group delay in filters, linearity in amplifiers, mixers and modulators, and characteristics of the transmission path. The digital engineer also has to understand these same effects, especially the limits on system performance. Then, he may be able to implement error-detection and correction schemes to minimize transmission problems.

Quite a few years ago, business and social analysts proclaimed that the "information age" had arrived. What they observed was only the tiniest tip of the iceberg. It may seem paradoxical, but information — in digital form — and its communication from one place to another, is becoming the biggest user of RF technology. ***RF***

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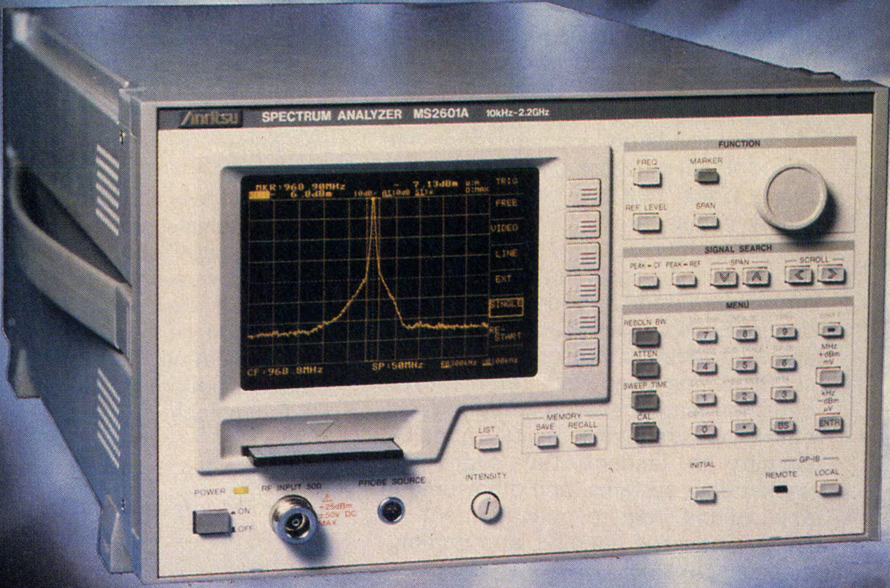

INFO/CARD 23

Please see us at the MTT-S Show, Booth #333.

A Lab Frequency Standard Distribution System

By Mitchell Lee
Linear Technology

A stable frequency source is a useful tool, but its cost prevents every bench in the lab from being so equipped. The lab frequency standard usually occupies its own bench and the designer is expected to take his work there — which is often inconvenient. And if someone else is already using the standard, projects can be stalled while waiting in line. The lab frequency standard could be more efficiently utilized if some means of signal distribution were available.

Single-chip RS-485 bus transceivers provide an answer to this dilemma. Intended for data transmission over a twisted pair, RS-485 interface chips can just as easily send a reference signal via the same, inexpensive medium. Figure 1 shows a simple system devised to pipe the 1 MHz output of a frequency standard around the lab using the LTC485 differential bus transceiver. The input is TTL compatible, but is shown pre-biased and AC coupled to accommodate signals as small as 300 mV_{RMS}. The receiver in this chip is enabled and used locally as a buffered output. The transmitter drives up to 1000 feet of shielded, twisted pair. Greater lengths can be driven at lower frequencies; just be sure to keep the line loss to 10 dB or less.

Receivers are tapped into the otherwise continuous twisted pair, and the end of the pair is terminated in its characteristic impedance. Since the input resistance of each receiver is roughly 40 kohms, up to 100 receivers could be connected to the twisted pair without seriously affecting the termination. The receiver circuit requires no external components except for a 10 nF supply bypass. With a CMOS load, a receiver will consume about 1.1 mA on a 5 V supply while switching at 1 MHz. The receivers are powered locally, yet they will not disturb the twisted pair when turned off. The input stage will present the same high impedance to the line regardless of whether or not power is applied.

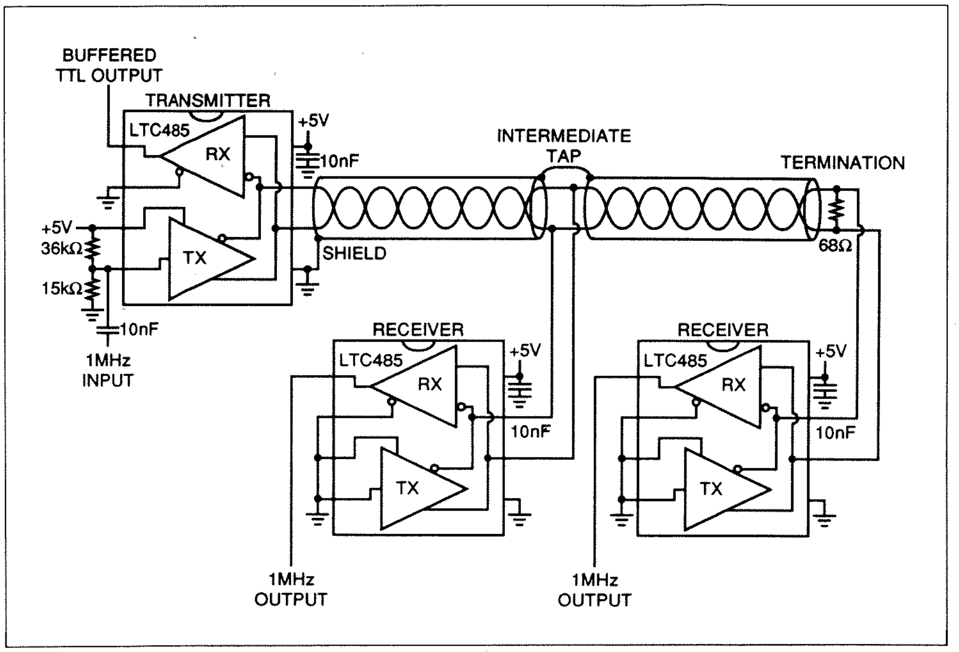

Figure 1. Standard frequency distribution system on shielded twisted pair.

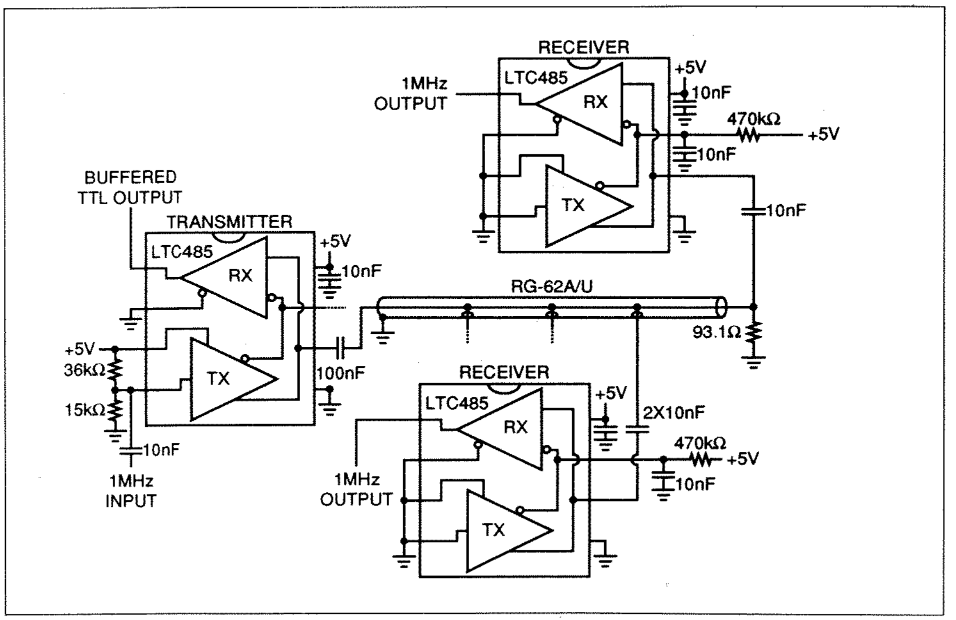

Figure 2. Standard frequency distribution system on coaxial cable.

Although shielded twisted pair (such as Belden #9841) is recommended, an unshielded pair will work just as well. The disadvantage is that the wire will inevitably radiate some energy — often a socially unacceptable move in an RF lab!

The LTC485 can also drive 50-, 75-, or 93 ohm coax (Figure 2). Since coaxial cable is single ended, the transmitter can drive two cables simultaneously. The cables are each terminated in their characteristic impedance, and the signal is AC-coupled in and out of the cable. The common mode range of the LTC485 extends from −7V to +12V, so the signal input is simply AC-coupled at ground potential. A small bias current is provided by the 470 kohm resistor to null a 200 nV offset built into the LTC485.

It is important to properly terminate the cable to preserve waveshape. Characteristic impedance is specified for RS-485 cables (120 ohms), but if a surplus spool of twisted pair is pressed into service its impedance will be unknown. The correct termination can be found by trial and error, by simply monitoring the transmitted waveshape at the driver's output as the termination resistance is varied.

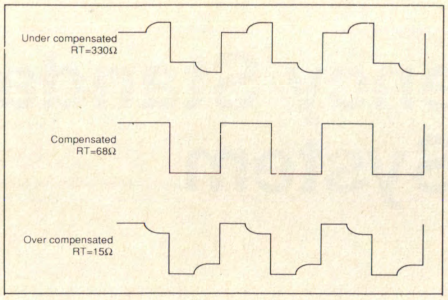

Figure 3. Effect of termination on transmitter output.

To find the right termination for 'unknown' cables, connect the cable to the driver (leave the far end open). Transmit a square wave of frequency = c/10L, where $c = 3 \times 10^8$ and L = length of cable in feet. Use an oscilloscope to monitor the waveform at one of the driver's outputs. The result should look something like the under compensated case in Figure 3. Now attach a resistor substitution box to the far end of the cable and vary the termination until a relatively flat square wave is observed at the transmitter's output. If the termination resistor value is reduced too far, the third (over compensated) waveform results. Most twisted pairs will exhibit an impedance of between 50 and 200 ohms. A termination of 68 to 75 ohms gave good results with the shielded PVC cable tested by the author.

The pulse width jitter introduced by the LTC485 is less than 0.005 percent (25 ps) from transmitter input to receiver output. In practice the jitter may reach 0.01 percent owing to mechanical disturbances along the length of the cable, or noise on the LTC485's power supply.

With this simple system, your lab can have a high precision reference frequency available at each bench. High-speed digital ICs make the system easy to construct, low cost, and reliable. *RF*

About the Author

Mitchell Lee is an Applications Engineer at Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035-7487. Tel: (408) 954-8400.

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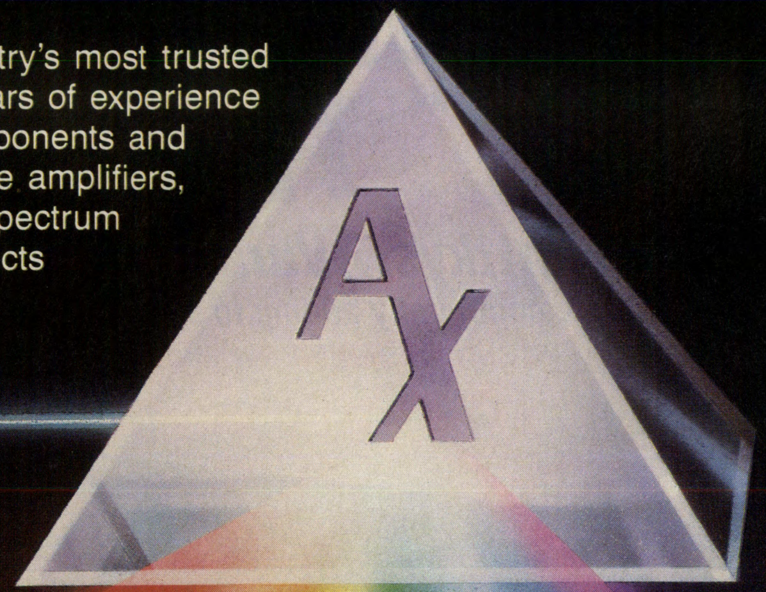

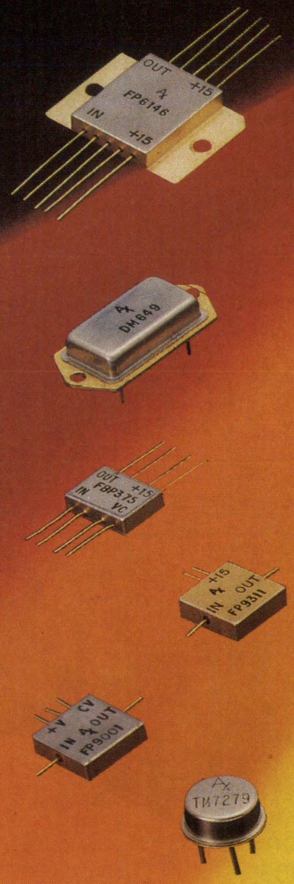

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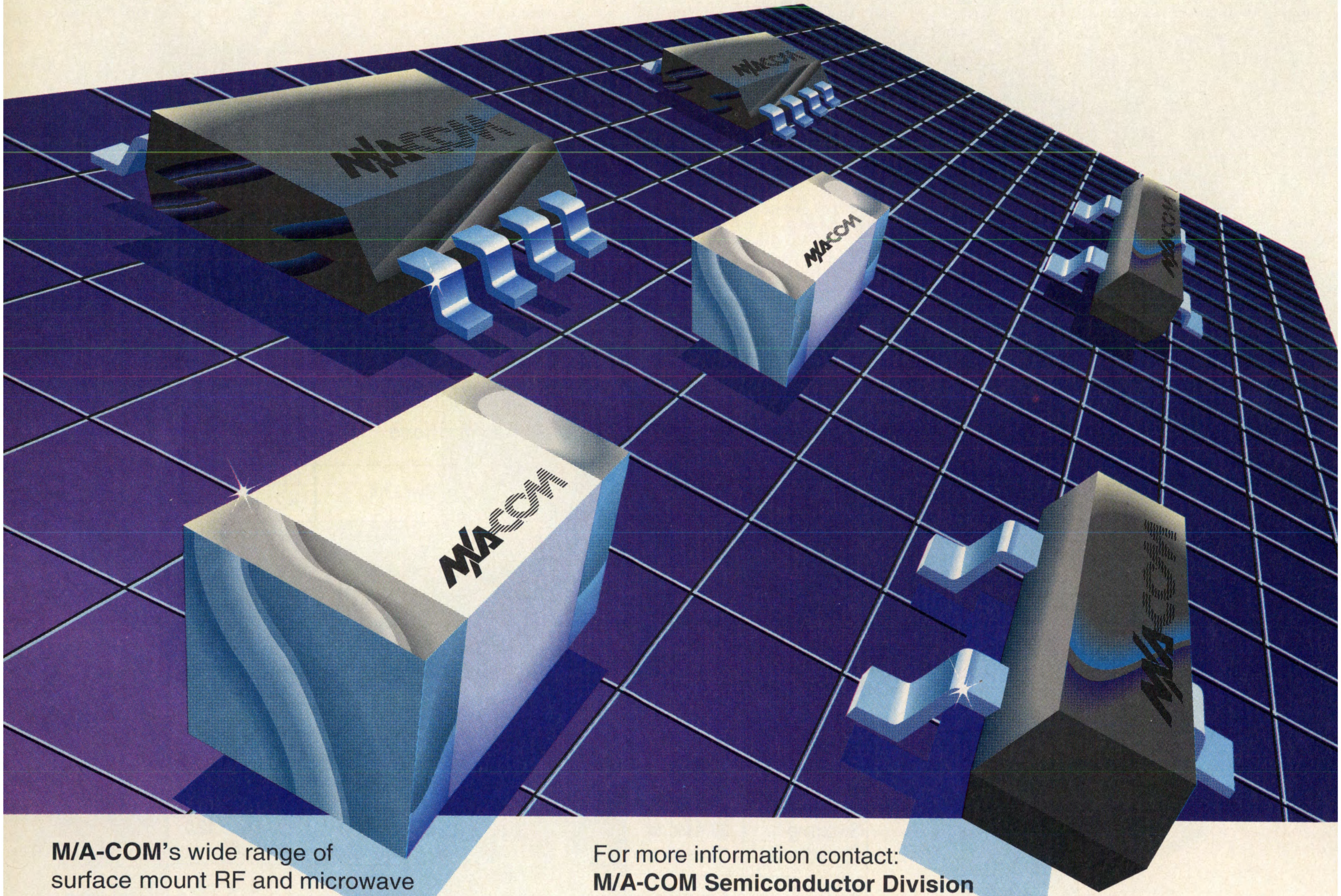

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INFO/CARD 26

Frequency Modulation in a Phase Lock Loop by Control of the Phase Inside the Loop

By Scott Grimmett
Hewlett-Packard Company

The 8920A test set requires a low cost single loop synthesizer as the RF signal generator. The signal generator needs synthesized frequency in 10 Hz steps from 500 to 1000 MHz with low noise and good FM performance on only 30 square inches of PC board area. This paper will focus on the techniques used for obtaining the FM performance for the 8920A signal generator. The FM performance of the generator provides distortion of less than 1 percent, an FM bandwidth of DC to 75 KHz, and deviation of 100 KHz.

Figure 1 shows a simple block diagram of a phase lock loop. The loop includes a phase detector, loop filter, voltage controlled oscillator (VCO) and a divider. Also included is a phase modulator and summing port for adding modulation into the loop.

The general transfer function of the loop is

$$\frac{\theta_o}{\theta_i} = \frac{K_d F(s) K_v}{s + \frac{K_d F(s) K_v}{N}} \qquad (1)$$

The response of the loop output frequency due to a voltage at the modulation inputs will be considered. The transfer function for frequency deviation of the output due to a voltage at the V_{fmod} input is

$$\frac{\omega_o}{V_{fmod}} = \frac{s K_v}{s + \frac{K_d F(s) K_v}{N}} \qquad (2)$$

With F(s)=1 the transfer function in equation 2 has the high pass response shown in Figure 2.

The phase lock loop frequency response characteristic shown in Figure 2 allows frequency modulation of the output frequency at rates greater than the loop bandwidth when a modulation voltage is applied at the V_{fmod} input. To provide for frequency modulation at rates inside the loop bandwidth the V_{pmod} modulation input will be examined. The transfer function in equation 3 is the phase deviation of the loop output when a modulation voltage is applied to the V_{pmod} input.

$$\frac{\theta_o}{V_{pmod}} = \frac{K_d F(s) K_v}{s + \frac{K_d F(s) K_v}{N}} \qquad (3)$$

When F(s)=1 the transfer function has the low pass response shown in Figure 3.

The low pass nature allows the loop to be phase modulated at rates inside the loop BW. This low pass phase response will be utilized to obtain frequency modulation inside the low BW. Since phase is the integral of frequency, adding the integrator K_i/s shown in Figure 4 prior to the V_{pmod} input effectively converts the in-band modulation path from a phase modulation port to a frequency modulation port. The result is frequency modulation at rates inside the loop BW.

Equation 4 shows the relationship between frequency and phase. Equation 5 shows the conversion of the in-band phase modulation path to a frequency modulation path by addition of the integrator.

$$\omega_o = s\theta_o \qquad (4)$$

$$\frac{\omega_o}{V_{mod}} = \frac{K_i}{s}\frac{s\theta_o}{V_{pmod}} = \frac{K_i K_d F(s) K_v}{s + \frac{K_d F(s) K_v}{N}} \qquad (5)$$

Frequency modulation is obtained for modulation rates inside and outside the loop bandwidth by applying the modulation signal to both the V_{fmod} and V_{mod} inputs. To obtain flat frequency deviation at rates inside and outside the loop bandwidth each modulation path must be scaled to provide equal FM gain when the modulation signal is input. However, for simplicity let's only scale the in-band FM path by setting $K_i = K_v/N$. Adding the frequency deviation transfer functions due to the V_{fmod} and V_{mod} input in equations 2 and 5 and scaling K_i gives the following results.

$$\frac{\omega_o}{V_{fmod}} + \frac{\omega_o}{V_{mod}} = \frac{s K_v}{s + \frac{K_d F(s) K_v}{N}} + \frac{K_v/N \; K_d F(s) K_v}{s + \frac{K_d F(s) K_v}{N}}$$

$$= K_v \frac{s + \frac{K_d F(s) K_v}{N}}{s + \frac{K_d F(s) K_v}{N}}$$

$$= K_v \qquad (6)$$

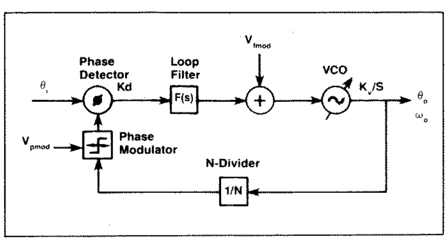

Figure 1. Phase lock loop block diagram with modulation inputs.

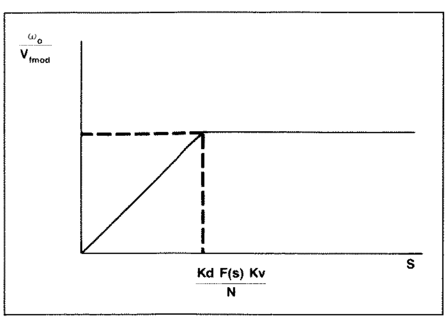

Figure 2. Frequency deviation response at loop output due to a modulation signal at the V_{fmod} input.

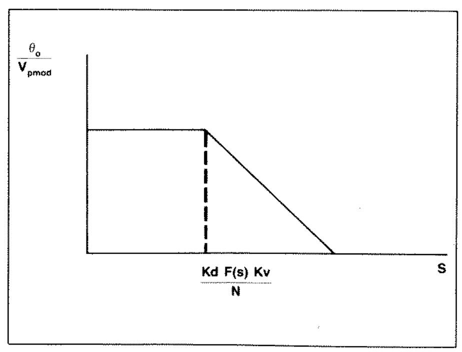

Figure 3. Phase deviation response of loop output due to a modulation signal at V_{pmod}.

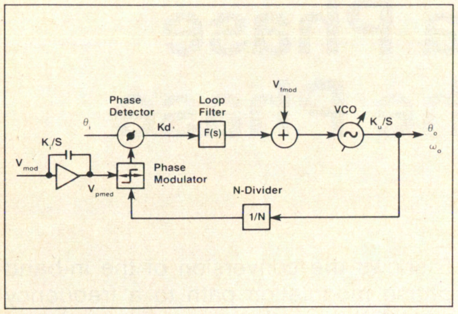

Figure 4. Phase lock loop with integrator added to phase modulator path.

The mathematical result is flat frequency modulation dependent only on K_v for modulation rates both inside and outside the loop bandwidth with no modification to the loop bandwidth. Further, scaling can be done for K_v to set the FM gain at any desired level. It is important to note that the loop can be modulated at rates down to DC with this method. Additionally, the F(s) block is canceled and does not affect the frequency modulation.

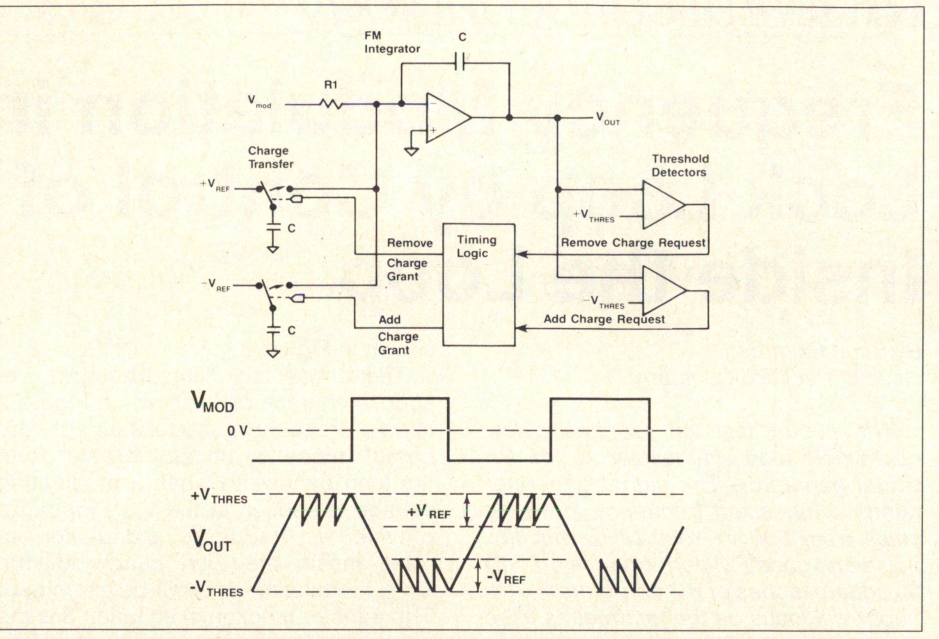

Figure 5. FM integrator reset circuit.

Realization of the FM Circuitry

The circuitry for the out of band FM (V_{fmod}) path is relatively easy to realize by simply capacitively summing the modulation signal onto the VCO tune line. This allows the loop to be frequency modulated at rates outside the loop bandwidth.

Unfortunately, there are limitations that must be overcome to implement frequency modulation through the in-band FM (V_{mod}) path. The biggest being the FM integrator. The output of an ideal integrator would slew up or down without bounds when a DC voltage is applied to the input. In reality the output of an integrator will slew up or down until the integrator power supply rail is reached. For this reason it is not practical to build an ideal integrator. If an integrator could be made to have very large output voltage bounds, any circuitry following the integrator would also have to handle the large voltages from the integrator output. A method used to overcome this limitation is to reset the integrator at some point before the rail is reached and transfer the phase information lost by resetting into the loop through the N-divider.

A description of how the integrator is reset follows. Figure 5 shows the circuit used to reset the integrator. A negative voltage applied to the integrator input causes the output of the integrator to ramp up. Once the integrator output crosses the threshold of the positive detector, the comparator output is activated. The active output causes the timing logic to switch the phase transfer capacitor from the charging voltage (V_{ref}) to the integrator input. The positively charged capacitor removes a fixed amount of charge from the integrator. The result is a fixed voltage removed from the integrator output before the rail is reached. Both positive and negative threshold detectors and charge transfer capacitors are provided thus allowing the integrator to be reset when either a positive or negative voltage is applied at the input. An example of the integrator output with a square wave input is shown in Figure 5.

Resetting the integrator as just described solves the problem of reaching the integrator rails; however, the phase information lost during the reset must be added back into the loop. The N-divider is an important part in adding the phase information into the loop.

The divider in the loop is made up of a custom fractional N IC and a 32/33 prescaler. The dashed box in Figure 6 shows the loop N divider. The IC controls the divide modulus of the prescaler to set the effective divide number (N) of the loop. The IC takes the place of the timing logic in Figure 5. Control of the charge request inputs on the IC is done by the FM threshold detectors. When either the remove charge request or add charge request line is activated by the detectors, the IC removes a VCO cycle or adds a VCO cycle, respectively. In the next reference cycle after the request has occurred, the divider will remove or add the VCO cycle. During the same reference cycle, the IC activates the corresponding remove charge grant or add charge grant line to transfer the necessary charge at the FM integrator. Removing a VCO cycle causes the effective N to change to N+1 and adding a VCO cycle changes N to N-1 for one reference period.

Figure 6 shows the combination of the integrator reset hardware and the divider. An example of how this circuit operates is described. A negative voltage applied to the integrator causes the

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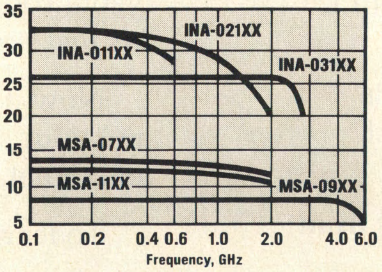

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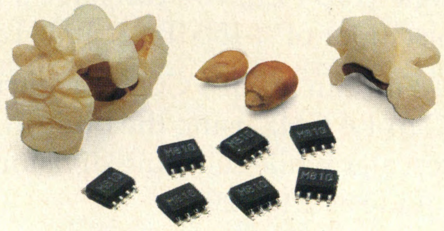

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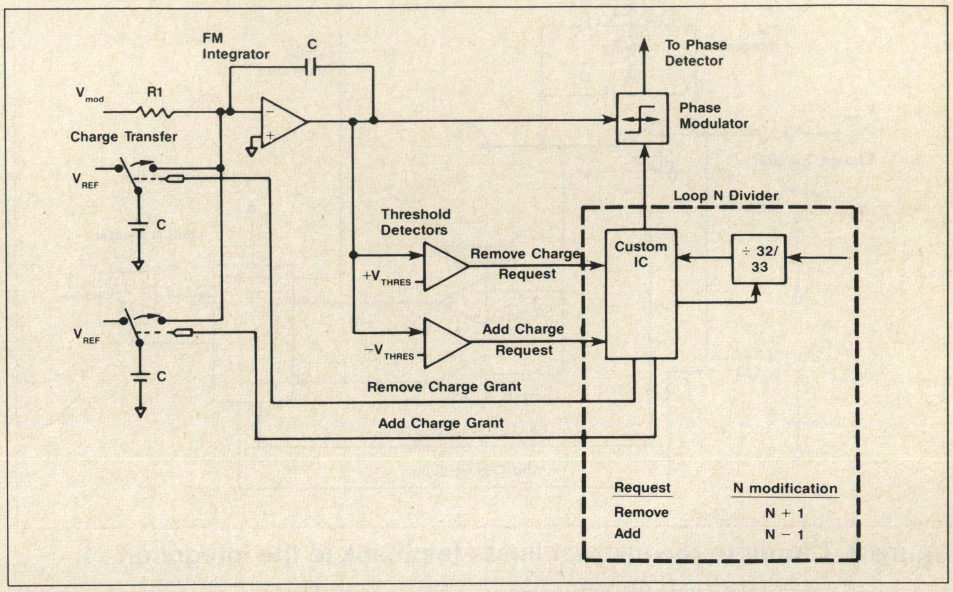

Figure 6. Phase lock loop with integrator reset circuit.

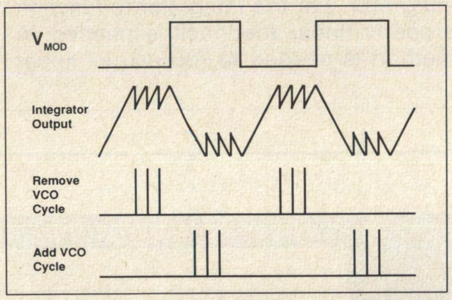

Figure 7. Relationship between integrator resetting and VCO cycle addition and removal.

integrator to ramp upward. Once the upper threshold is crossed, the positive detector triggers the remove charge request line. On the next reference cycle the divider IC modifies the N number by N +1 thus removing one VCO cycle from the loop. During the same reference cycle the remove charge grant line switches the charge transfer capacitor from the reference voltage (V_{ref}) to the integrator input thus resetting the voltage at the output. The voltage removed from the integrator output is equivalent to the phase that is removed from the loop when the divider removes the VCO cycle. The integrator output voltage is applied through the N-scaling block and summed into the loop through the phase modulator. A similar response occurs when a positive voltage is applied to the integrator except the IC adds one VCO cycle of phase to the loop and voltage is added to the integrator. The net effect is that even though a step change in phase has occurred at the phase modulator input, the divider corrects for that step by removing or adding one VCO cycle during that reference period. Figure 7 shows the relationship between the resetting of the integrator and the VCO cycle addition or removal.

Using the method just described overcomes the integrator limitation and allows the loop to be frequency modulated at rates inside the loop bandwidth through the phase modulator input. This also allows for true DC coupled FM of the phase lock loop through this input.

AC Coupled FM

Any DC offsets at the integrator input will cause a center frequency offset proportional to the offset at the integrator input. This is desirable for DC coupled FM. However, for many applications it is necessary to have the output frequency locked at the correct center frequency. In this case, AC coupled FM is needed to prevent DC offsets at the integrator from translating into a center frequency offset.

Since the integrator itself can have voltage offsets, it is necessary to use the integrator to remove the DC offsets. This can be done by adding DC feedback to the integrator. Adding the feedback moves the integrator pole away from 0 Hz. This causes the integrator to no longer integrate but settle to a DC voltage set by the DC gain of the integrator. The loop output frequency now has no offset from the desired center frequency. At modulation rates above the integrator AC corner, the integrator functions as expected. Thus,

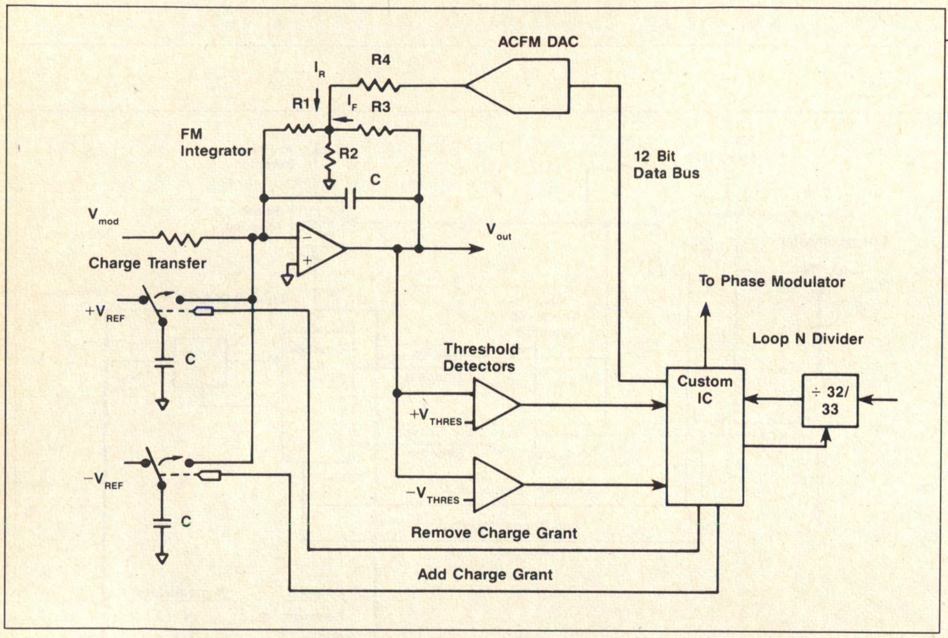

Figure 8. Circuit to reconstruct linear feedback to the integrator.

frequency modulation can be obtained at rates down to the low frequency corner of the integrator.

DC feedback in the integrator creates some problems when the integrator has to be reset. The resetting causes a very non-linear feedback at the input of the integrator. For the integrator to function properly linear feedback is needed. A method is needed to reconstruct linear feedback to the integrator.

The divider IC has an internal counter which keeps track of the net number of cycles that have been added or removed due to the resetting of the integrator. The value of this counter is used for reconstruction of the integrator feedback. The circuit in Figure 8 shows how this is done. The divider IC puts the counter value on the 12 bit parallel data bus which is connected to the ACFM DAC. The DAC is programmed with the counter value to recreate a staircase voltage approximation of the feedback voltage lost during the resetting of the integrator. The ACFM DAC output is summed with the integrator output through the resistor network R1, R2, R3, and R4 to reconstruct the feedback to the input. The feedback resistors are selected to match the gain of the ACFM DAC and the integrator output to set the proper feedback current. Figure 9 is an example of the reconstructed feedback to the integrator.

The overall effect is that of an ideal integrator with DC feedback to cancel

offsets at the input. The integrator will remain ideal as long as the range of the ACFM DAC and internal counter in the divider IC can keep track of the net number of cycles added or removed. The divider IC and the DAC have 12 bit resolution which allows for 4096 counts. Each count is equivalent to one VCO cycle of phase, making the DAC output voltage proportional to the instantaneous phase deviation in the loop. Since the total counts of the 12 bit DAC is 4096, the total phase deviation allowed in AC coupled FM is ± 2048 or a modulation index (B) of 4096pi.

The ACFM DAC and integrator feedback resistor and capacitor set the AC corner of the integrator. The effective resistance is 212 Mohm and the capacitor is 1000 pF which sets the corner at less then 1 Hz.

Conclusion

This frequency modulation method allows for DC coupled FM and AC coupled FM. The low frequency corner in AC coupled FM is .75 Hz with a

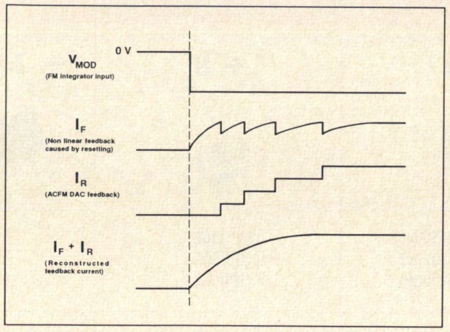

Figure 9. Reconstruction of linear feedback to the integrator.

modulation index limit of ± 6000. The maximum frequency deviation of this system is 100 KHz.

FM distortion is a function of the matching of the charge added or removed at the FM integrator to the VCO cycle added or removed at the loop N-divider. If they are not matched, the errors show up as spurious phase modulation on the output signal. These spurs appear around the carrier at a repetition rate equal to the integrator reset rate. In this implementation the spurs are better than 50 dBc at rates greater than 1 KHz.

This modulation technique was developed for the 8656B signal generator by Marcus DaSilva, Dave Whipple, and Bob Temple of Hewlett Packard Spokane Division. The 8920A hardware implementation of this technique was developed to reduce hardware complexity over the 8656B implementation. The 8920A hardware realization uses fewer parts while suffering only a slight increase in FM distortion over the 8656B scheme. Bob Conley also of Hewlett Packard Spokane Division contributed to the design of the 8920A FM hardware. ***RF***

About the Author

Scott Grimmett is an RF design engineer for Hewlett-Packard. He holds a BSEE from the University of Idaho, Moscow. He can be reached at Hewlett-Packard, Spokane Division, TAF-C 34, Spokane, WA 99220. Tel: (509) 921-3819.

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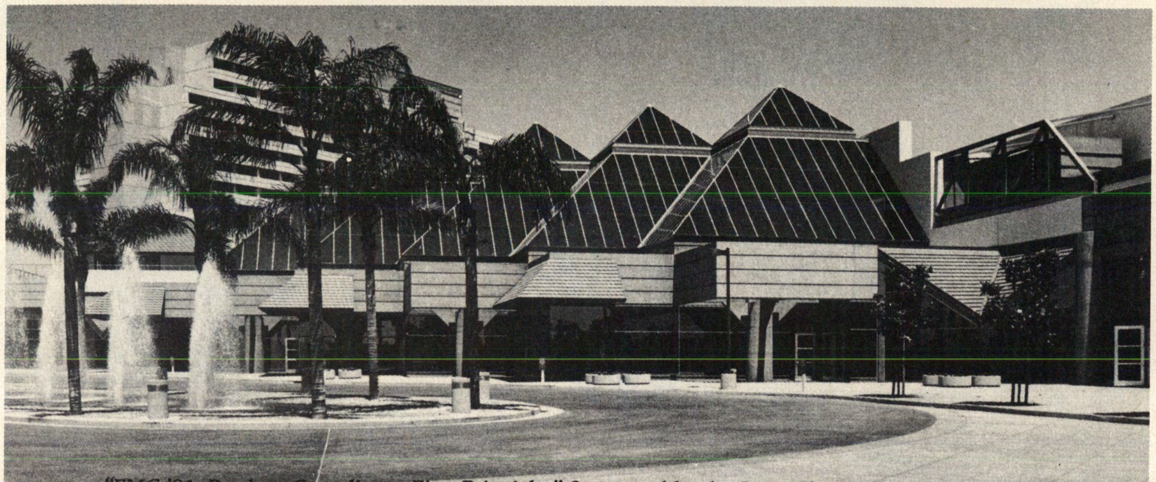

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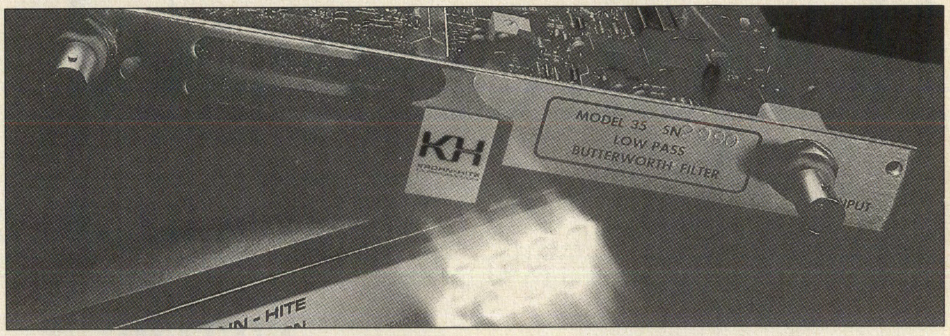
RFD 6/91

Tunable Active Filter Reaches 25 MHz

By Bill Kulas
Krohn-Hite Corp.

In recent years, demand for tunable filters in the low RF range has grown. This demand, combined with new high frequency signal conditioning needs, prompted the development of Krohn-Hite's Model 35 filter. Through an unconventional design approach, the Model 35 achieves a classic 4-pole Butterworth response over the tuning range of 170 Hz to 25.6 MHz. Key to the development of the filter was the availability of current-feedback amplifiers with bandwidths exceeding 100 MHz, along with Krohn-Hite's extensive experience with wideband closed-loop amplifier stabilization.



Since introducing its first filter in 1950, the Model 330, Krohn-Hite's product line has evolved with the industry. The Model 35 was developed as the list of requests for a high frequency tunable active filter began to grow steadily. Customer applications included EMI testing, phone system testing of Part 68 requirements, prefiltering for digitizing oscilloscopes, ultrasonic inspection to 15 MHz, video recording and testing, high speed tape recording, and digital transmission testing.

The filter's design required pushing tunable active RC filters more than an order of magnitude beyond existing technology. To design wideband discrete circuits for maximum bandwidth, the engineer is required to minimize the number of lags or poles within a closed loop, taking care not to overpower the response with added lags. Peaking at the cutoff frequency depends on the amount of phase shift in the loop as it goes through unity gain. This became the seed for the approach used in the Model 35 filter design. The 2-pole section used in the Model 35 is shown in Figure 1. Two sections create the overall 4-pole response.

An analysis of component sensitivity shows that the least sensitivity (which eases component selection) occurs when the two RCs are equal. Another feature of the design is that the two capacitors in the time constant networks return to ground, improving rejection of signals above cutoff. It also avoids reactive feedback, which is not allowed with the very fast current-feedback amplifiers used.

The single penalty paid in selecting this design is a dynamic amplitude limitation at the output of the first amplifier, e_2. As the RC time constants introduce phase shift and bring internal loop gain down prior to the output of the loop dropoff, the signal amplitude rises at e_2. To minimize this, the most peaked section is placed last, and using Sallen-Key topology to provide a portion of the required peaking.

The performance of the Model 35 filter includes 50 ohm or 1 megohm input impedance, AC or DC coupling, input gains of 0, +10 and +20 dB, output gains of 0, +6, +20 and +26 dB, tunable cutoff from 170 Hz to 25.6 MHz, and an amplified bypass mode with a bandwidth greater than 50 MHz.

The unit is Krohn-Hite's newest filter card that plugs into their Models 3905B and 3916B programmable filter systems, offering filtering options from 0.01 Hz to 25.6 MHz. The highpass complement to the Model 35 is in progress and will be available soon. For more information on this new product, circle Info/Card #250. **RF**

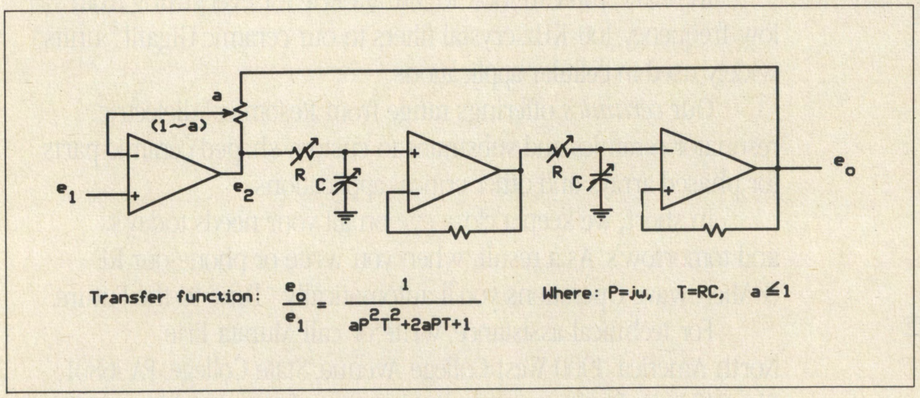


Figure 1. 2-pole filter section used in the Model 35.

About the Author

Bill Kulas is Vice President of Engineering at Krohn-Hite Corporation, 255 Bodwell Street, Avon, MA 02322; telephone (508) 580-1660.

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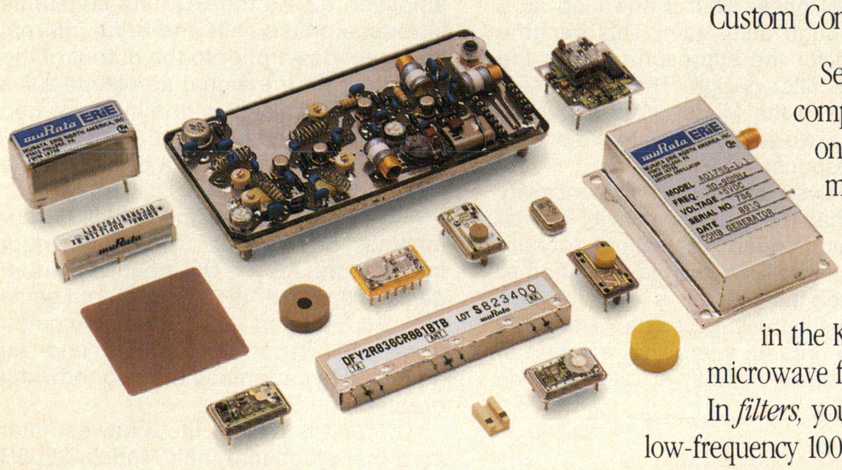

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RF products

IFR Introduces a 9 kHz to 22 GHz Spectrum Analyzer

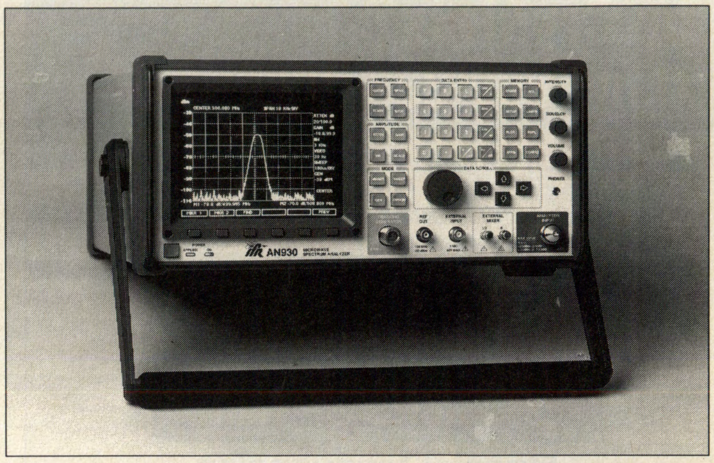
The AN930 from IFR Systems, Inc. is a new microwave spectrum analyzer for a wide range of amplitude and frequency measurements, featuring low-order, preselected mixing and a synthesized RF system for coverage from 9 kHz to 22 GHz. Support for external mixers extends the measurement range beyond 22 GHz. A high impedance input allows baseband measurements down to 0 Hz.

Standard features include 300 Hz to 25 MHz analog resolution bandwidth, 3 Hz to 100 Hz digital resolution bandwidth, a built-in frequency counter, high speed time-domain sweep with pretrigger and delayed trigger, AM/FM receiver, RS-232 and IEEE-488 interfaces, and DC power capability for field operation.

Options include a rechargeable battery pack, a built-in tracking generator, 200 Hz to 1 MHz resolution bandwidth with EMI bandwidth filters, quasi-peak detector, and a 0.02 ppm high stability time base.

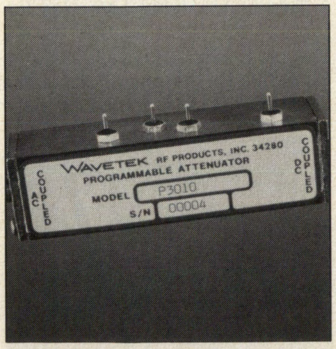
The unit also features IFR's user-friendly parameter selection and measurement function selection, extensive marker capability, trace and setup storage, as well as full programmability.

IFR Systems, Inc.
INFO/CARD #249



300 kHz-3 GHz Programmable Attenuator

Wavetek RF Products announces the P3010 programmable attenuator, covering 300 kHz to 3 GHz with 0-60 dB attenuation in 10 dB steps, 0.7 dB accuracy and 0.2 dB repeatability at any setting. Specifically designed for OEM applications, the attenuator features 2.4 dB insertion loss and VSWR performance of 1.4:1. The

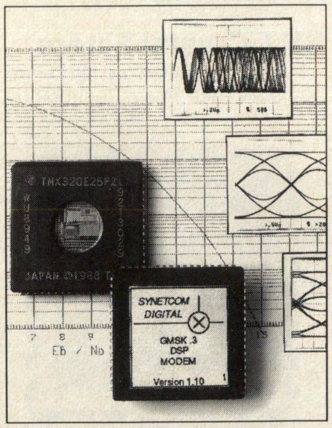


most impressive feature is its small size, just 2.81 inches long, plus connectors, and 0.8 × 0.8 inches in cross-section, plus control pins, or 0.8 × 1.62 inches plus a 9-pin "D" connector. Applications with restricted real estate space will benefit from this product. Power rating is 1 watt continuous, and relay operating voltage is 12 VDC. A TTL version requires an additional 10 mA from a 12 VDC supply. Pricing is $485.00 per unit (U.S), $555.00 export.

Wavetek RF Products
INFO/CARD #248

Mobitex DSP Mobile Modem

Synetcom Digital has announced standard and customized versions of their Mobitex compatible GMSK .3, 8 kBPS



modem, designed for use in the RAM Mobile Data Packet Radio Networks in the U.S. and U.K. A Texas Instruments DSP chip executes proprietary real-time algorithms to carry out modulation and demodulation of Mobitex signals. The modem accepts an IF input from the receiver and implements digital demodulation, producing TTL compatible data and clock signals. External data is accepted, or the modem can run internal PN generators — encoded, using FIR filtering, into the transmit baseband signal. An evaluation board (EB-1000) containing the standard modem and support hardware is available.

Synetcom Digital
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Frequency Converter Test Set

A 300 kHz to 3 GHz frequency converter test set is introduced by Hewlett-Packard. The HP8753C, Option E20 provides swept-frequency and swept-power measurement of conversion loss, compression, RF and IF port SWR, LO feedthrough, isolation, group delay and amplitude/phase tracking. The system consists of an HP 8753C network analyzer, HP 85046 Option H20 mixer test set, HP 8625A synthesized RF sweeper, a power meter and power sensor. All four conversion schemes are supported: up- and down-conversion with high- and low-side LO injection. In addition to the $26,500 price of the HP 8753C, the components included in Option E20 total $40,115.

Hewlett-Packard Company
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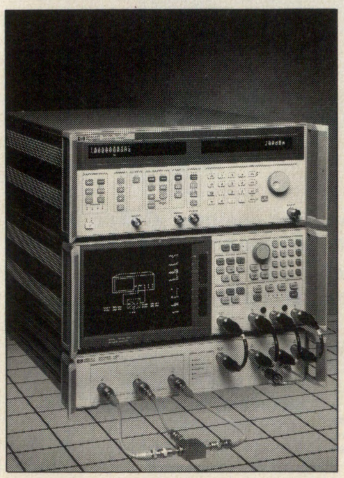

Low Cost ELF Magnetic Field Meter

Holaday Industries has introduced the HI-3624 ELF Magnetic Field Meter for simple, convenient and accurate field measure-

ment. The HI-3624A option adds the capability to measure to the Swedish test protocol for ELF measurements on VDTs. Reading sensitivity covers from 0.2 milligauss to 20 Gauss with true RMS detection. The frequency sensitivity is from 30-2000 Hz. The Swedish measurement option provides a switched lower frequency limit of 5 Hz. Power is provided by two 9-volt alkaline batteries. Price of the HI-3624 is $389 and the HI-3624A is $459.

Holaday Industries, Inc.
INFO/CARD #245

1 kW PIN Diode Switch

A PIN diode switch which handles 1 kW CW power has been introduced by ENON Microwave. The unit will switch in under 10 microseconds, with 0.3 dB insertion loss and 40 dB isolation. The operating frequency is specified at 20-100 MHz. Configurations for SPST, SPDT or SP3T are available.
ENON Microwave, Inc.
INFO/CARD #244

300 MHz DDS Hybrid

The STEL-2373 from Stanford Telecommunications is a 0-300 MHz synthesizer module using GaAs NCO and 8-bit DAC circuits to generate sine or cosine output waveforms. The hybrid features 32-bit frequency resolution, 2-bit phase modulation (BPSK and QPSK), −40 dBc maximum spurious levels, and frequency switching in 25 clock cycles. The STEL-2373 is provided in a 70-pin molybdenum package.
Stanford Telecommunications
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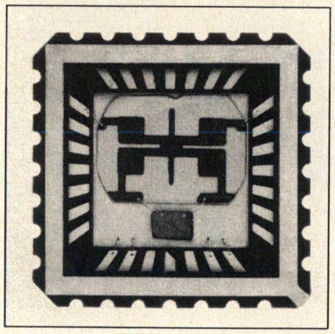
SMT Crystal Filters

Miniature, low profile filters are available from Piezo Technology



in leaded or leadless packages. The leadless packages may contain two or four poles of selectivity. 21.4 MHz filters with 50 ohm impedance and 8 poles have been fabricated in a 1.25 × 0.53 × 0.22 J-lead package.
Peizo Technology, Inc.
INFO/CARD #242

Low Cost MESFET

California Eastern Laboratories announces availability of the NE76038 MESFET from NEC. The device is intended for second and third stages of LNAs, as well as oscillators and mixers, in the 0.5 to 14 GHz range. The NE76038 comes in a plastic package, and is available on tape and reel for automated manufacturing. In 10,000 quantities, the price is $2.75 each.
California Eastern Laboratories
INFO/CARD #241

Medium Power Amplifiers

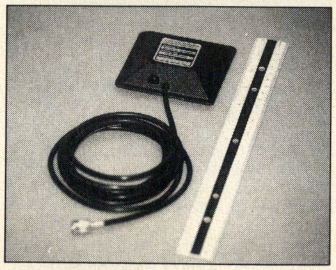
Broadband 50 ohm amplifiers in one-half to five watt models are now available from RF Products and Richardson Electronics. The UNA family of devices utilize a one-hole flanged package (0.25 × 0.5 inch) and are operated exactly like low-power MMICs. The UNA devices operate over 1-1000 MHz.
Richardson Electronics, Ltd.
INFO/CARD #240

DIP Oscillators

S-Type crystal oscillators from AT&T are packaged in a 6-pin DIP and available in frequencies up to 52 MHz. Tri-state outputs allow simple switching among several oscillators, and the output is selectable for either CMOS or TTL waveform symmetry. Fixed frequency or VXCO models are available.
AT&T Microelectronics
INFO/CARD #239

900 MHz Low Profile Antennas

Two concealable antennas for the 904-928 MHz Teletrac Stolen Vehicle Service are available from Scientific Research Laboratories. The Little David model is only



0.575 inches high with a base of 3.75 inches square. The Big David model provides 1 dB greater efficiency in a package 0.775 inches high. Measured performance is typically 2.5 to 4 dB below a reference dipole. The antennas can be used with FCC part 15 equipment, or provided retuned for 800 MHz and cellular applications. Price is $35.00 (500 qty.) to $28.00 (5000 qty.).
Scientific Research Laboratories, Inc.
INFO/CARD #238


Now You Can Take It With You
Performance, versatility, and efficiency — now they can go wherever you go. Introducing the portable R3271 Spectrum Analyzer with the capability to cover a frequency range of 100Hz to 26.5GHz. With a microwave frequency that is internally preselected to provide a variety of applications, including mobile radio equipment, microwave component testing, and radar. Other features include:
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Advantest UK Limited CI Tower, St.Georges Square, High Street, New Malden, Surrey, KT3 4HH, U.K. (081)336-1606 FAX (081)336-1657
INFO/CARD 35

Three New MOS Power Transistors

New high power push-pull transistors for VHF applications are available from Philips Components. The BLF378 is a 250-watt dual device, specified for operation up to 225 MHz with a 50 VDC supply, 14 dB power gain, and 50 percent efficiency. The BLF368 is a 300 watt device intended for VHF television transmitters, using a 32 VDC supply, with 12 dB power gain and 55 percent efficiency. The BLF 278 is intended for FM broadcast transmitters, with 300 watts power output, Class B gain of 20 dB or more. All are N-channel enhancement mode devices with a vertical D-MOS structure. In 1000s, the BLF378 is $272.00, the BLF368 is $272, and the BLF278 is $132.
Philips Components
Discrete Products Division
INFO/CARD #237

Lab Attenuator Kit

JFW announces its laboratory fixed attenuator kits, available with various connector types and attenuation values. Custom combinations can be created to suit the customers particular requirements. Attenuators, feedthough terminations, matching pads and adapters are available in 50 or 75 ohm impedances, and are available off-the-shelf.
JFW Industries, Inc.
INFO/CARD #236

VSB Filter for HDTV

Thomson-CSF has developed a VSB demodulator filter for HDTV, based on SAW technology. The System D2-MAC filter, model FBH865, operates at 38.9 MHz, with a passband ripple of ±0.25 dB and ±20 ns. Adjacent channel rejection is 50 dB. Packaging is a 24-pin DIP. Additional models are available for current TV broadcast systems.
Thomson-ICS Corp.
INFO/CARD #235

1 GHz Network Analyzer

The Anritsu MS3606B Network Analyzer covers 10 kHz to 1 GHz with 120 dB dynamic range. Resolution bandwidth as low as 300 Hz is available with 1 mHz frequency resolution. With applicable accessories, such as a reflection bridge, detector, high impedance probe, or S-parameter test set, the unit offers a complete range of network measurement capabilities. Full computer control and analysis features are offered, including an optional internal computer with keyboard to serve as a test system controller.
Anritsu America, Inc.
INFO/CARD #234

Spread Spectrum Filter

New 2-pole and 3-pole dielectric bandpass filters for 902-928 MHz spread spectrum applications is announced by Toko. Insertion loss is 1.8 dB, and out-of-band rejection is 20 dB minimum at F_o ±77.5 MHz. Other ceramic dielectric filters are available in 2 to 8 poles in the 700-1700 MHz range.
Toko America, Inc.
INFO/CARD #233

Panoramic IF Display

Spectrum Display EPZ 513 from Rohde & Schwarz covers common IFs used in VHF/UHF and microwave equipment. Two versions are available; model 02 has center frequencies of 160/70/21.4/10.7 MHz with maximum spans of 100/40/7 MHz, while model 04 monitors 21.4/10.7 MHz IFs with a 7 MHz span. 12 watt power consumption allows economical battery power usage for portable field service. Applications include radio monitoring and detection for checking signal levels and band usage.
Rohde & Schwarz
INFO/CARD #232

0.1-12 GHz Amplifier

Miteq announces a wide bandwidth amplifier covering 0.1 to 12 GHz with a gain of 26 dB, a noise

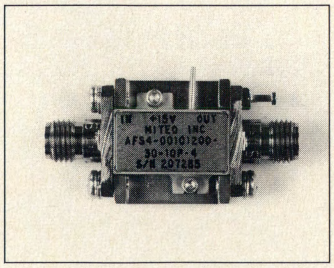
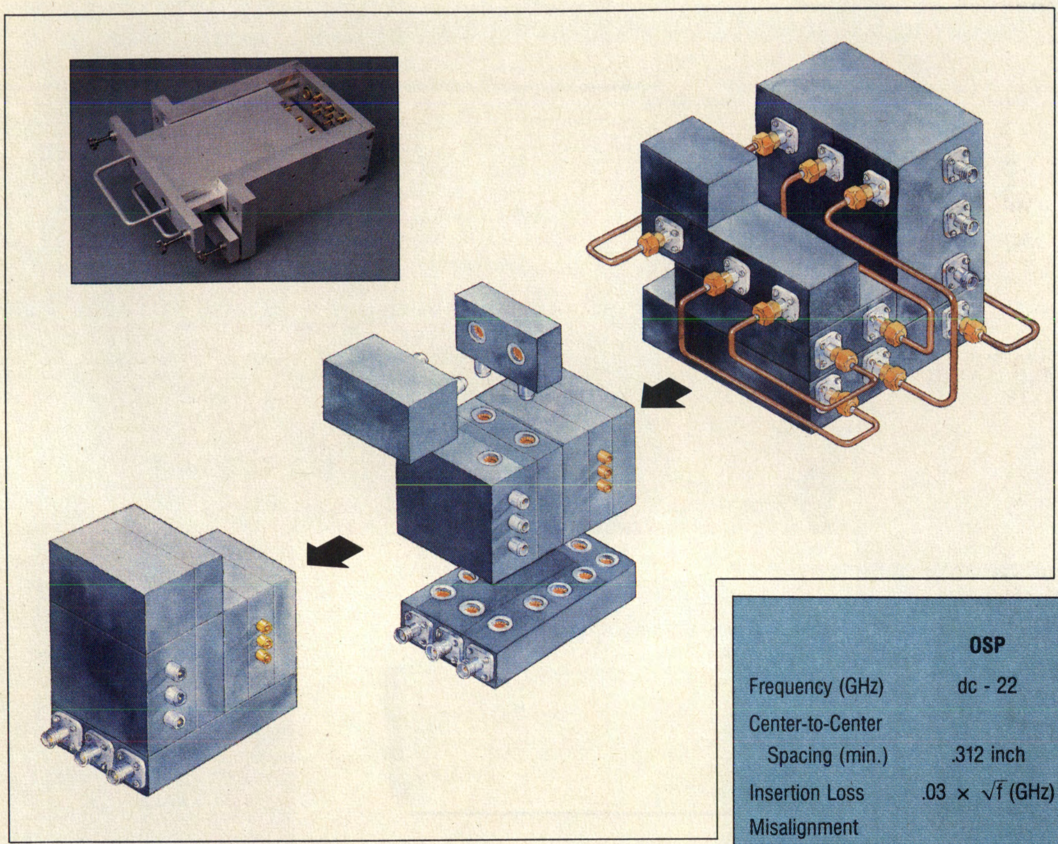


figure of 3.0 dB, 2:1 in/out VSWR and +10 dBm output power. The AFS4-00101200-30-10P-4 is available with MIL-STD-883 screening.
Miteq Inc.
INFO/CARD #231

6 dB Power Splitter

Avantek has introduced a DC-10 GHz resistive power divider in

Tough Problems...Easy Solutions



	OSP	OSSP	OS-50P
Frequency (GHz)	dc - 22	dc - 28	dc - 40
Center-to-Center Spacing (min.)	.312 inch	.225 inch	.187 inch
Insertion Loss	$.03 \times \sqrt{f}$ (GHz)	$.04 \times \sqrt{f}$ (GHz)	$.04 \times \sqrt{f}$ (GHz)
Misalignment			
Rigid Mount	±.004 inch	±.0025 inch	±.0015 inch
Float Mount	±.020 inch	±.0200 inch	±.0065 inch
Durability	1,000 cycles	1,000 cycles	500 cycles

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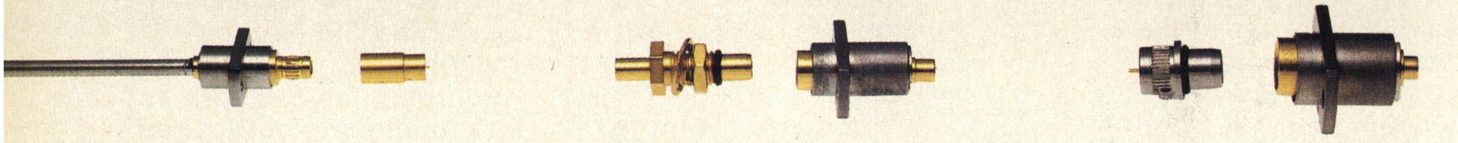


Omni Spectra

A M/A-COM COMPANY

INFO/CARD 39

a hermetic 0.25 inch square package. The PSP-1002 features 0.7 dB arm-arm amplitude and ±3 dB phase balance, and 1.7:1 maximum VSWR at all ports. It is available with Avantek "R" Series qualification, based on MIL-STD-883. The PSP-1002 is priced at $51.00 in 50-piece quantities, in stock at Avantek distributors.
Avantek, Inc.
INFO/CARD #230

Wireless Cable/ MMDS Antenna

An omni-directional antenna for MMDS and wireless cable has been introduced by RF Technology. The antenna has a power handling capability of 50 watts and offers 14 dBi omni-directional gain. The antenna weighs less than 10 lbs. **RF Technology Inc.**
INFO/CARD #229

Programmable Attenuator

Kay Elemetrics' line of programmable attenuators has added the model 4450, with 0-127 dB attenuation (50 ohms) in 1 dB steps. The frequency range is DC-1.5 GHz, usable to 2 GHz. VSWR is 1.3:1 at lower frequencies, rising to a maximum of 1.5:1 at 1.5 GHz. Insertion loss is 2.5 dB to 4.0 dB from low to high frequencies.
Kay Elemetrics Corp.
INFO/CARD #228

High Power Sweep Generator

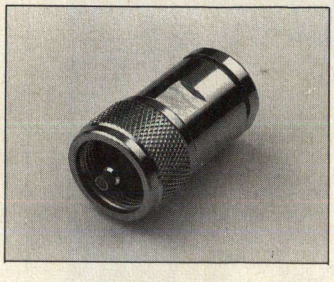
A 300 kHz to 3 GHz synthesized RF sweeper is announced by Hewlett-Packard. The HP 8625A is a stand-alone unit with +20 dBm output level, offering the stability of a synthesizer along with the CW and swept-frequency capabilities of a sweeper. the unit can be synchronized with the HP 8753C network analyzer for use as a tracking local oscillator for sweep testing mixers and other frequency conversion products. A power sweep of 25 dB is available for compression testing, and an optional attenuator reduces power output to as low as −75 dBm. Price of the HP 8625A is $22,500.
Hewlett-Packard Co.
INFO/CARD #227

Direction-Finding System

The MD-103A from Maxim Technologies is a VHF/UHF communications intercept and direction finding system combining effective signal search features and accurate DF processing in a compact portable package. Operating software can acquire and determine direction of a signal lasting as little as 10 ms. Frequency coverage is 25 to 1000 MHz with frequency sweep rate as high as 24 MHz per second.
Maxim Technologies, Inc.
INFO/CARD #226

Weather Resistant UHF Connector

RF Connectors division of RF Industries has announced the RFU-503, a weather resistant ver-



sion of the PL-259 plug, usable with any UHF female connector. The RFU-503 fits RG-8, RG-213 and RG-214 cables, and has a nickel plated body, silver plated pin with PTFE dielectric, and silicone rubber gaskets. No external boot or tape is required.
RF Connectors
INFO/CARD #225

Wide Range Power Meter

The 4220, a low cost power meter from Boonton Electronics, covers 100 kHz to 110 GHz. Packaged in a 3 1/2 inch high half-rack unit, the 4220 has a 4 1/2 digit readout, with an analog meter for peaking or nulling. Zeroing is automatic, and measurements are displayed in dBm or watts, either directly or relative to a reference. Depending on which of many sensors are used, levels can be measured from −70 to +30 dBm. Complete calibration data for up to four sensors can be stored. GPIB bus interface is an option. The 4220 is priced at $1795, or $2045 with GPIB.
Boonton Electronics Corp.
INFO/CARD #224

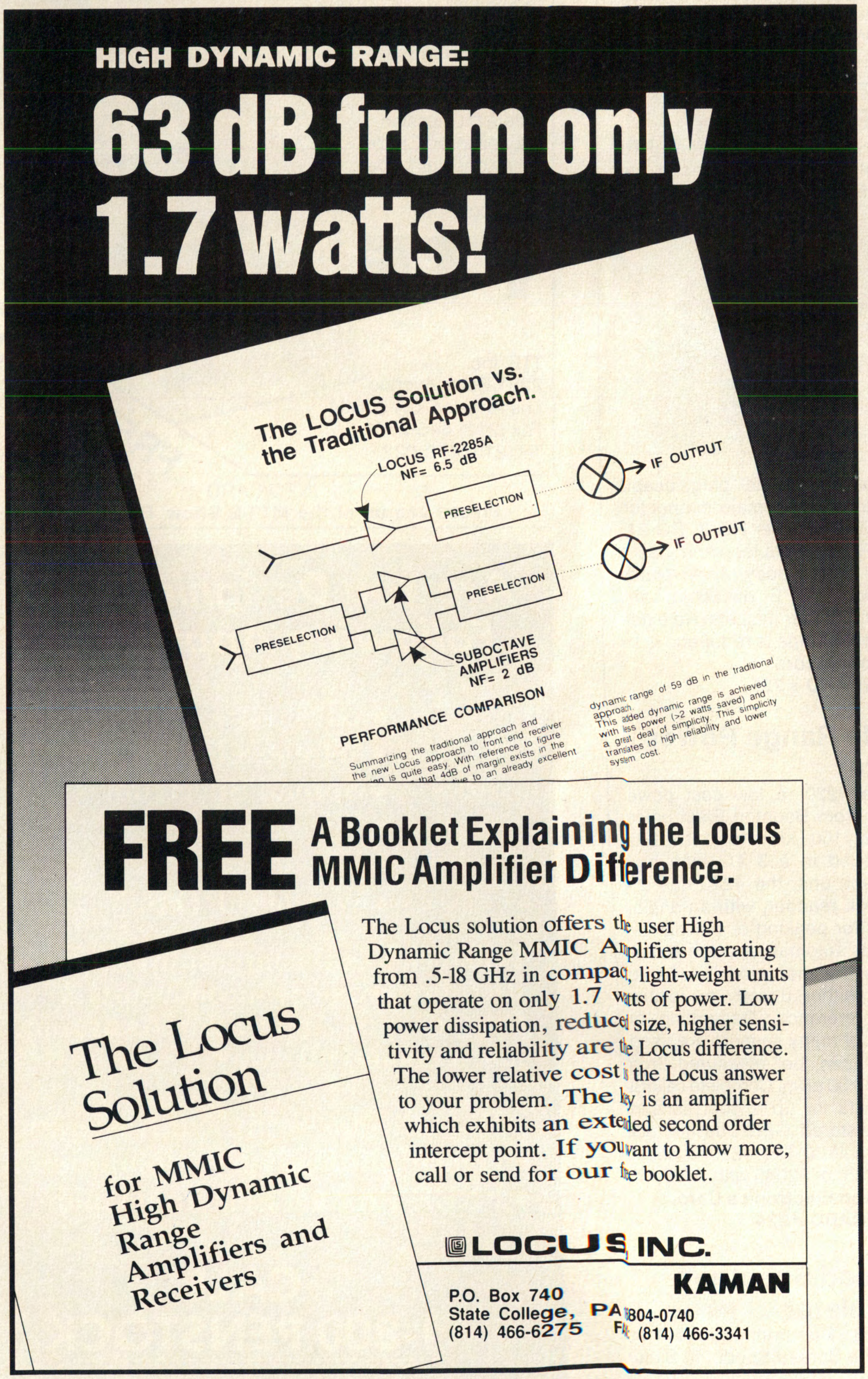
Spread Spectrum Simulator

LNR Communications has added a Spread Spectrum Simu-

lator to their line of SIGINT products. The SIM-xx series provides signal simulation to exercise specific signal detection capabilities of ESM/ECM systems under development. Models cover standard microwave IF frequencies, or may include band specific modules or tunable frequency extenders for 1.0 to 40 GHz. Available formats include pulse, frequency hop, chirp and direct sequence (BPSK).
LNR Communications Inc.
INFO/CARD #223

RFI Gaskets

Dual elastomer gasketing from Vanguard now includes diameters of 2.0, 1.5 and 1.0 mm. These silver-filled extrusions are suitable for groove mounting and areas where only a small amount of compression is required. Attenuation of 110 dB is maintained up to 10 GHz.
Vanguard Products Corp.
INFO/CARD #222



INFO/CARD 42
Please see us at the MTT-S Show, booth #1019.

Clip-on Shielding

Pawling Corporation announces Clip Strip™ low compression RFI/EMI shielding gaskets. Open bulb carbon silicone gasket material allows easier compression than earlier closed-bulb types, and the clip-on mounting strip cuts through painted surfaces to make metal-to-metal contact.
Pawling Corporation
INFO/CARD #218

Digital Attenuator

Model DAS-124 from KDI/Triangle operates over 1-4 GHz with 4-bit switching. Other models are available with up to 6-bit control with reduced frequency

coverage. The attenuators are available in 0-31.5 dB at 0.5 dB per bit, and 0-63 dB in 1 dB steps. Advanced CMOS (ACT) drivers provide switching speeds of less than 100 nsec. Prices start at $400 in small quantities.
KDI/Triangle Electronics
INFO/CARD #217

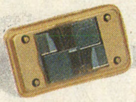
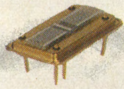
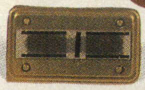
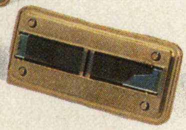
Low-Loss SAW Filter

Sawtek has developed an 83.1 MHz low-loss filter to meet the requirements of the TDMA system to be used in cellular telephone networks. The SAW filter has a 30 kHz minimum passband, 5 dB insertion loss, and a 70 dB rejection floor. The design can be adapted to any frequency in the 80-95 MHz range. Both DIP and surface mount packaging is available.
Sawtek Inc.
INFO/CARD #216

CMOS Analog Switches

The DG308A/DG309 quad monolithic SPST analog switches have been announced by Maxim Integrated Products. The switches feature less than 60 ohm on resistance and less than 130 ns switching speed. The DG308A is "normally open" and the DG309 is "normally closed." Standard DIP and narrow small outline packages are available. Pricing starts at $2.16 (1000s).
Maxim Integrated Products
INFO/CARD #215

Our Standard Filter Family Keeps GROWING!


First came commercial 70 MHz . . .

3dB Bandwidth	Part Number
0.125	851539
0.25	851541
0.50	851542
0.75	851543
1.0	851544
1.5	851545
2.0	851546
2.5	851547
3.0	851548
3.5	851549
4.0	851550
4.5	851551
5.0	851552
5.5	851553
6.0	851554
6.5	851555
7.0	851556
7.5	851505
8.0	851557
8.5	851558
9.0	851559
9.5	851560
10.0	851475
11.0	851841
12.0	851842
13.0	851843
14.0	851844
15.0	851845
16.0	851846
18.0	851847
20.0	851848
22.0	851849
24.0	851850
26.0	851851
28.0	851852
30.0	851853
32.0	851854
34.0	851855
36.0	851856
38.0	851857
40.0	851858

Then commercial 140 MHz . . .

3dB Bandwidth	Part Number
0.25	851900
0.50	851901
0.75	851902
1.0	851903
1.5	851904
2.0	851905
2.5	851906
3.0	851907
4.0	851909
5.0	851911
6.0	851913
7.0	851915
8.0	851917
9.0	851919
10.0	851921
12.0	851923
14.0	851925
16.0	851927
18.0	851929
20.0	851931
24.0	851933
28.0	851935
32.0	851937
36.0	851939
40.0	851941
44.0	851943
48.0	851945
56.0	851947
64.0	851948
72.0	851949
80.0	854101

And *now* standard military 160 MHz SAW filters!

3dB Bandwidth	Part Number
0.25	**851950**
0.50	**851951**
0.75	**851952**
1.0	**851953**
1.5	**851954**
2.0	**851955**
2.5	**851956**
3.0	**851957**
4.0	**851959**
5.0	**851961**
6.0	**851963**
7.0	**851965**
8.0	**851967**
9.0	**851969**
10.0	**851971**
12.0	**851973**
14.0	**851975**
16.0	**851977**
18.0	**851979**
20.0	**851981**
24.0	**851983**
28.0	**851985**
30.0	**851986**
32.0	**851987**
36.0	**851989**
40.0	**851991**

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Please see us at the MTT-S Show, Booth #1421.

New radiation monitor from narda

Any signal environment. Any type of modulation.

The new Series 8700 is the most capable, accurate, expandable system ever developed. And it's available only from Narda.

With it, you get a test set that combines automatic zeroing with true RMS average results. It measures any signal environment, even pulsed RF, and any type of modulation. Isotropic detecting, magnetic field probes are virtually immune to the out-of-band responses that in the past compromised the integrity of field surveys below 300 MHz.

Field probes are available in a wide selection of measurement levels and frequency ranges including ultra-broadband 300 KHz to 40 GHz, with FLAT or ANSI-shaped responses.

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INFO/CARD 43

EMC Design Techniques for Printed Circuit Boards

By Bernard Cooperstein
EMC Consultant

This article describes design processes and techniques that have been found to be effective in minimizing Electromagnetic Emissions (EME) and improving the overall EMC characteristics of circuit boards. Because the functional requirements and cost constraints of different products vary widely, there may still be aspects of particular designs that may appear to be ambiguous. In such cases, experience is often the best guide to selecting the most effective design.

This article is not intended to make the reader an EMC expert, but should help in reducing the number of design iterations necessary to result in a product with acceptable EMC characteristics. Specifically, this article will focus on those EME reduction techniques directly related to the placement of high frequency devices on PCBs, and to the routing of high frequency signals, and will briefly discuss impedance matching and control of signal waveforms. Other important aspects of circuit board design, such as layering configurations for multilayer boards, on-board power distribution and filtering, and transient and ESD protection, are beyond the scope of this article.

Electronic equipment sold almost anywhere in the world is, or soon will be, required to comply with specific EME limits set by government regulatory agencies or by military standards. By now, almost everyone is aware of FCC Part 15 requirements, and will soon become aware of the EMC requirements of CISPR Publication 22 (CISPR-22) in one or another of its final forms (EN55022 in Western Europe, and VCCI in Japan). Those who sell to the U.S. military organizations are aware of MIL-STD-461. Therefore, it is in the best interests of equipment manufacturers to design their products, from the initial design phases, to comply with all applicable EMC requirements. Although it is possible to reduce EME after a product has been designed and built, that approach often results in schedule slippage, increased maintainability problems, and increased costs.

Design Process

The EMC control process should begin immediately after the initial schematic diagrams have been completed. A review of the PCB's functions will identify the most likely sources of EME, and should result in an understanding of whether any of the ICs have high frequency characteristics that are beyond those necessary for adequate performance of the circuit. Put in other terms, "Do any of the devices have output transition time characteristics, or input response times that are faster than needed to get the job done?" The next steps will be to identify the high frequency signal paths, and to develop a preliminary layout that will minimize the high frequency path lengths. Unless the PCB operates at frequencies below about 12 MHz, it will be prudent to design it as a multilayer board with at least one power plane and one ground plane. The reader is referred to Reference 1 for the details of layering configurations as well as some aspects of power distribution and grounding. Some signal paths will, of necessity, be long enough to require that impedance control techniques are used. Depending on the number of layers used, either microstrip or stripline configurations should be used. Reference 2 provides a good basic understanding of these configurations, and References 3-5 should also prove to be of value. Finally, IC decoupling and power input filtering components will be selected and positioned on the board. Power input filtering will not be discussed here.

EME Sources

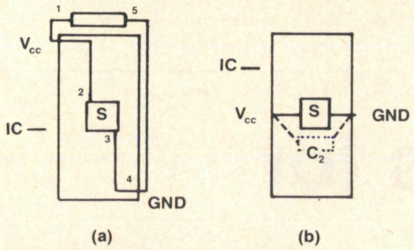
The most important EME sources are oscillators and microprocessors because they generally drive the largest high frequency currents, and have the shortest transition times. Other important sources are high frequency crystals and line drivers. Actually, any device that amplifies or alters signal waveforms may be an EME source. It is important to remember that the EME potential of a device is directly proportional to its operating frequency and its output current, and is inversely proportional to its rise and fall times.

$$EME \propto \frac{F \cdot I}{t}$$

where: F = pulse repetition frequency
I = output current
t = rise time or fall time, whichever is shorter.

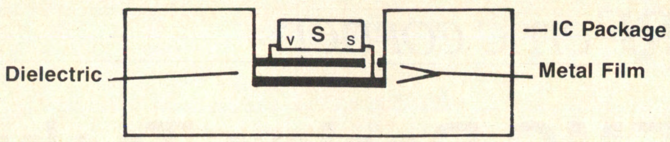
The output current waveforms on the signal traces between drivers and loads are usually the primary EME radiators on PCBs, but the DC power input to the PCB can also be a major EME radiator. The designer must realize that the input current to the IC is not really clean DC. If one looks at the DC input to a microprocessor, with a high frequency current probe and oscilloscope, one will see spikes that correspond to the high frequency power switching that is taking place. Therefore, the higher the output current, the higher the input current spikes are likely to be. For these reasons, the designer should select the slowest, least powerful ICs that can be used to successfully perform the required function. When high speeu, high frequency devices are required, it will often be necessary to decouple them (V_{cc} to GND) with two capacitors. Typically, these will be 1000 pF in parallel with either 0.1 uF or 0.01 uF. It is strongly recommended that the designer use only those ICs that have their V_{cc} and ground pins located at the center of the IC package, whenever possible. Surface mounted capacitors (SMC), located on the underside of the PCB, directly below the IC, should always be used whenever one of these ICs is used. This will drastically reduce the effective lead length of the capacitors, compared to that of a conventional IC pin arrangement (See Figure 1).

Figure 1a shows the typical V_{cc} and ground pin configuration of a conventional IC. The total effective lead length of the decoupling capacitor follows the path from 1 to 2, and 3 to 4 to 5. If the IC is one inch long, the resulting path length will be more than two inches. Placing an SMC directly below the IC, on the underside of the board, would reduce the path length slightly, and may provide some benefit. Figure 1b shows the center pin configuration. When the SMC is placed below this IC, its effective lead length may be less than one-half



Notes: IC = Integrated Circuit Package
S = Silicon Chip inside the IC
C_1 = DIP Capacitor
C_2 = Surface Mounted Capacitor on the underside of the PCB

Figure 1. a) IC with conventional V_{cc} and ground pins, b) IC with centered V_{cc} and ground pins.



Notes: S = Silicon Chip inside the IC
V = V_{CC} pin of the chip
G = Ground pin of the chip

Figure 2. Cutaway view of IC with internal decoupling capacitor.

inch. The decoupling performance of the capacitor will be significantly better than in the conventional configuration shown in 1a. In any situation, keeping the effective lead length of a decoupling or filter capacitor as short as possible will maximize its resonant frequency, and minimize its high frequency impedance.

An even better approach would be for IC manufacturers to add the decoupling capacitors to the IC package before inserting the silicon chip (See Figure 2). The two layers of metal film, separated by a thin layer of dielectric, forms a high quality parallel plate capacitor. Because the applied voltage is very low, the dielectric layer can be very thin, resulting in adequate capacitance in a very small area. The effective lead length is nearly zero, and the resonant frequency of the parallel plate configuration will be very high. The cost to manufacturers will be trivial compared to the cost of the IC. In addition to improved performance, the PCB cost will be reduced because it will usually be unnecessary to add external capacitors to each IC.

High Frequency Signal Paths

It is a commonly held belief that, if a ground plane and a power plane are added to the PCB, there will be no radiation from signal traces. This belief is based on experiences with lower frequency signals, where the propagation delay time (t_{PD}) of the trace is short when compared to the transition times (t_r) or the pulse. In this always desirable situation, it is usually unnecessary to design the signal paths as transmission lines. As long as the ground plane is not cut (See Reference 1), the signal return on the ground plane will follow the path of the signal trace, resulting in very low levels of radiation. Unfortunately, at higher frequencies, it is often difficult, if not impossible, to satisfy the condition that t_{PD} is short compared to t_r. When that condition is not satisfied, waveform distortion and ringing and radiated EME will increase unless other steps are taken.

For a first approximation, the designer can use 2 nanoseconds per foot as the propagation delay time, and may assume that if $t_{PD} > 0.3\ t_r$, he will have to either shorten the path length, increase the pulse's transition times, or use a controlled impedance transmission path. For example, if t_r is 3 ns, and the path length is longer than five inches, additional design constraints must be imposed. A complementary criterion that can be used is that any spectral line current at a frequency over 30 MHz, with an amplitude greater than 20 microamperes, should be considered to be a possible EME problem, unless its path length is less than one-tenth of a wavelength at that frequency. As the basics of spectrum analysis have been covered in many other articles on EMC, they will not be repeated here.

The easiest way to minimize radiated EME from signal traces is to position each high frequency load as close to its signal source as possible, because radiation is a direct function of the path length of the net high frequency current. This will also decrease t_{PD}, thereby increasing the likelihood that t_{PD} will be short compared to t_r.

The first step is to partition the board so that functions are clustered to the extent possible. The oscillators should be positioned so that they are not near any I/O connectors or I/O traces. The input pins of the oscillator's IC loads should be as close to the oscillator as possible, preferably less than one-half inch away. If the oscillator is intended to drive more than one IC, it is often necessary to use a buffer with multiple outputs in order to avoid waveform distortion, and to maintain the one-half inch criterion between oscillator and load. Identify the microprocessor clock-out traces and their loads, and all other high frequency data and signal lines and their loads. All these loads should be as close as possible to their high frequency signal sources. Line drives should be within one inch of their output connectors. Arrange the order of the high frequency signals so that the shortest paths will be used for the highest frequency signals. Try to arrange connectors to minimize high frequency signal paths across the PCB. If a noisy line (motor drive, etc.) or high frequency signal must go across a PCB, locate the input and output connectors close to each other, and run separate ground traces for the noisy lines.

Waveform Control and Impedance Matching

One of the first things to be investigated, after it has been determined that a high frequency path can not be shortened, is the possibility of increasing the transition times of the signal waveform at the driver output. It is often found that the output transition times are much shorter than are required at the load input. When this is so, the transition times of the output waveform can be slowed by adding a small series resistor at the output pin, and a small capacitor between the output pin and ground. Typical component values are 25 ohms and 50 picofarads. The object of this is to slow the transition time so that t_{PD} is less than $0.3\ t_r$. The capacitor is to be at the output pin, not at the load side of the resistor, because the resistor is also intended to help with impedance matching of the transmission line.

When the functional performance re-

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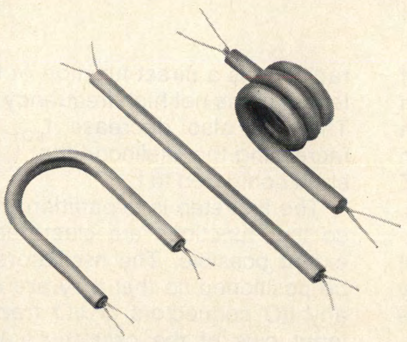

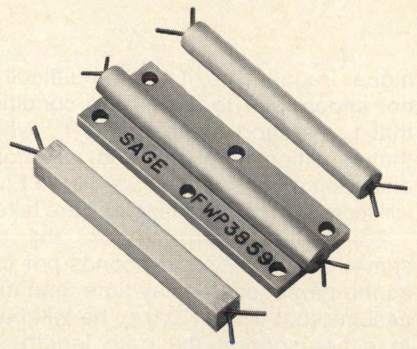

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	Good isolation	20 dB MIN	30 dB MIN
	Low insertion loss	0.3 dB MAX	0.2 dB MAX
	Handles average power	HC 100 Watts / JC 200 Watts	500 Watts
	Handles peak power	2000 Watts	2500 Watts
	Frequency range	100 MHz to 5 GHz	246 MHz to 6.5 GHz
	Outside dimensions	HC = .105″ JC = .145″	KC = .25″ dia round LC = .25″ square
	High reliability product	Used in communication satellites	Used in high power amplifiers
PLUS THESE ADVANTAGES	It's easy to use	To trim, use a razor blade and thermal strippers	Comes cut to length
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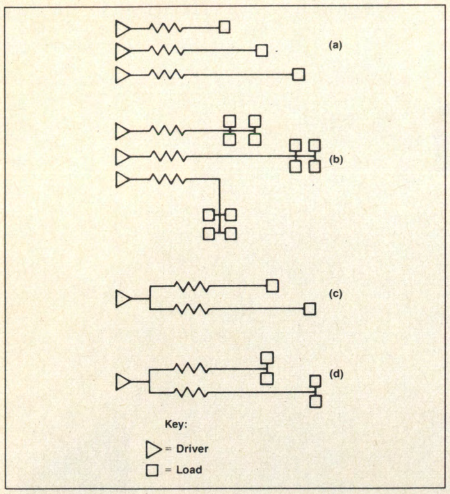

Figure 3. Acceptable high frequency signal distribution schemes, a) ideal, b) very good, c) usually OK, d) usually OK for small fanout.

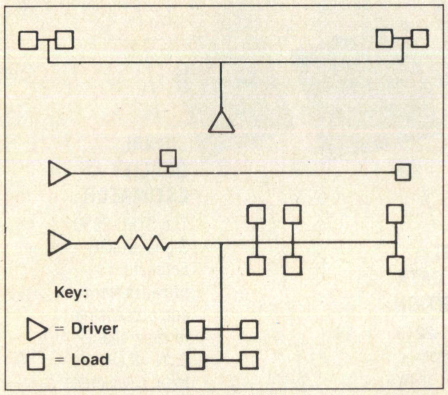

Figure 4. Unacceptable high frequency signal distribution schemes.

quirements of the circuit make it impossible to slow the transition time of the signal output, it then becomes necessary to control the impedance of the transmission path. References 2-5, or other sources, should be consulted for information on designing microstrip or stripline transmission lines. Even when these are used, the following high frequency distribution guidelines should be followed. Figure 3 shows a variety of acceptable high frequency distribution schemes, and Figure 4 shows some that are likely to cause problems. In general it will be necessary to add a series resistor (25 to 30 ohms) at the output pin of each driver, and to avoid having more than four loads per output. Loads common to any one driver should be physically close to each other.

Even when all of the above techniques are used, there are still instances when problems occur because of necessary discontinuities in the transmission path, or when the load impedance is too low at high frequencies. The discontinuities are most likely to be found when headers are used to connect a daughter board to the PCB, but sometimes at a point where the line splits to feed multiple loads from one driver, especially when the loads are not very close to each other. If this kind of problem is discovered, it is often possible to fix it by adding a small ferrite bead or SMT ferrite to the line at the source side of the discontinuity, as close to the discontinuity as possible. The exact value to be used in a given situation is best found by experimentation.

Additional Guidelines

Unused IC inputs and outputs should be connected to ground or to V_{cc}, according to the manufacturer's recommendation. The ideal PCB aspect ratio is one, 1, i.e., the board will be square. The higher the aspect ratio, the more difficult it will be to design a good EMC layout. The layout around an operational amplifier should be controlled such that input and output traces are as far from each other as possible, to prevent amplifier oscillations. Also, care should be taken to assure that the outputs do not drive undefined reactive loads, as that could also result in oscillations.

Designers of PCBs must consider EMC aspects of their designs at the inception of layout and device selection. This article presents a few suggestions for controlling EME at the beginning of the design cycle. ***RF***

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About the Author

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INFO/CARD 51

Crystal/Transformer Networks for Filtering

By Gerald Maliszewski
SAIC Range Systems

Many communication systems have interfering signals inside their frequency band which disrupt the receiving function. If the receiver can tolerate removal of narrow sections of the operating band then an ideal filter can be realized with sections of attenuation in the pass band. The Range Systems division of SAIC produces several types of transponders used for both position location and communications. SAIC is under contract to provide a version of our spread spectrum system, the R Cubed, to a customer with an application where many strong interferers operate in the same frequency allocation band. The filter described below will permit using this proven system without the added design expenses of shifting frequency, changing the receiver concept, or reallocating frequency spectrum use of other systems. For a low parts cost, a simple LC four pole filter was modified to reject multiple narrow band interferers without compromising the fundamental bandpass function.

The filter design described below allows the use of standard polynomial filter design look-up tables to calculate the filter type, the number of sections necessary, and the element values. A transformer/crystal network is created as an element dictated by the design. At the resonant frequency of the crystal, however, this network creates a low impedance path to ground, and a narrow band of attenuation inside the bandpass filter.

A narrow band notch of attenuation can be created by taking advantage of the crystal's series resonance. At resonance the reactance of C_s and L_s in Figure 1 is equal and creates a minimum impedance that is represented by R_s. C_o represents the capacitance of the case in which the crystal is mounted (1). A crystal placed from a 50 ohm node in shunt to ground would appear as a parallel impedance of R_s at the resonant frequency of crystal. If the value of R_s is relatively small compared to 50 ohms, then a low impedance point exists at the frequency of crystal resonance. The shape of this attenuation notch is determined by the Q of the crystal. Away from resonance, the reactance of C_o, about 5 pF, becomes dominant. The reactances of C_s and L_s are even larger and are insignificant compared to 50 ohms or 5 pF. Figure 2 shows the notch attenuation effect of placing a 62.3 MHz crystal (third overtone) in shunt to ground in a 50 ohm system. This attenuation notch can be made more pronounced by increasing the difference between the nominal impedance and the series impedance of the crystal.

A simple way to increase the impedance differential is to parallel crystals. Two crystals at the same frequency with a series resistance of 25 ohms now have a cumulative series resistance of 12.5 ohms and the attenuation notch depth can be described as follows:

$$\text{attenuation (dB)} = 20 \log \left(\frac{12.5}{50}\right) \quad (1)$$

The difficulty with this method is that the parallel case capacitances are additive and introduce a significant shunt load away from resonance.

The difference between the nominal nodal impedance and the crystal R_s can also be increased by raising the nominal impedance, but this can introduce interface difficulties with other assemblies or test equipment. An alternative is to maintain the nominal system but to shunt the crystals from high impedance nodes. The center nodes of filters with equally loaded ports are usually of much higher impedance than the system nominal value. Crystals shunted from these nodes can therefore produce a deeper notch but the case capacitance must be used as a tuning element of the tank circuit.

The crystal series impedance can also be reduced to achieve greater attenuation by using the crystal in a transformer network. The transformer translates the crystal impedance at resonance to a still lower value (2).

Figure 3 shows a schematic of a 4:1 impedance transformer. The impedance at port 1 can be described as follows:

$$R = \frac{V}{I} \quad (2)$$

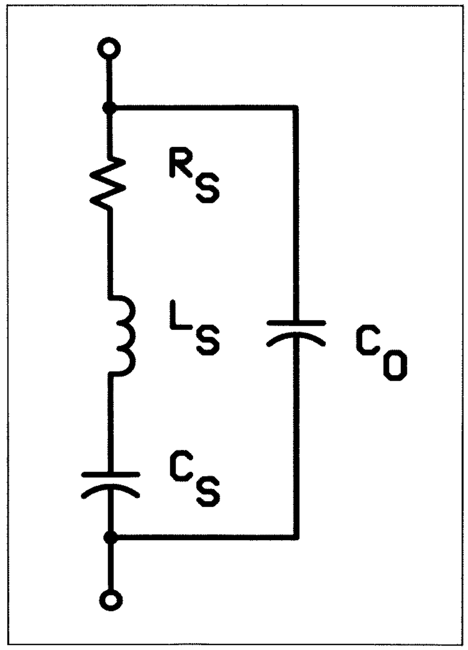


Figure 1. Series resonant crystal model.

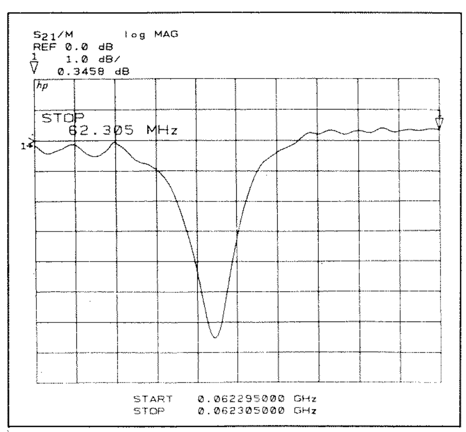


Figure 2. Crystal shunt load.

At port 2 the impedance, R, is transformed and seen as R_t.

$$R_t = \frac{(V/2)}{(2I)} = \frac{(V/I)}{4} \quad (3)$$

$$R_t = \frac{R}{4} \quad (4)$$

In theory the transformer ratio can be increased to any squared whole number (9:1, 16:1, etc.), but these transformers are larger and more complicated. Although the concept of a transformer is simple, the physical construction of one can be difficult to realize, especially at higher frequencies.

A common rule of transformer construction is to make the characteristic impedance the square root of the product of the load resistances.

$$Z_o = ((R)(R_t))^{1/2} = \frac{R}{2} \quad (5)$$

Another common rule is to make the reactance of the transformer large enough so that the (parallel) load impedance, R, becomes dominant (3). Figure 4 shows the increased attenuation made possible by adding a 4:1 transformer between the 50 ohm node and the crystal. An ideal transformer changes the crystal R_s of 25 ohms to 6.25 ohms creating a notch of 18 dB. Compromises were made in the design that degraded the characteristic impedance and the transformer inductance to allow the crystal/transformer to be useful at non-resonant frequencies.

With just the crystal shunted in a 50 ohm system, Figure 2, the case capacitance (5 pF) could be ignored, representing a shunt impedance of −500j ohms at 60 MHz. The effects of a transformer on the large imaginary impedance, C_o, requires further analysis. The transformer can no longer be represented as a simple transmission line

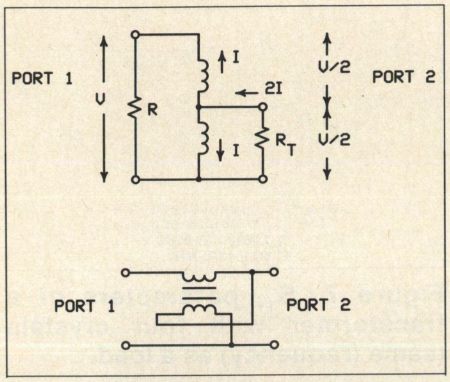


Figure 3. Transformer model.

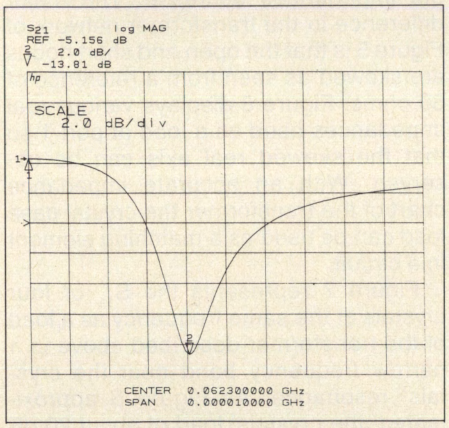
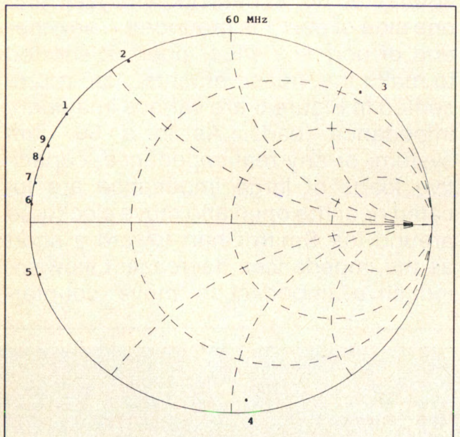


Figure 4. Crystal shunt load with transformer.

with a characteristic impedance of Z_o.

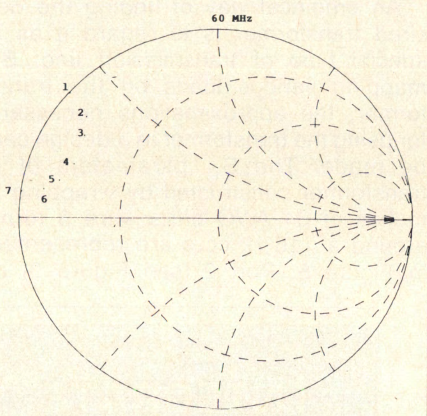
There are two methods of characterizing the transformer for all possible loads. One is to treat it as a linear two port network. With known S parameters for a particular transformer the impedance transformation of any load can be calculated. A close correlation was observed between calculated transformations and actual measurements. Before a transformer can be characterized by S parameters the designer must invent one that meets a number of design requirements. The transformer and its load of crystals must be an element that tunes the tank circuit at non-resonant frequencies of the crystals but still must perform its impedance transformation function at resonance.

An empirical way of finding the desired transformer is to regard it as a special type of transmission line. By mapping various loads on the transformer, the approximations necessary for using the transformer in a design can be made. The S_{11} parameters of a transformer constructed by wrapping 2 inches of 34 AWG bifilar wire 5 turns around a T16-12 core are represented in Figure 5. Port 2 (see Figure 3) is connected to a network analyzer and one side of port 1 is grounded. The other end of port 1 is either open or shorted to make the measurements. Also represented in Figure 5 are various imaginary impedance loads. As in a 50 ohm system, or any real impedance, capacitive loads of large impedance are located near the open and move clockwise around the Smith Chart toward a short as the impedances decrease. Likewise, inductive impedances move counter-



	LOAD	IMPEDANCE
1	OPEN	.02 + j15.5
2	20pf	.3 + j28
3	36pf	9 + j114
4	51pf	3.6 - j53.8
5	100pf	0.238 - j7
6	SHORT	0.116 + j2.35
7	41nh	0.113 + j5.2
8	113nh	0.107 + j8.5
9	151nh	0.114 + j10.4

Figure 5. S_{11} parameters of a transformer under various imaginary loads.



	LOAD	IMPEDANCE
1	OPEN	0.1 + j18.9
2	200 OHMS	4.5 +j17.5
3	100 OHMS	6 + j14.6
4	49.9 OHMS	6.4 + j9.3
5	25.5 OHMS	4.9 + j6.0
6	12.7 OHMS	3.0 + j4.3
7	SHORT	0.099 +j3.6

Figure 6. S_{11} parameters of a transformer under various real loads.

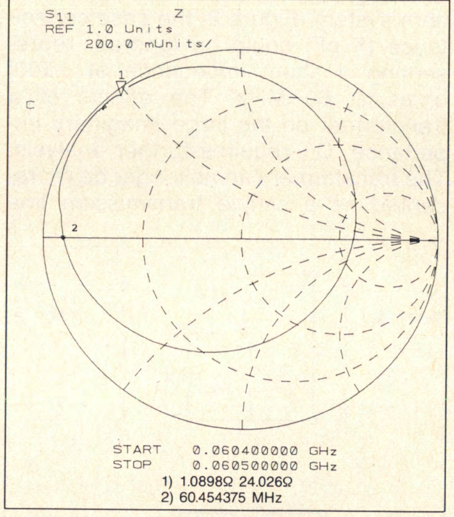


Figure 7. S_{11} parameters of a transformer with four crystals (same frequency) as a load.

clockwise from the open to the short as the impedances decrease. The major difference in the transformer network of Figure 5 is that the open and short nodes are skewed as seen from a reference of 50 ohms. Figure 6 displays various real impedances used as a load at port 1 so that the skewed real axis can be observed. With an accurate impedance chart of the transformer the crystal case load can be used as a matching element in a circuit.

Figure 7 represents the S_{11} of four crystals at the same frequency as a load of the transformer described above in a narrow frequency band near the crystals' resonance. As Figure 5 approximated, the crystals' load of about 20 pF appears as 24j ohms away from crystal resonance. Thus, the crystal/transformer network can be used as a 79 nH element with an unloaded Q of 22, yet at crystal resonance it will create a low impedance path of 2.5 ohms. The characteristic impedance of the transformer is approximately 77 ohms, it should be at least an order of magnitude lower to properly transform the cumulative series resistance of 6 ohms to 1.5 ohms. Normally in transformer construction the type and the length of wire are chosen to create the ideal Z_o to transform a resistive load. However, a low impedance transformer with high inductance would be a physically large, difficult device to construct. In practice the attenuation penalty paid due to ignoring the ideal Z_o is relatively slight, especially if the wire length is small compared to the wavelength (4).

The rule of making the transformer

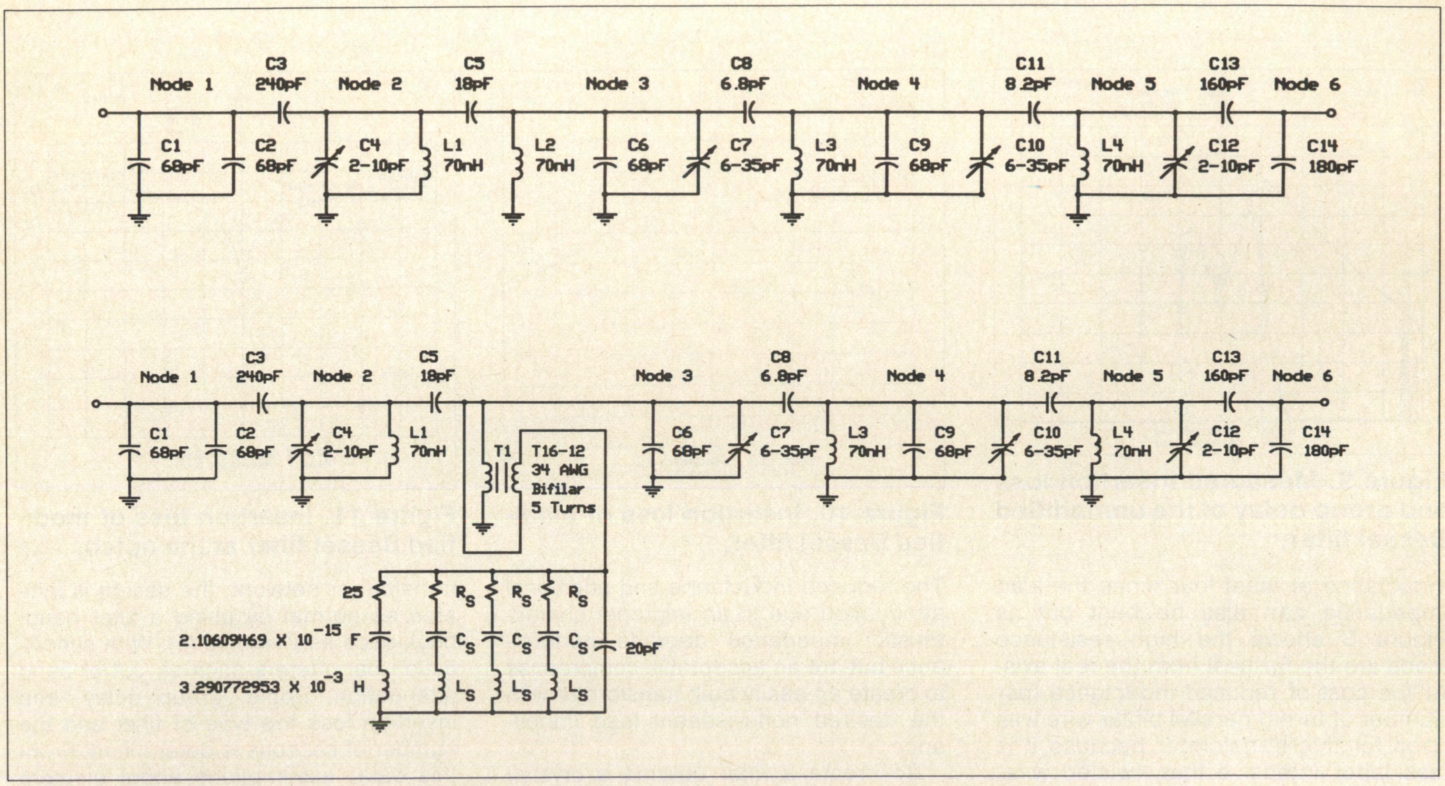


Figure 8. (a) a Bessel filter, (b) Bessel filter with crystal/transformer network.

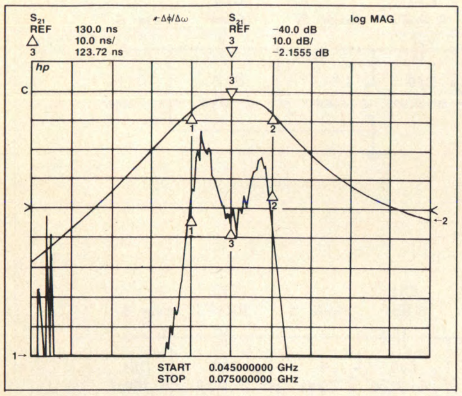


Figure 9. Measured insertion loss and group delay of the unmodified Bessel filter.

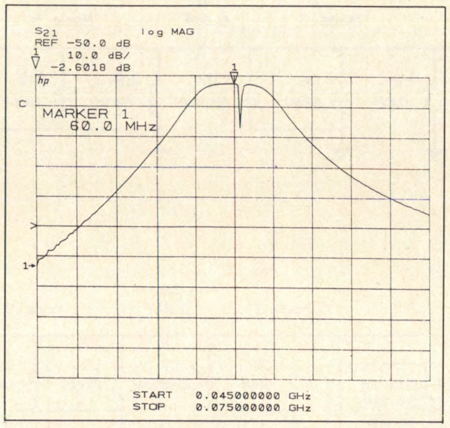


Figure 10. Insertion loss of modified Bessel filter.

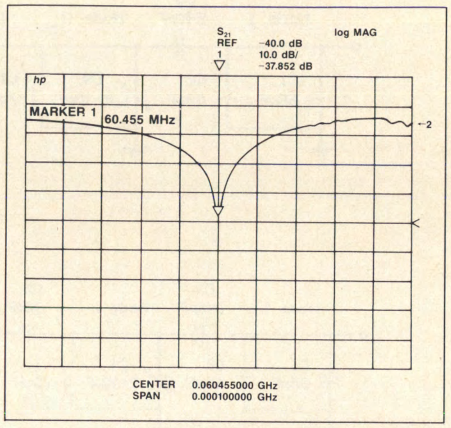


Figure 11. Insertion loss of modified Bessel filter at the notch.

inductance at least four times the load impedance can also be bent but as Figure 6 shows the high resistance loads are the furthest from the real axis. At the cost of reduced inductance (per number of turns) parallel bifilar wire was used for this transformer because it is less labor intensive than twisted wire.

The reduced inductance and additional attenuation due to an improper characteristic impedance degrade performance but are an acceptable compromise to create an easily built transformer with the desired non-resonant load impedance.

To create a filter utilizing a crystal/transformer network, the design is initiated as normal by using a filter handbook such as Zverev's (5). With specification parameters such as out of band attenuation, ripple, group delay, and insertion loss the type of filter and the number of sections is determined. From this data, assumptions about element values and unloaded Qs are developed. Once the element values of each section are determined then a crystal transformer network can be designed.

Using crystals in a filter allows the designer to take advantage of all three methods of increasing the impedance differential between the system nominal impedance and the crystal R_s. Multiple crystals can be paralleled, the crystals can be used in a transformer network, and the transformer network can be placed at a node of high nominal impedance. The number of crystals needed depends on the depth of the desired attenuation notch and the nodal impedance. With the number of crystals known, a transformer can be constructed to transform the total case capacitance to the desired tank inductance value. Variations in transformer characteristics can be accommodated by different core types, varying wire gauges and the number of turns, or the number of twists per inch of the bifilar wire.

In practice some time must be expended characterizing transformers empirically in order to meet filter design requirements. Once a transformer is chosen, S parameters can be measured. When it has been reduced to a two port network the filter design can continue as normal. This two port network and the required number of crystals can be readily added to computer filter models to accurately describe the overall filter response as well as the narrow band notches. With an accurate model the filter can be realized with a minimum of laboratory development.

The following description is an example of a filter design that includes a crystal/transformer network. The filter specifications are: 60 MHz center, a 3 dB bandwidth of 6 MHz, minimum variation in group delay, a 50 dB bandwidth of 80 MHz, and a 30 dB attenuation notch at 60.45 MHz, 3 kHz wide. The filter handbook dictates the design of a Bessel filter of four sections as shown in Figure 8a. The input and output resonators were modified to create optimum input and output matches. The actual insertion loss and group

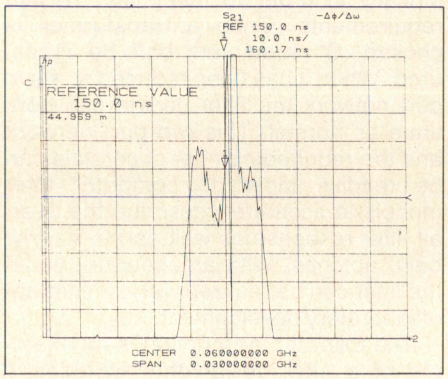


Figure 12. Group delay of the modified Bessel filter.

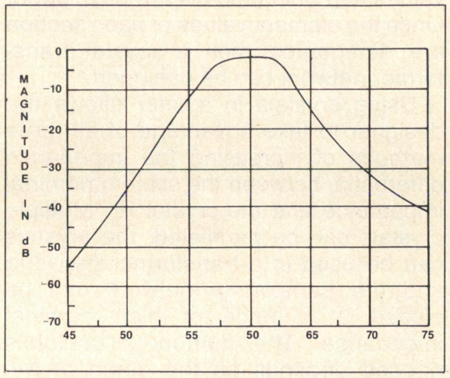


Figure 13. Insertion loss of computer modeled filter.

delay of this filter are displayed in Figure 9.

Next, the crystal/transformer network described above (Figure 7) was added. It was designed to provide an inductive load of 79 nH to replace L2 (Figure 8b). The crystals used have a series resistance of 25 ohms and a Q of 50k. They are third overtone crystals series resonant at 60.455 MHz. With the node (3) impedance calculated to be 150 ohms at 60 MHz, it was determined that four crystals were required to create the impedance differential necessary for the specified notch attenuation. Replacing L2 with the transformer and four crystals provides the S^{21} results shown in Figures 10, 11 and 12.

A computer generated model of the filter was developed with Super-Compact software. The resonator sections were set for an unloaded Q of 70. Figures 13 and 14 are the computer model analysis of the unmodified four pole Bessel filter described by Figure 8a and measured in Figure 9. Next the L2 element was removed and the S parameter values of the transformer were added to create a two port network between node 3 and the four crystals. The crystals were represented per the model of Figure 1 with a series resistance of 25 ohms and a Q of 50K. Figures 15-17 were generated by the computer and correspond to the actual measurements of Figures 10-12. As the figures show, the correspondence between the actual measurements and the model predictions are very close.

One of the primary considerations in the creation of the transformer network was the value of the unloaded Q. Five turns on a T16-12 produced a Q of 22. This unloaded Q is less than the value of 70 of the original inductor and contributed to an additional insertion loss of 0.5 dB. If insertion loss was a primary concern then a transformer network with a better Q could be developed. A higher Q transformer might present a different non-resonant load and the filter element values would be forced to accommodate the transformer network. Thus, transformer attributes such as load, unloaded Q, and characteristic impedance become part of the

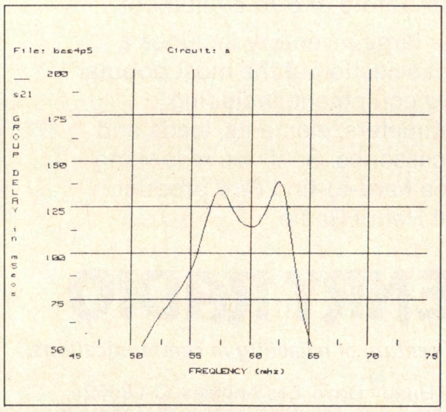


Figure 14. Group delay of computer modeled filter.

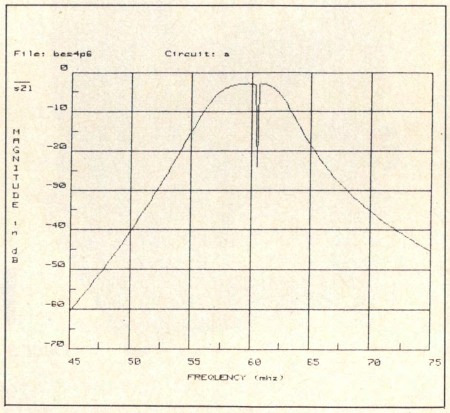


Figure 15. Insertion loss of computer modeled modified filter.

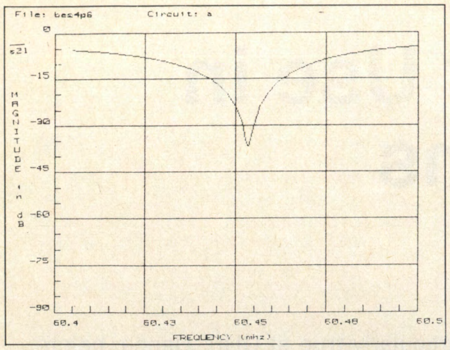


Figure 16. Insertion loss, at notch, of computer modeled modified filter.

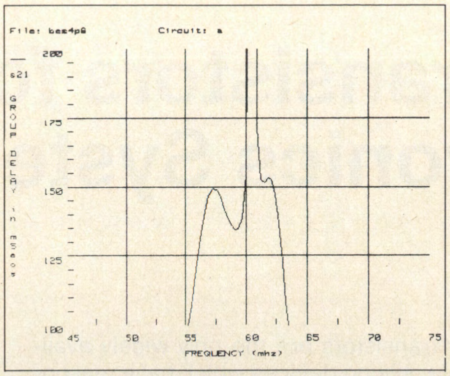


Figure 17. Group delay of computer modeled modified filter.

trade-off process of the filter design.

The notch created by a perfect transformer would have a depth of 40 dB. The price paid for using a transformer with a characteristic impedance of 77 ohms instead of 3 ohms is 3 dB. In this design notch attenuation was traded against concern for overall insertion loss.

Since the filter design is not dependent on the crystal frequency, crystals can be exchanged as notching requirements change. Wider, less deep, notches can be created by offsetting the crystal frequencies slightly. The exact offset is based on the crystal's Q and how flat a notch is required. By offsetting frequencies, a notch suitable for the attenuation of narrow band AM and FM signals can be constructed.

Of concern is the unintended ripples and notches created in the bandpass and group delay at frequencies close to crystal resonance. These effects are caused by the crystal's spurious responses which are relatively low series resonances at nearby frequencies. They could be modeled as parallel crystals with an R_s of hundreds or thousands of ohms. The spurious effects can be reduced by proper crystal parameter specification.

In summary, it is possible to add narrow band attenuation notches to filters without fundamental changes in design principles by the inclusion of a crystal/transformer network in place of one of the tank circuit elements. Compromises must be made in the transformer design that affect the overall filter response (unloaded Q), the attenuation notch (resonant load), and the desired tank element value (non-resonant load). The advantage of using the crystal/transformer networks is a low cost and easily implemented method of handling interference signals that can often be retro-fit into existing receivers.

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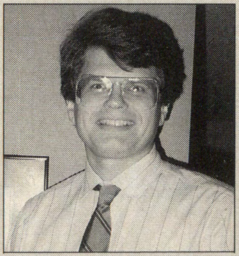
About the Author



Gerald Maliszewski received a BA in Sociology and a BSEE at the University of Buffalo, and is currently studying law at USD. He is the Project Engineer for the Upgraded Micro-B Transponder at SAIC Range Systems and can be reached at 10260 Sorrento Valley Road, San Diego, CA 92121.

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UHF Power Transistors for Use in Military Electronics Systems

By David W. Hughes
Georgia Tech Research Institute

The deployment of reliable, high performance military electronics for use at ultrahigh frequencies (UHF) requires the insertion of appropriate transistors. For receiver-type applications, the requisite transistor should enjoy exceptional dynamic range. For transmitters, an ability to deliver high power is desirable. This article examines four different types of UHF transistors and elucidates their respective abilities to address the needs of military, electronics systems.

A number of solid state devices are worthy of consideration by the UHF design engineer. Certainly, bipolar transistors are widely available for operation at UHF and their continued proliferation seems assured. However, high performance metal-oxide-semiconductor field effect transistors, static induction transistors and solid state triodes are beginning to make inroads into the ultrahigh frequency regime.

Bipolar Transistors

Bipolar power transistors are the workhorse of contemporary, solid state UHF modules. These transistors provide an attractive output power per unit cost and are widely available from a number of domestic suppliers. At present, bipolar transistors are the only widely available, silicon devices which have reasonable performance at 450 MHz and above.

Table 1 summarizes a number of characteristics of bipolar devices. One problem with such transistors is the exponential relationship between the collector current and the base-to-emitter voltage. This dependence tends to limit the dynamic range of practical, bipolar transistors.

Another feature of bipolar devices is the requirement to ballast the emitter array with small resistors in order to prevent localized thermal runaway. Unfortunately, a large fraction of the nonlinear feedback in bipolars is delivered back to the emitters through these ballast resistors (1). Consequently, the requisite emitter ballasting tends to degrade the distortion characteristics of the transistor.

Finally, the base impedance of bipolar devices is inherently low and this is particularly true at UHF. Hence, before power combining bipolars, it is necessary to transform each base impedance to a higher level in order to facilitate the design of the combiner matching networks (1).

Susceptible to both termal runaway and second breakdown
Higher-order intermodulation distortion is a function of both the type and the value of the emitter-ballasting resistors
Input impedance is a function of input drive voltage
Suffers from both shot noise and thermal noise
Currently, the only UHF solid state device that is widely available

Table 1. Selected characterisitics of bipolar transistors.

Metal-Oxide-Semiconductor Field Effect Transistors

N-channel, metal-oxide-semiconductor field effect transistors (MOSFETs) for power applications are typically fabricated using the vertical arrangement illustrated in Figure 1. A positive voltage applied to the gate tends to invert the surface of the p-wells and, thus, allows conduction between the source and the drain. Notice that the drain contact is on the back of the wafer and, as a result, the current ultimately flows vertically through the substrate. Adjustment of the substrate doping and thickness permits tailoring the drain-to-source breakdown voltage of the device. Furthermore, because an

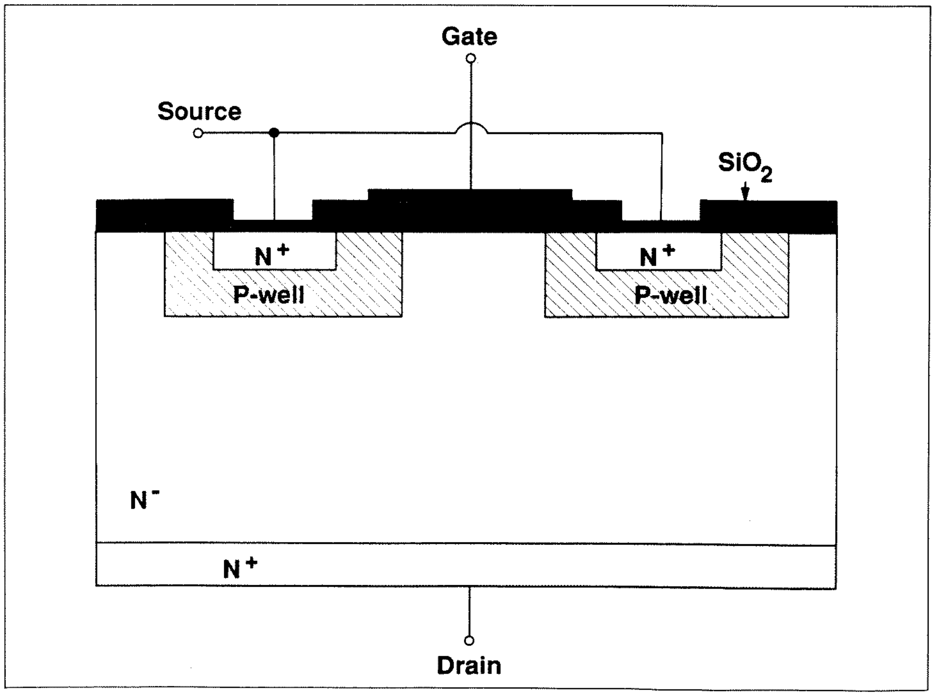


Figure 1. Simplified cross section of a power MOS transistor.

important portion of the conduction path is in the bulk of the crystal, the vertical MOS transistor is less sensitive to surface-charge problems than a more conventional, lateral MOSFET.

Although the power MOSFET is a majority carrier, enhancement-mode device, there are certain analogies to the bipolar transistor as elucidated in Table 2. In contrast, some of the characteristics peculiar to MOS are summarized in Table 3 (2).

One significant feature of the MOSFET is the square law dependence between the drain current and the gate-to-source voltage. Consequently, it is possible for a properly designed MOS device to have a higher dynamic range than a bipolar transistor. It is also interesting to note that the high gate impedance of MOSFETs tends to remain capacitive to fairly high frequencies. Therefore, it is possible to power combine such FETs without the use of ancillary matching networks (1).

A few manufacturers have begun to build vertical MOS structures which can operate well into the UHF band. Table 4 summarizes some important performance parameters of several such transistors. Note, in particular, that low noise figures have been achieved for even high power devices. Presumably, con-

Bipolar Nomenclature	MOS Analog
Collector	Drain
Emitter	Source
Base	Gate
BV_{CES}	BV_{DSS}
BV_{CBO}	BV_{DGO}
I_C	I_D
I_{CES}	I_{DSS}
I_{EBO}	I_{GSS}
V_{BE} (on)	V_{GS} (threshold)
V_{CE} (saturation)	V_{DS} (on)
R_{CE} (saturation)	R_{DS} (on)
h_{fe}	g_{fs}

Table 2. Some analogies between bipolar and MOS nomenclature.

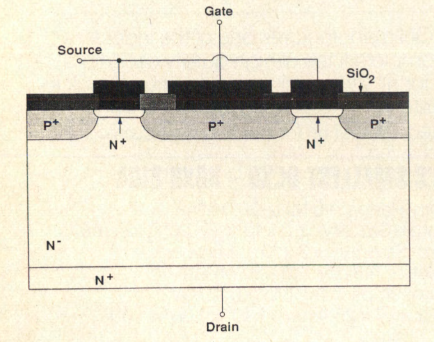


Figure 2. Simplified cross section of a static induction transistor.

tinuing advances will result in even better performance in the future. Consequently, it is interesting to ponder the possibility of using an appropriate high power MOSFET in the front end of a solid state receiver.

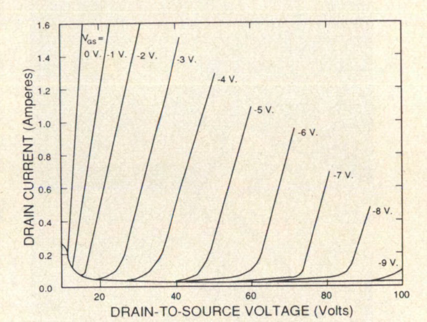


Figure 3. Current versus voltage characteristics for a static induction transistor.

Static Induction Transistors (SITs)

The static induction transistor is a vertical, field effect device as shown in Figure 2. However, unlike the vertical MOSFET, the current conducted by the SIT is a strong function of both the gate and the drain potentials (3). Consequently, a varying drain bias changes the output current, even in the presence of a fixed gate voltage. This leads to vacuum tube-like transfer characteristics as shown in Figure 3.

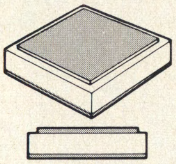
The static induction transistor is a high voltage device and, thus, derives its power handling capability via an elevated breakdown voltage rather than by an ability to conduct extreme values of current (4). Previous research has suggested that the SIT may enjoy reasonable noise performance because the channel region is buried in the substrate and, therefore, removed from the relatively more defective surface region (5). In any event, there are no minority charge storage problems because the SIT is a voltage-controlled, majority carrier device. Consequently, the static induction transistor can operate at high frequencies and high power performance into the UHF range has been reported (3).

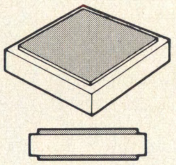
Solid State Triodes (SSTs)

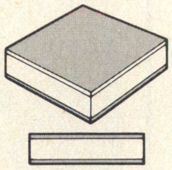
A variation of the static induction transistor is illustrated in Figure 4 and is being commercially produced under the trade name "solid state triode" (6). The current flowing out of the SST is a function of both the gate and the drain potentials. Consequently, the SST exhibits the familiar triode-like charac-

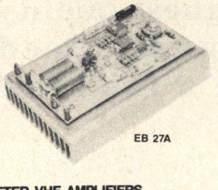
- Can be biased Class A without fear of thermal runaway
- Higher-order intermodulation distortion is better than with bipolars
- Lower-order intermodulation distortion is worse than with bipolars
- Input impedance is fairly insensitive to input drive voltage
- Input terminal has very high impedance and, thus, must be de-Q'd with a shunt resistance or negative feedback
- Displays no shot noise
- Easier than bipolar to broadband
- Requires a higher idling current than with bipolars
- Requires more chip area than bipolar to get equal output power
- May be readily used in switchmode power amplifiers

Table 3. Selected characterisitics of power MOS transistors.









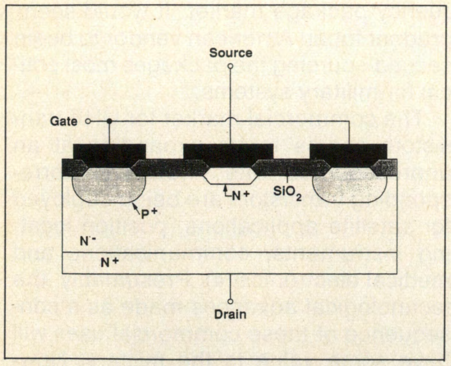


Figure 4. Simplified cross section of a solid state triode (Courtesy of Adrian Cogan, MicroWave Technology).

teristics shown in Figure 5. However, the SST operates by potential barrier control rather than relying on the space-charge-limited behavior of the SIT. Published results have demonstrated that these commercial solid state triodes are capable of high power operation into the UHF range and future work is expected to push this limit past one gigahertz (6).

Circuit Integration Issues

The vertical power devices discussed above employ the back of the semiconductor wafer for their respective output terminals. It is recognized, of course, that the unique requirements of these types of transistors preclude their monolithic integration, by conventional means, with other circuitry. Fortunately, advanced wafer preparation methods are becoming available which permit circumvention of these difficulties. One such technique involves semiconductor etch and refill as illustrated in Figure 6 (7,8). This method begins by photolithographically defining selected ar-

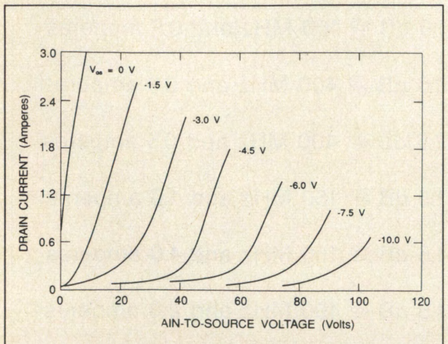


Figure 5. Current versus voltage characteristics for a solid state triode (Courtesy of Adrian Cogan, MicroWave Technology).

eas on a <100>-oriented, silicon substrate. The regions so defined will ultimately contain the conventional circuitry ancillary to the vertical power device. In the meantime, material in these regions is etched away using a caustic etch. Subsequently, three layers of epitaxy, alternating in conductivity type, are grown in a single operation. Finally, the composite assembly is mechanically ground back to expose the desired wafer configuration. In the example shown in Figure 6, it is apparent that a vertical transistor can now be fabricated in the center region of the wafer. Flanking this area are a pair of epitaxial islands which are junction-isolated from the central power device. These islands are useful for housing control devices and other, laterally-integrated circuitry.

Conclusion

There is intense pressure in the solid state device arena to reduce the cost of UHF power transistors. Conversations with industrial UHF radar module fabricators suggest that up to 60 percent of the cost of building the transmitter function results from power transistor procurement. Clearly, methods for reducing this cost handicap should be vigorously pursued. Unfortunately, a major contributor to the transistor cost lies in the price of the package itself (4). At present, a Japanese company named Kyocera totally dominates the high frequency package market. It would seem prudent for an American vendor to begin second-sourcing the packages most critical for military systems.

The commercial market for UHF transistors seems to be expanding at an unprecedented rate (4,9). The corresponding transistors are being deployed for satellite applications, position locating instruments, communications and medical electronics (4). Presumably, the technological advances made as a consequence of these commercial uses will have some value to the military. However, a significant fraction of the commercial devices is designed to operate with either a 12.5 volt or 7.5 volt power supply. Thus, the ease with which this commercial technology can be applied to military systems is yet to be determined.

Finally, the power device engineer must make a fundamental decision regarding the type of semiconductor substrate that will be specified. Silicon handles UHF nicely, although historically there has been some tendency to lean toward gallium arsenide as the microwave band is approached. Based on the maturity of the wafer processing technology and, also, the impressive performance achieved to date, it seems appropriate to recommend that silicon be considered for any system being developed for operation up through about 3-4 GHz.

Part Number	Output Power (Watts)	Frequency Of Operation (Megahertz)	Noise Figure
MRF 134	5	2-400	2.0 dB @ 150 MHz and 0.2 amperes
MRF 161	5	2-400	3.0 dB @ 400 MHz and 0.1 amperes
MRF 136	15	2-400	1.0 dB @ 150 MHz and 0.5 amperes
MRF 162	15	2-400	2.0 dB @ 400 MHz and 0.3 amperes
MRF 163	25	2-400	2.5 dB @ 400 MHz and 0.5 amperes
MRF 137	30	2-400	1.5 dB @ 150 MHz and 1.0 amperes
MRF 171	45	2-200	1.5 dB @ 150 MHz and 1.0 amperes
MRF 172	80	2-200	1.5 dB @ 150 MHz and 2.0 amperes
MRF 174	125	2-200	3.0 dB @ 150 MHz and 2.0 amperes

Table 4. Some performance parameters of selected, high frequency, power MOS transistors (Data courtesy of Motorola).

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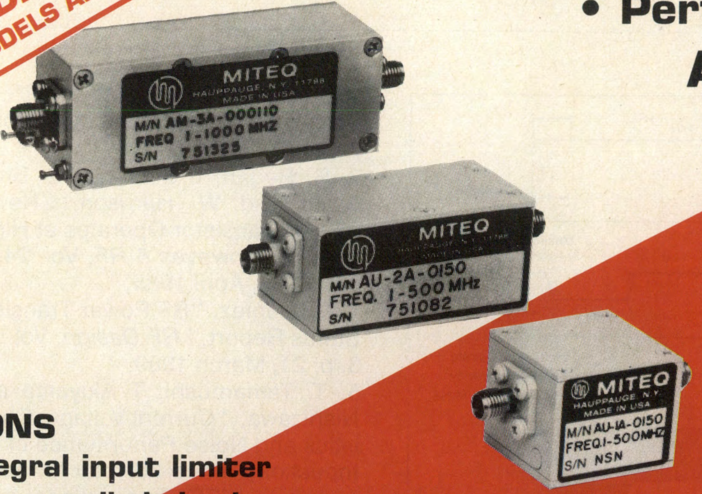

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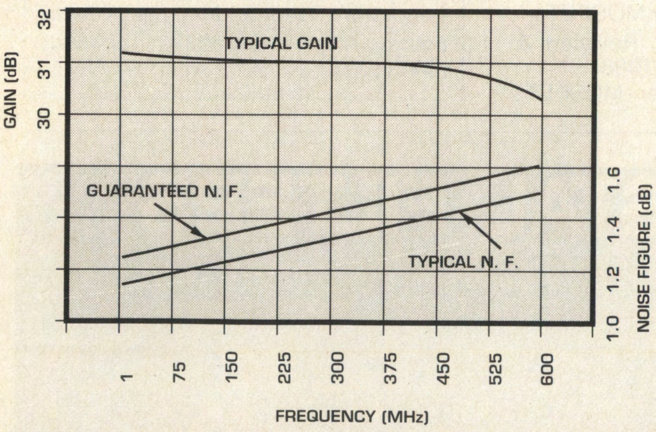
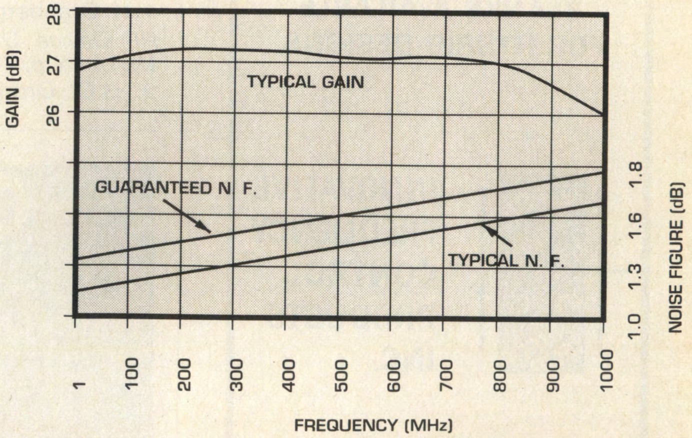
Model Number	Frequency (MHz)	Gain (Min.) (dB)	Gain Var. (Max.) (±dB)	Noise Figure (Max.) (dB) Low End	Mid Band	High End	VSWR (Max.)	Dynamic Range 1 dB Gain Comp. Output (Min.,dBm)	Nom. DC Power (+15V, mA)
AU-1054	1-500	30	0.5	1.25	1.4	1.5	2:1	+8	55
AU-2A-0150	1-500	30	0.5	1.25	1.4	1.5	2:1	+8	55
AU-3A-0150	1-500	45	0.5	1.25	1.4	1.5	2:1	+10	67
AU-1149	10-180	15	0.5	4.5	5.5	6.5	2:1*	+18	75
AU-1291	.015-500	60	0.75	1.25	1.4	1.5	2:1	+8	90
AM-1300	.01-1000	25	0.75	1.4	1.6	1.8	2:1	+6	50
AM-1052	1-1000	26	0.75	1.4	1.6	1.8	2:1	+6	50
AM-2A-000110	1-1000	27	0.75	1.4	1.6	1.8	2:1	+8	50
AM-1299	1-1000	38	0.75	1.4	1.6	1.8	2:1	+9	75
AM-3A-000110	1-1000	37	0.75	1.4	1.6	1.8	2:1	+9	75

* 75 ohm impedance level

AU-1054 and AU-2A-0150



AM-1052 and AM-2A-000110



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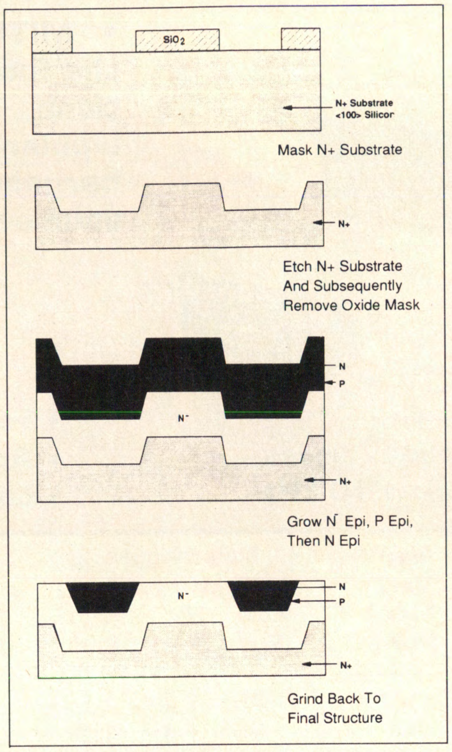

Figure 6. Simplified schematic of the semiconductor etch and refill technique.

Acknowledgment

It is a pleasure to acknowledge discussions with Dr. David Hertling during the preparation of this article. This work was partially supported by the United States Air Force, Rome Air Development Center. *RF*

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A Handy BASIC Program for High Resolution Plots

By Piotr Lochowicz
Warsaw Technical University

In engineering, it is often useful to have a computer program that gives a graphical display of a mathematical function, like the frequency response of a network, for example. It may also be desirable to have the capability of sweeping along the x-axis with simultaneous readout of the coordinates of the actual point of the plot. This article describes a BASIC program named GRAF that allows such display and manipulation of data.

The input data for the program are: a definition of the function to be plotted and endpoint values of the independent variable. An example of the plot is shown in Figure 1. It presents an exponentially damped cosine wave (see listing line 10 in Figure 3), namely:

F(X) = EXP(−X/3)* SIN(X)*COS(10X)

X is defined as ranging from 0 to 10.

The screen has been arranged to leave maximum space for the actual plot, allowing greatest resolution. PgDn and End keys move the marker up and down along the x-axis. However, it takes some time to get from one end of the graph to the other. Therefore, use Left and Right cursor keys to move the marker in 25-pixel steps. If you want to expand the x-axis for more detailed insight into a certain interval, press the X-key and enter new endpoint values. Press the E-key to exit the program.

A special feature of the program is an optional logarithmic scale for the x-axis which is needed for plotting frequency characteristics. It can be chosen after entering endpoint values and is signaled by graduations on the x-axis. One must bear in mind that, in this case, endpoint values have to be both smaller or greater than zero (error trapping is provided). This feature was used to draw the magnitude-squared transfer function in Figure 2 (listing line 20)

$$F(\omega) = 10 \text{ Log } \frac{0.1 + 6.2 * 10^{-6}\omega^2 + 9.2 * 10^{-12}\omega^4}{1 - 2 * 10^{-6}\omega^2 - 6.3 * 10^{-11}\omega^4 + 3.6 * 10^{-16}\omega^6}, \text{ dB}$$

over the frequency range of 10 to 10,000 rad/sec. Though useless for frequency characteristics, logarithmic scale is available for negative arguments as well.

The procedure may also be used as a subroutine of your own program. For this purpose, lines 10 through 30 must be deleted and the remaining ones RENUMbered as desired. Function definition (DEF FNF(X)=...) must then appear in the calling segment. For higher accuracy, arrays X( ) and FUNC( ) and variables FHI, FLO, MANT, PREV, RANGE, XHI, and XLO should be declared as double precision ones; PRINT USING defaults in lines 780-790 should be changed accordingly.

The subroutine requires a Hercules, CGA or EGA (or VGA

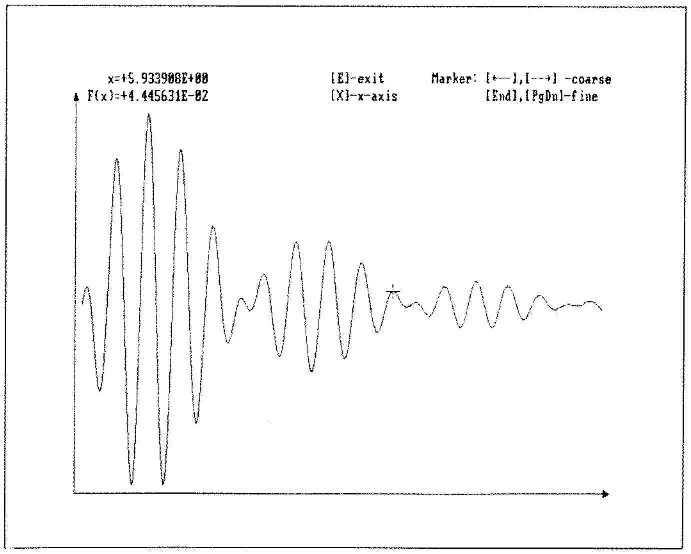


Figure 1. Plot of a damped modulated cosine wave generated by the program.

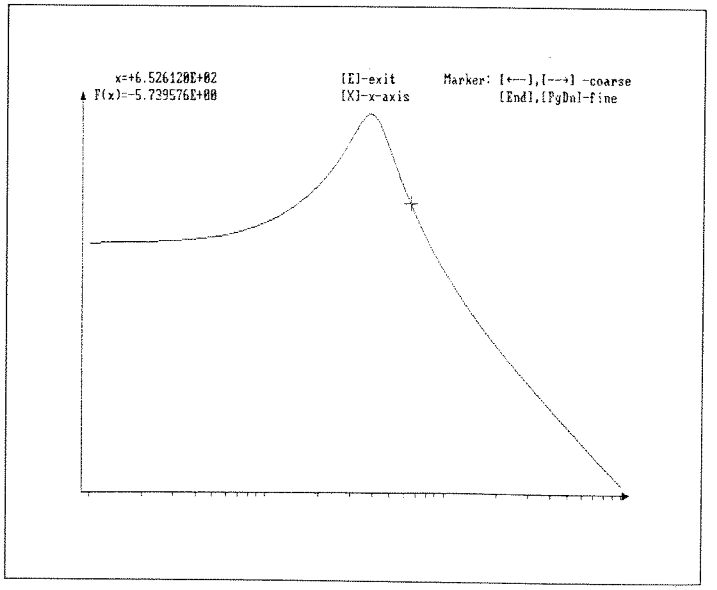


Figure 2. An example using a logarithmic scale.

working in EGA mode) graphics card. It may be run using Microsoft's QuickBasic, GWBasic or Basica. Since the BASIC language built-in graphics functions have been used, it is essential to have a version furnished with those functions. The program was developed using GWBasic version 3.20.

As noted above, the procedure may be used as a subroutine. Hence, a special effort was made to make it short, leaving as much of the computer memory for the main program as possible; any extra tricks and fancies were intentionally given up. Variables that store integer numbers were made integer and arrays which occupy a serious amount of memory are ERASEd before exiting the routine. The variables were also given unique names so that they would not interfere with those of the user's program.

This program can add high resolution graphics capability to your favorite computation program, or display a mathematical function for analysis simply and with an economy of memory. *This program is available on disk from the RF Design Software Service; see the ad on page 71 for ordering information.*

About the Author

Piotr Lochowicz can be reached at the Institute of Electronics Fundamentals, Warsaw Technical University, Nowowiejska 15/19, Warsaw, Poland.


```
10 DEF FNF(X)=EXP(-X/3)*SIN(X)*COS(10*X)
20 REM DEF FNF(X)=10*LOG((.1+.0000062*X^2+9.2E-12*X^4)/(1-.000002*X^2-6.3E-11*X^
4+3.6E-16*X^6))/LOG(10)
30 GOSUB 40:END
40 KEY OFF:CLS:LOCATE 10,26:PRINT"Choose graphics adapter:"
50 LOCATE 12,33:PRINT"[C]GA":LOCATE 13,33:PRINT"[E]GA"
60 LOCATE 14,33:PRINT"[H]ercules"
70 X$=INKEY$:IF X$<>"C" AND X$<>"c" THEN 90
80 II%=2:SCRWIDTH%=639:SCRHEIGHT%=199:GOTO 130
90 IF X$<>"E" AND X$<>"e" THEN 110
100 II%=9:SCRWIDTH%=639:SCRHEIGHT%=349:GOTO 130
110 IF X$<>"H" AND X$<>"h" THEN 70
120 II%=3:SCRWIDTH%=719:SCRHEIGHT%=349
130 SCREEN II%
140 CHRWIDTH%=(SCRWIDTH%+1)/80:CHRHEIGHT%=(SCRHEIGHT%+1)/25
150 AXLEFT%=3:AXRIGHT%=SCRWIDTH%
160 AXBOT%=SCRHEIGHT%-5:AXTOP%=1.25*CHRHEIGHT%
170 GRLEFT%=AXLEFT%+1+CHRWIDTH%:GRRIGHT%=SCRWIDTH%-CHRWIDTH%-1
180 GRBOT%=AXBOT%-CHRHEIGHT%/2:GRTOP%=2.5*CHRHEIGHT%
190 GRWIDTH%=GRRIGHT%-GRLEFT%+1:GRHEIGHT%=GRBOT%-GRTOP%+1
200 GRWIDTH1%=GRWIDTH%-1:CHRHEIGHT2%=CHRHEIGHT%/2
210 DIM X(GRWIDTH1%),FUNC(GRWIDTH1%),SCAL%(GRWIDTH1%)
220 CLS
230 LOCATE 7,26:PRINT"Enter endpoint values:"
240 LOCATE 9,33:INPUT"xmin=",XLO:LOCATE 11,33:INPUT"xmax=",XHI
250 IF XHI<=XLO THEN 220
260 LOCATE 13,26:PRINT"x-axis li[N]/lo[G] ?":X$=INKEY$
270 IF X$="N" OR X$="n" THEN X$="N"
280 IF X$="G" OR X$="g" THEN X$="G"
290 IF X$<>"N" AND X$<>"G" THEN 260
300 LOCATE 13,48:PRINT X$
310 IF X$="G" AND XLO*XHI>0 OR X$="N" THEN 330
320 CLS:LOCATE 1,8:PRINT"Error: xmin and xmax must be of equal sign, both <> 0 !
!!":GOTO 230
330 LOCATE 19,31:PRINT"Please wait...":FLO=FNF(XLO):FHI=FLO
340 IF X$="G" THEN 410
350 RANGE=XHI-XLO:MULT=RANGE/GRWIDTH1%
360 FOR II%=0 TO GRWIDTH1%
370 X(II%)=XLO+II%*MULT:FUNC(II%)=FNF(X(II%))
380 IF FUNC(II%)>FHI THEN FHI=FUNC(II%)
390 IF FUNC(II%)<FLO THEN FLO=FUNC(II%)
400 NEXT:GOTO 470
410 RANGE=XHI/XLO
420 FOR II%=0 TO GRWIDTH1%
430 X(II%)=XLO*RANGE^(II%/GRWIDTH1%):FUNC(II%)=FNF(X(II%))
440 IF FUNC(II%)>FHI THEN FHI=FUNC(II%)
450 IF FUNC(II%)<FLO THEN FLO=FUNC(II%)
460 NEXT
470 RANGE=FHI-FLO:CLS:LINE(AXLEFT%,AXBOT%)-(AXRIGHT%,AXBOT%)
480 FOR II%=1 TO 3:LINE-(AXRIGHT%-CHRWIDTH%+1,AXBOT%-II%)
490 LINE-(AXRIGHT%-CHRWIDTH%+1,AXBOT%+II%)
500 LINE-(AXRIGHT%,AXBOT%):NEXT
510 LINE(AXLEFT%,AXBOT%)-(AXLEFT%,AXTOP%)
520 FOR II%=1 TO 3:LINE-(AXLEFT%-II%,AXTOP%+CHRHEIGHT2%-1)
530 LINE-(AXLEFT%+II%,AXTOP%+CHRHEIGHT2%-1)
540 LINE-(AXLEFT%,AXTOP%):NEXT
550 LOCATE 2,3:PRINT"F(x)=":MULT=(GRHEIGHT%-1)/RANGE
560 PSET(GRLEFT%,GRBOT%-((GRHEIGHT%-1)*(FUNC(0)-FLO)/RANGE))
570 FOR II%=0 TO GRWIDTH1%
580 SCAL%(II%)=GRBOT%-MULT*(FUNC(II%)-FLO)
590 LINE-(GRLEFT%+II%,SCAL%(II%)):NEXT
600 IF X$="N" THEN 700
610 L10=LOG(10):PREV=X(0)/10^(INT(LOG(ABS(X(0)))/L10))
620 IF PREV<>INT(PREV) THEN 640
630 LINE(GRLEFT%,AXBOT%)-(GRLEFT%,SCRHEIGHT%)
640 FOR II%=1 TO GRWIDTH1%
650 MANT=X(II%)/10^(INT(LOG(ABS(X(II%)))/L10))
660 IF INT(MANT)=INT(PREV) THEN 690 ELSE MID%=INT(MANT)
670 IF ABS(PREV-MID%)>ABS(MANT-MID%) THEN MID%=0 ELSE MID%=1
680 LINE(GRLEFT%+II%-MID%,AXBOT%)-(GRLEFT%+II%-MID%,SCRHEIGHT%)
690 PREV=MANT:NEXT
700 LOCATE 1,39:PRINT"[E]-exit       Marker: [ --],[-- ] -coarse"
710 LOCATE 1,63:PRINT CHR$(27):LOCATE 1,71:PRINT CHR$(26)
720 LOCATE 2,39:PRINT"[X]-x-axis                 [End],[PgDn]-fine"
730 LOCATE 1,6:PRINT"x=":MARKSCAL%=GRWIDTH%\2
740 XCUR%=MARKSCAL%+GRLEFT%:YCUR%=SCAL%(MARKSCAL%)
750 LINE(XCUR%-CHRWIDTH%,YCUR%)-(XCUR%+CHRWIDTH%,YCUR%)
760 LINE(XCUR%,YCUR%-CHRHEIGHT2%+1)-(XCUR%,YCUR%+CHRHEIGHT2%-1)
770 PRESET(XCUR%,YCUR%)
780 LOCATE 1,8:PRINT USING"+#.######^^^^";X(MARKSCAL%)
790 LOCATE 2,8:PRINT USING"+#.######^^^^";FUNC(MARKSCAL%)
800 X$=INKEY$:IF LEN(X$)=2 THEN 830
810 IF X$="E" OR X$="e" THEN 900
820 IF X$="X" OR X$="x" THEN 220 ELSE 800
830 IF RIGHT$(X$,1)="Q" THEN STP%=1:GOTO 870
840 IF RIGHT$(X$,1)="M" THEN STP%=25:GOTO 870
850 IF RIGHT$(X$,1)="O" THEN STP%=-1:GOTO 870
860 IF RIGHT$(X$,1)<>"K" THEN 800 ELSE STP%=-25
870 IF STP%<0 AND MARKSCAL%<ABS(STP%) THEN 800
880 IF STP%>0 AND MARKSCAL%>GRWIDTH1%-STP% THEN 800
890 GOSUB 910:MARKSCAL%=MARKSCAL%+STP%:GOTO 740
900 ERASE X,FUNC,SCAL%:CLS:RETURN
910 LINE(XCUR%-CHRWIDTH%,YCUR%)-(XCUR%+CHRWIDTH%,YCUR%),0
920 LINE(XCUR%,YCUR%-CHRHEIGHT2%+1)-(XCUR%,YCUR%+CHRHEIGHT2%-1),0
930 LINELEFT%=MARKSCAL%-CHRWIDTH%:IF LINELEFT%<1 THEN LINELEFT%=1
940 LINERIGHT%=MARKSCAL%+CHRWIDTH%+1:IF LINERIGHT%>GRWIDTH1% THEN LINERIGHT%=GRW
IDTH1%
950 FOR II%=LINELEFT% TO LINERIGHT%
960 LINE(II%-1+GRLEFT%,SCAL%(II%-1))-(II%+GRLEFT%,SCAL%(II%))
970 NEXT:RETURN
```

Figure 3. The plotting program GRAF listing.

Capacitors and Resistors — Niche Markets Carry the Load

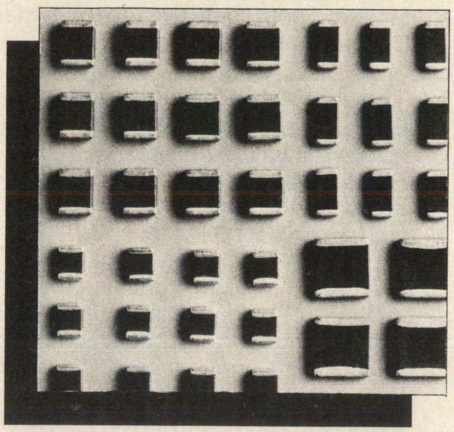
By Liane G. Pomfret
Associate Editor

Because capacitors and resistors are high volume, generic parts, they have been affected by the recession more than much of the RF industry. There aren't major, new developments or radical new applications to fuel the marketplace so, companies are looking elsewhere to generate sales.

Despite the war in the Persian Gulf, the military market has dropped off. In all likelihood, the war generated the need for replacement parts but very little else. The military market has been slow for the past year due to lack of new projects and is expected to remain slow for the time being. Most of the military market involves retrofitting or upgrading of equipment. On the brighter side, the demand for capacitors and resistors has picked up in the commercial communications area. This hardly comes as a surprise, the communications market is doing exceptionally well despite the recession. Even with a growing communications market, there is only so much business to go around and manufacturers are realizing that they can either try to win a larger share of the domestic market or break into the overseas market. Both are tough to do, but they offer a chance to earn profits.

Don Davis, Director of Sales and Marketing for American Technical Ceramics notes, " Sales are expected to change little. Increased efforts in some areas cannot make up for decreases in other areas. We continue to grow our overseas markets which we view as very important to us." Their strategy has been to become a marketing liaison for other companies overseas in order to counteract the slowdown they have felt in domestic sales. Other companies are trying other approaches. "We are positioning ourselves to be more responsive to large volume, low cost applications," according to Gunther Vorlop, Sales and Marketing Manager for Dielectric Laboratories. They are moving from a traditional military market into the commercial communications market.

Other companies are fighting the downturn in the market by turning to or remaining in niche-oriented markets.



Specialized markets rarely suffer the same effects as the rest of the market does. Provided they are well marketed and carefully chosen, a niche can be profitable. Carborundum is an excellent example of this. As Don Cooke, Product Manager notes, "We're not a commodity market. We're used when there's a problem involved; the feature that they [the customer] are using is the non-inductiveness. We have a niche market." Carborundum is also positioning itself to make the RF community more aware of them as a supplier. Even with these strategies, "we're seeing a flat market," says Cooke. But their market orientation and products position them to survive the recession with a minimum of disruption.

A Different Approach

While the companies already mentioned deal mostly in high volume or specialized parts, one company has taken another approach — low volume, low cost. Communications Specialists entered the capacitor/resistor business through the back door. Spence Porter, President of Communications Specialists explains, "When we started to convert our production line to surface mount, we needed small quantities [of capacitors and resistors] for prototyping and couldn't find them. So, we bought a reel in each value and recouped our investment by putting together kits of small quantities for other people to buy." Recently, they also started offering individual values for sale. Manufacturers or service repair people who only need a small quantity are often unable to find a source that offers reasonably priced, low volume sales. Porter also points out that "people who are repairing equipment or prototyping need small quantities, and manufacturers won't talk to you if you want anything less than a reel." Communications Specialists has received excellent response to their small quantity service — an indication that it is much needed.

Applications

Capacitors and resistors are found in virtually anything electronic. The list of applications keeps expanding into areas such as pulsed RF, solid state radar, fusion work, medical electronics, navigation equipment, and more. These applications often have unusual requirements in size, power handling and heat handling capabilities. High power is another area that companies are concentrating on. In many cases, the object is to get as much power handling as possible into as small a device as possible. Small size combined with large power handling capabilities inevitably creates a heat problem. Carborundum has come up with a different solution to the heat sink. In addition to using ceramics with higher thermal conductivity, they are using direct water cooling of the ceramic. In essence, sandwiching the ceramic between layers of water.

The capacitor/resistor market appears to be full of contradictions. For some companies, times are tough; for others business is going well. There are few new innovations or developments in the capacitor and resistor area, but there are constant refinements and improvements to existing technology. While there is no doubt that the capacitor and resistor market has been affected by the recession, it is still a healthy market with many stable suppliers. ***RF***

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Ionospheric Radio

By Kenneth Davies
Published by Peter Peregrinus Ltd, for the Institution of Electrical Engineers, 1990, 580 pages
List price: $68.00

This book should be included in the library of anyone doing serious work in ionospheric research or communications. It updates two earlier works by the same author, published in 1965 and 1969, including new material on earth-space propagation, medium frequency propagation, and ionospheric modification. Intended for scientists, engineers and advanced students working in many different areas of ionospheric phenomena, the text emphasizes the physical principles that affect radio propagation. The book begins with an analysis of plasmas and their interaction with electromagnetic waves, followed by substantial chapters on solar-terrestrial relationships and magnetoionic theory.

With this theoretical foundation, succeeding chapters address radio soundings, structure of the ionosphere in D, E and F layer models, oblique (reflective) propagation, amplitude/phase characteristics of propagated signals, earth-space propagation, and ionospheric disturbances. Chapters on low, medium, high, and very high frequencies cover practical RF propagation characteristics. The book concludes with a very interesting chapter on ionospheric modification, both natural and man-made. Circle **INFO/CARD #210.**

The ARRL UHF/Microwave Experimenter's Manual

Published by the American Radio Relay League, 1990, 448 pages
List price: $20.00

If you have any doubts about the quality of work done by "amateur" experimenters, this book will remove them. Of the approximately 20 contributors, nearly all of them are engineers working in RF and microwave industries. The book emphasizes techniques for building and evaluating equipment operating in the frequency range of 420 MHz to 10 GHz and above. For non-amateurs, this book would shed some light on the practical aspects of turning theoretical designs into working hardware.

Topics covered include tutorial reviews of microwave principles and components, plus design information for printed microstrip elements, filters, frequency multipliers, MMIC applications, and coaxial switches. Several chapters address performance and its measurement, including system noise temperature, antenna performance, sun and moon noise calibration procedures, and basic test equipment and measurement procedures. Yagi, parabolic and helical antenna design and construction are described,as well. A chapter devoted to computer modeling and computer-aided design of microwave circuits and systems rounds out the book. **INFO/CARD #209.**

Reflections: Transmission Lines and Antennas

By M. Walter Maxwell
Published by the American Radio Relay League, 1990, 384 pages
List price $20.00

A pioneer in spacecraft antenna design, the author presents an intuitive and practical approach to the subject of antennas, transmission lines, and impedance matching. Basic transmission line and antenna concepts are presented, along with standard matching techniques used either at the antenna, at the transmitter, or distributed throughout the feed system. Since the book is primarily intended for an amateur audience, many of the examples are for specific antennas (double-bazooka, extended double-zepp), and accessories (transmatch tuners) used by amateurs. This approach results in little information on impedance measurements, since few amateurs are equipped for them.

One of the purposes for writing the book was to correct the common misconception among amateurs that a 1:1 VSWR is the only important or acceptable situation. Unfortunately, this message is repeated so often as to become tedious. But, the information presented is both correct and necessary for any amateur or professional dealing with antennas. This, combined with its low price, makes it a worthwhile reference text. For more information, circle **INFO/CARD #208.**

CAE Speed Increased

Hewlett-Packard's microwave design system (HP 85150B) and high-frequency structure simulator (HP 85180A) are now ported to the HP Apollo 9000 Series 700 workstations. The new RISC-based workstations are five times faster than previous systems. In addition to running on the Series 700, the design system and structure simulator run on Sun and other HP and Apollo workstations. The HP 85150B High Frequency Design System is $44,500 with delivery scheduled for September 1991. The HP 85180A is $45,000 with delivery slated for July.
Hewlett-Packard Co.
INFO/CARD #205

Expanded Filter Types

Version 2.07 of ACTIVE™ has added three more filter types — elliptic, Gaussian and linear phase to the present selection of Butterworth, Chebyshev, Bessel, and Real Pole. These operate as a LPF, HPF, BPF, all pass or notch filters. In addition, the number of possible circuit configurations has been expanded to 23. Based on selectable component tolerances, ACTIVE displays the ideal characteristics along with a statistical graphic presentation of the random Monte-Carlo sweeps of the filter's performance. ACTIVE runs on IBM PC/XT/AT and compatibles with Hercules, CGA or EGA graphics. Price is $745.
Tatum Labs, Inc.
INFO/CARD #204

HTBasic Upgrade

High Tech Basic Release 3.0 is now available from TransEra. HTBasic now offers complex numbers which are integrated directly into the program. International language support has also been added. Release 3.0 includes the software drivers for most IEEE-488 controller cards and another loadable driver allows the use of "Super VGA" display adapters. Additional syntax extensions simplify structured programming, data acquisition, user interaction, and type conversion.
TransEra
INFO/CARD #203

PC-Based Data Acquisition

Asyst Software Technologies is now offering a series of complete data acquisition systems that combine hardware and software in one package. The systems range from the EASYEST™ System 8, designed for basic applications such as data logging and product testing, to the high-end VIEWDAC System 575, design for complex applications on a 32-bit 386- or 486- based PC. Specialized start-up sequences allow the user to test for proper system configuration. Built-in sequences for performing as a strip chart recorder, oscilloscope, spectrum analyzer and limit controller are also included. Prices start at $995 for EASYEST and range up to $4195 for the System 575.
Asyst Software Technologies, Inc.
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CAE Software Driver

The HP 11755A RF simulator WorkSystem driver provides a computer-aided-engineering software linkage between HP's vector arbitrary-waveform synthesizer and the Signal Processing WorkSystem from Comdisco. This software/hardware combination shortens system- and circuit-design cycles. A real-life, system-test signal can exercise breadboards and circuit modules with the equivalent signal used in the software block diagram routines. The HP 11755A RF simulator is priced at $5000 and delivery is estimated at four weeks ARO.
Hewlett-Packard Co.
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INFO/CARD 72

RF literature

Control Components Catalog

The M/A-COM Control Components Division has announced a 352 page catalog covering over 1900 solid state and passive control components. Products featured range from integrated packages to attenuators and waveguide adapters. An appendix has been included which lists a full glossary of technical terminology and drop-in module applications. Each product section contains complete specifications and outline drawings, plus a design guide to aid in specifying standard or custom products.
M/A-COM Control Components Division
INFO/CARD #199

Wire Products

A wire reference guide and data book is now available from MWS Wire Industries. The brochure provides specifications for more than 25,000 different wire products available off-the-shelf. Products include copper and aluminum magnet wire, Litz wire, plated wire and ribbon, and resistive wire. A series of conversion tables, specification cross references and material selection guides are also included.
MWS Wire Industries
INFO/CARD #198

Cellular RF Product Brochure

Alpha Industries has introduced their new Cellular RF Product Source brochure, containing product ordering information for an integrated product line including both catalog and customized products for cellular or cordless handset and base station design.
Alpha Industries, Inc.
INFO/CARD #197

Surface Mount Inductors

A new brochure describing inductive chip beads and surface mount inductors from .01 uH to 1000 uH is available from J. W. Miller. Listed are PM20 "1210" Series chip inductors from .01 uH through 220 uH, PM20S "1210" Series shielded chip inductors from 10 uH through 270 uH, PM40 "1812" Series chip inductors from .1 uH through 1000 uH, and PMB Series chip beads with impedance ratings from 10 ohms through 120 ohms at 100 MHz.
J.W. Miller Division
Bell Industries
INFO/CARD #196

Oscillator Data Sheet

Frequency Electronics, Inc. has issued a data sheet on their new MCXO Microcomputer Compensated Crystal Oscillator which features a unique approach to solving the problem of stability and aging, coupled with very low power. The data sheet contains full specifications, charts, diagrams and outlines.
Frequency Electronics, Inc.
INFO/CARD #195

Component Catalog

Microflect's new 120 page Component Catalog CC391 has over 1,000 items for waveguide support and protection, tower accessories, and tower hardware. It also includes support structures for antennas. The waveguide support system components, entries, and related products and examples show recommended installation configurations. Tower accessories, including antenna mounting kits, climbing kits, lighting and grounding accessories, and galvanized and stainless steel tower hardware are listed.
Microflect, Salem
INFO/CARD #194

IF and RF Component Catalog

RTI has announced its new IF and RF components product literature catalog, containing RTI's current product offering of linear amplifiers, logarithmic amplifiers, discriminators, telemetry receivers, down converters and monopulse subsystems.
Radar Technology, Inc.
INFO/CARD #193

Microwave Components

A 512 page catalog detailing a complete line of microwave components and instruments has been announced by Loral Microwave-Narda. Reference guides and technical data open each of the sixteen product group sections followed by descriptions, specifications, and outline drawings. Catalog 26 covers four application categories: millimeter wave, high power passive products, passive products for communications, and custom passive components and networks.
Loral Microwave-Narda
INFO/CARD #192

RF Cable Catalog

A new RF cable catalog presents the product range of coaxial cable from Huber +Suhner AG. Besides the standard cables available from stock, numerous special cables are listed with properties such as flame retardant, halogen free, high flexibility or good screening effectiveness. The catalog also includes a material selection guide and a glossary of terms used in cable technology.
Huber + Suhner AG
INFO/CARD #191

High Intercept Amplifier Handbook

AML, Inc. has announced the release of its new High Intercept Low Noise Amplifier Handbook. This catalog contains wideband performance and outline information on sixty new high intercept amplifier products. Frequencies from 0.1 to 2000 MHz are covered, some with second order intercepts as high as 80 dB above the 1 dB compressed power. Package types include connectorized, TO-8 and surface mount.
AML, Inc.
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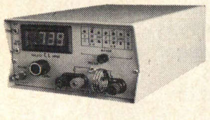

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