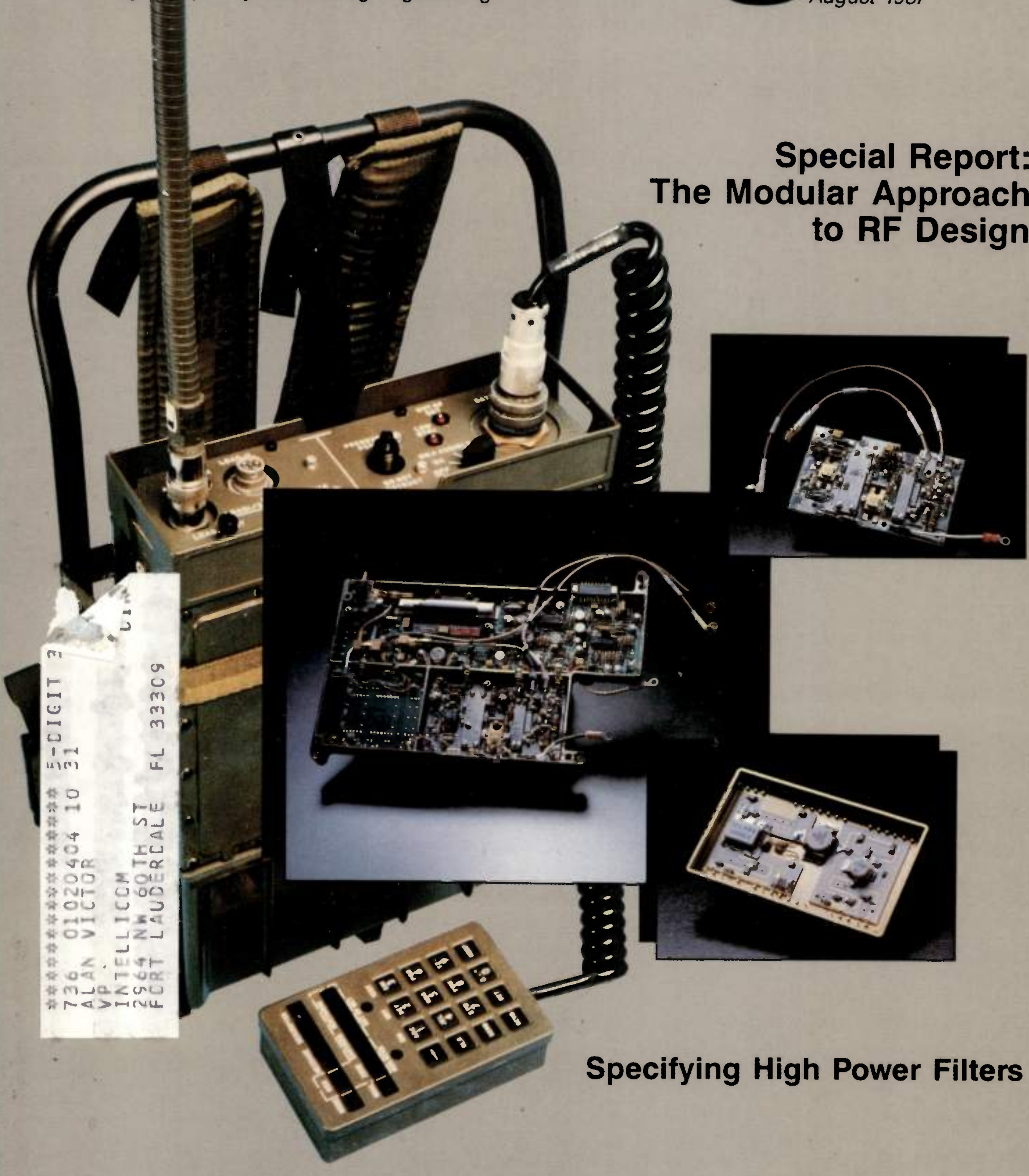
rf design

high frequency and analog engineering

August 1987



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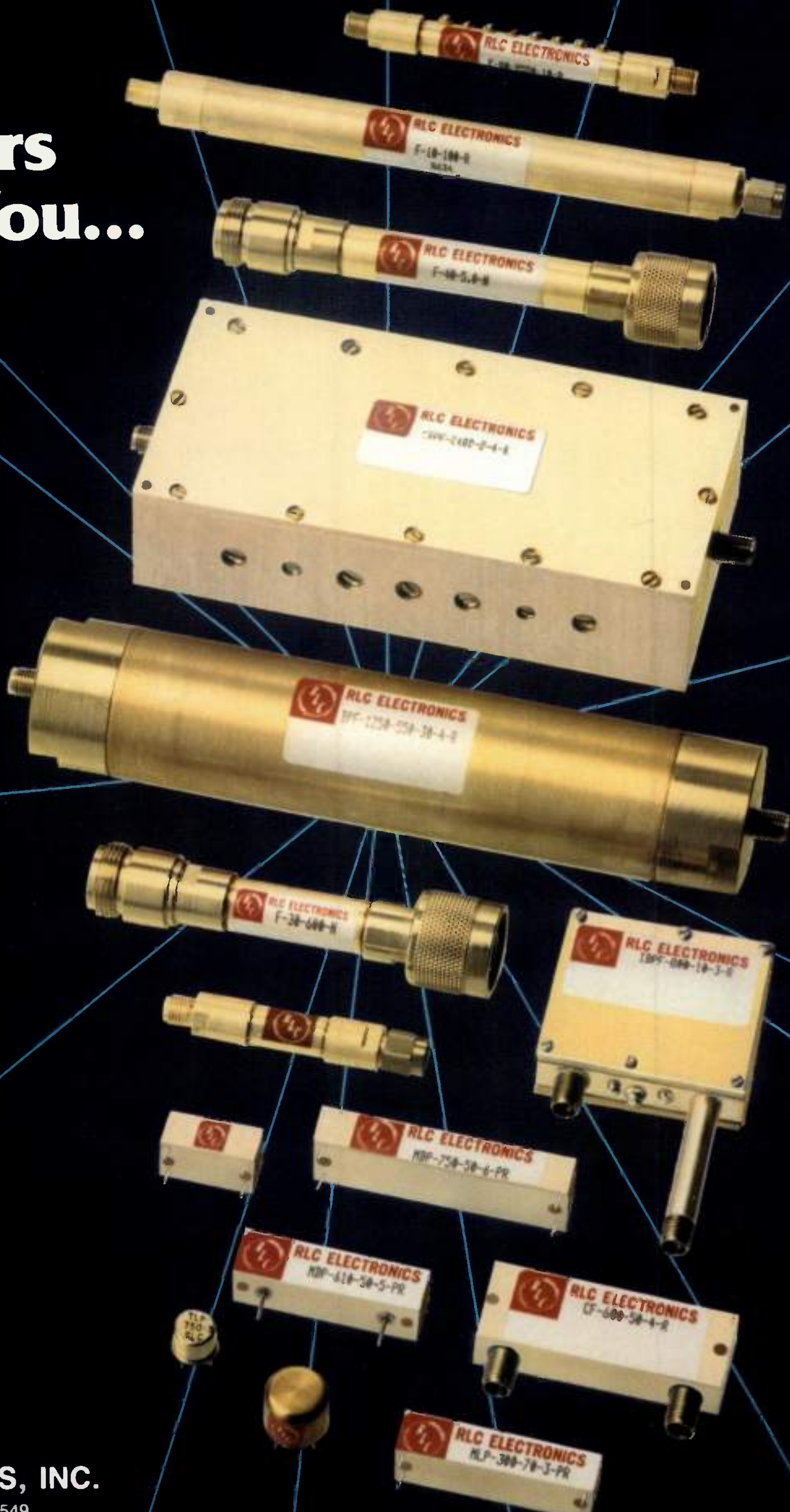

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INFO/CARD 1

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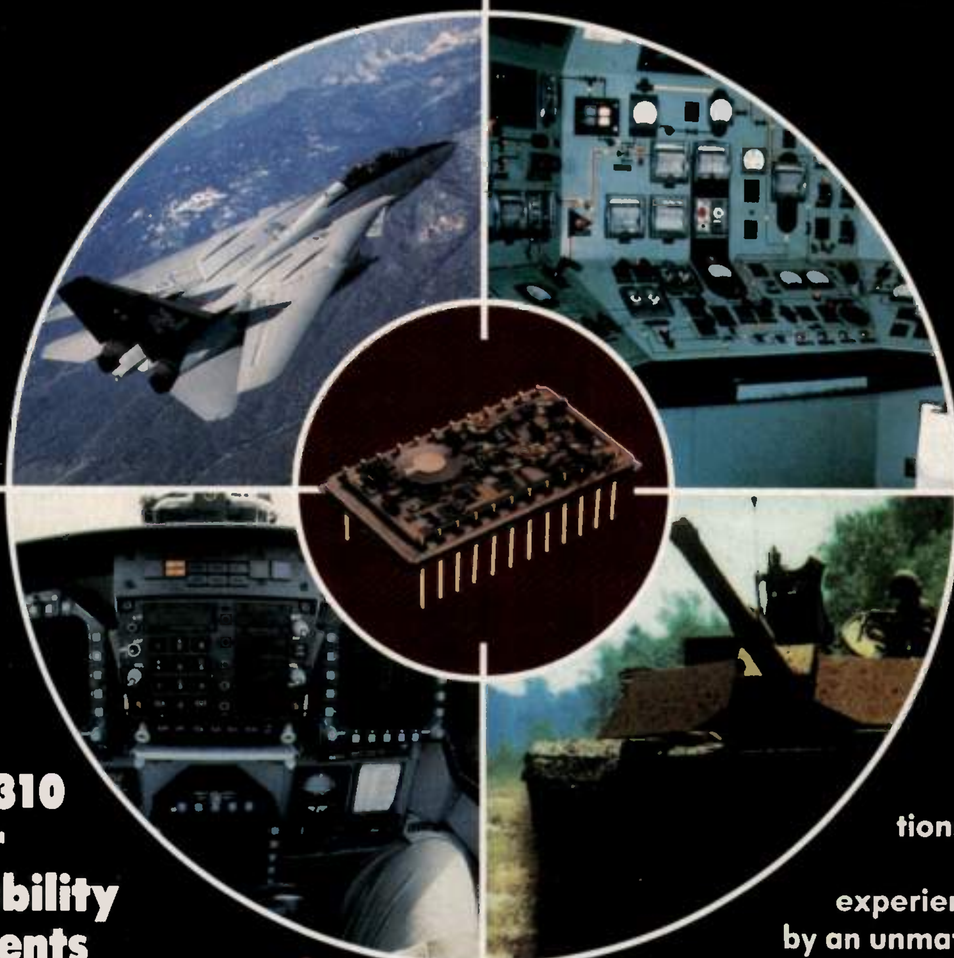

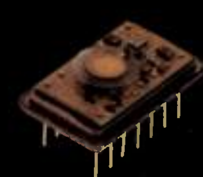

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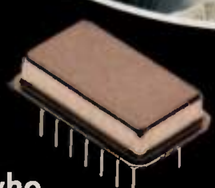

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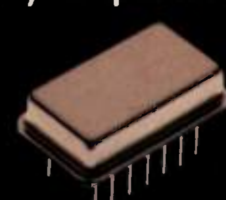

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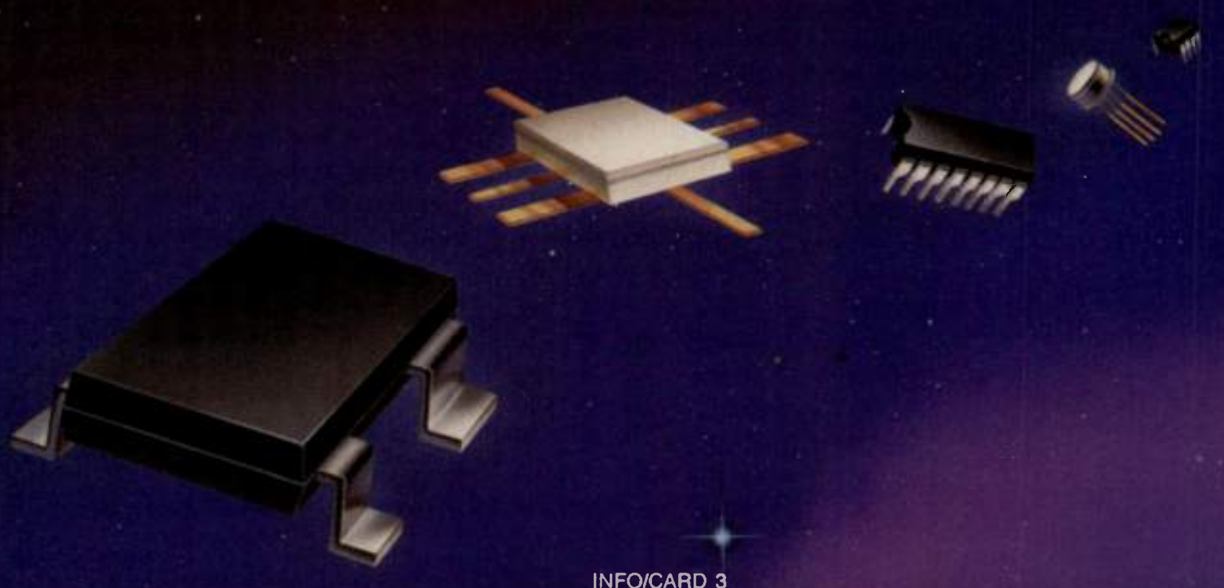
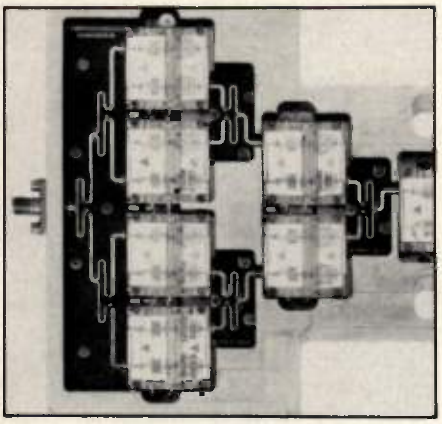


rf design

August 1987



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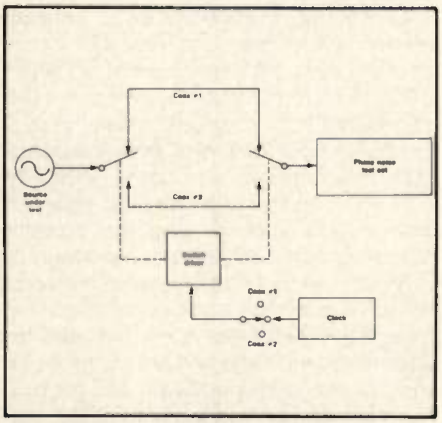

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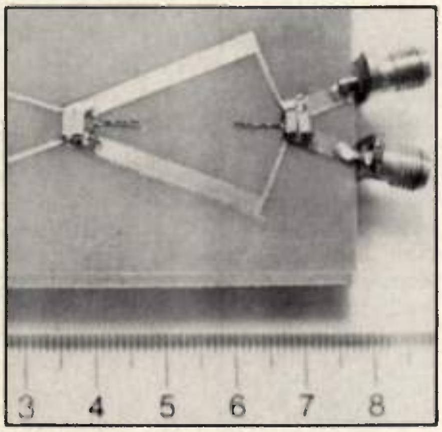

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Cover Story

27 **Modules Deliver the RF Punch for PLRS**
Modular design is carried out to three levels in the PLRS position reporting system — amplifier assembly, three board-level subassemblies, plus thick and thin film hybrid circuits. The assembly is made for Hughes by Microwave Modules and Devices, a young company whose sole business is modular components and subsystems.

Features

28 **Special Report — RF "Building Blocks" — The New Approach to Design**
Hybrids, modules and subassemblies are different names for the modular components that have become as well known to RF designers as discrete transistors and diodes. This report examines the rise of building block technology and the changes it brings to the role of the RF engineer. *— Gary Breed*

32 **Featured Technology — Specifying High Power Filters**
Whether building or buying filters for high power applications, an engineer must consider the important performance factors that lie beyond passband performance. This article notes the electrical and physical characteristics that must be taken into account. *— Dick Wainwright*

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This article describes a new topology for a microstrip power divider requiring minimum board space. This was another runner-up winner in the recent Design Awards Contest. *— Peter Vizmuller*

58 **RFI/EMC Corner — Conductive Plastic Composites Offer Shielding Solution**
Among the options for EMI/RFI shielding is the use of conductive plastics. This note covers some of the factors that influence a designer's choice of these materials over coatings or laminates. *— Mark Gomez*

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rf editorial

'Building Block' Technology is Coming on Strong

By Gary A. Breed
Editor

With regrets, I have finally accepted the fact that the Renaissance Man is gone from the world of RF. While there are many exceptional RF engineers, the technology has advanced beyond the point where one person can master it all. As a result, the design process requires expertise from different people with knowledge of different areas — power amplifiers, oscillators, modulators, IF circuits.

However, with the present demand for RF engineers, many companies do not have all areas of design represented on their own staff. Some may choose to get by with the available talent, accepting the compromise in overall quality. Others may hire outside consultants to handle a specific design area. A rapidly growing number are buying complete subsystems from specialized companies whose purpose is to do one thing, and do it very well.

This modular approach to design and manufacturing is nothing new. The construction industry has been using preassembled doors, windows, and cabinetry for a long time. Automobiles have almost always been assembled from engines made at one plant, body panels from another, instruments from still others. "Building Block" design isn't really new to electronics, either — but it is my observation that it's the hottest thing in the RF industry right now.

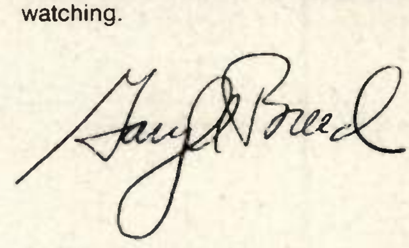
A Shortage of Engineers? Talent Can be Purchased

There is a reason for the current high activity in RF modules, hybrids, and other supercomponents. There just aren't enough RF engineers available to meet the design needs of every company. A second reason is cost and competition. Why design a TCXO, log amplifier, or diode mixer when you can buy one that meets your specifications from several different companies that specialize in that type of design? By the time development costs are added up, it may be a lot less expensive (and certainly faster) to use a purchased module.

Of course, the drawback is *control.* Manufacturers are quite used to the purchase of individual components, but when design and manufacturing processes are purchased from suppliers instead of performed in-house, there is an understandable new concern for quality, reliability and delivery. The need for trust between the module supplier and the product manufacturer is extremely important.

Most module companies are teams of entrepreneurs with a particular type of RF expertise. They have seen the need for specialized products and are trying to use their talents both creatively and for profit. A few companies have achieved outstanding reputations, some are just starting. Like most RF companies, they are relatively small, with distinct personalities that reflect their owners and managers. Dealing with such companies is a new experience for some purchasing agents, who have only been involved with individual components from large companies.

Like every other industry, RF is evolving and changing. Because module companies are, in effect, "middle-men," they add another level to the manufacturing chain. If the present trend continues, this intermediate level could become the major force in the RF industry. We'll be watching.



The Engineering Personality

By Keith Aldrich
Publisher

The subject of what kind of person becomes an engineer has been a recurring theme of sociopsychological commentary since engineering first emerged as a profession about the time of the industrial revolution.

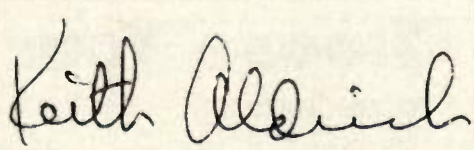
Prior to that, the application of new scientific principles had been the sometime avocation of well-read, well-bred generalists, in much the same way that the "renaissance man" wrote sonnets and madrigals. With the "age of enlightenment," today's engineer was born, stereotypically seen as not a very social creature, more comfortable with logarithms than people, less involved with the social or economic implications of an engineering project than would seem justified to social critics.

The subject of the engineering personality and the engineer's role in project structure is again a topic of discussion, with recent announcements by MIT and other schools that they will foster a new element in the training of engineers, to develop their graduates' sense of judgment and responsibility (see Editorial, July). It is hoped that engineering expertise will thereby be brought into the highest levels of decision-making, perhaps averting such tragic and senseless decisions as the one to launch Challenger in January 1986.

As a publisher who has worked with engineering audiences all his adult life without being an engineer, I feel I have some insights into the engineering personality that differ from the usual bromides. I offer them here as my contribution to the current discussion.

- In spite of their professional skepticism, engineers tend to be less jaded or cynical than most people when it comes to assessing other peoples' credibility, sincerity, and motives.
- In spite of a certain shyness about expressing it, engineers tend to feel more unspoiled, childlike enthusiasm about new experiences, places and people than many others, and about their own and others' achievements.
- The practice of engineering is much more akin to the creation of art of several sorts than is often recognized, and the engineer tends to share the artists' sensitivity to such phenomena as musical harmonics and rhythms, shades of color and light, nuances of expression, and *weights of arguments*.
- Engineers by professional training and instinct tend to be superior in sorting through spurious data to spot real facts and fairness.

These characteristics add up, it seems to me, to a relatively clear-headed kind of vision, cognizant of facts but not insensitive to sentiment, conscious of corporate or national goals but not a slave to them. And this sort of vision is, I would think, especially appropriate to the highest level of decision-making.



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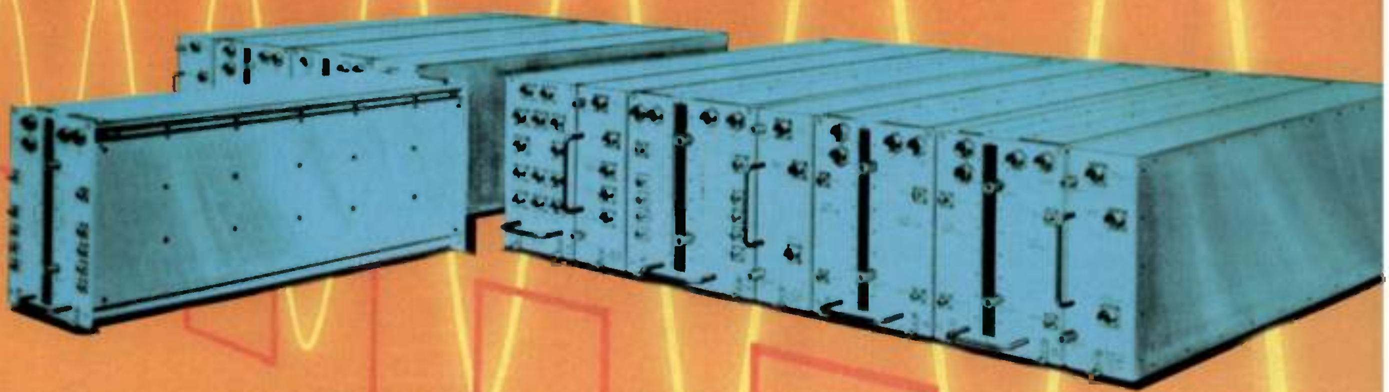

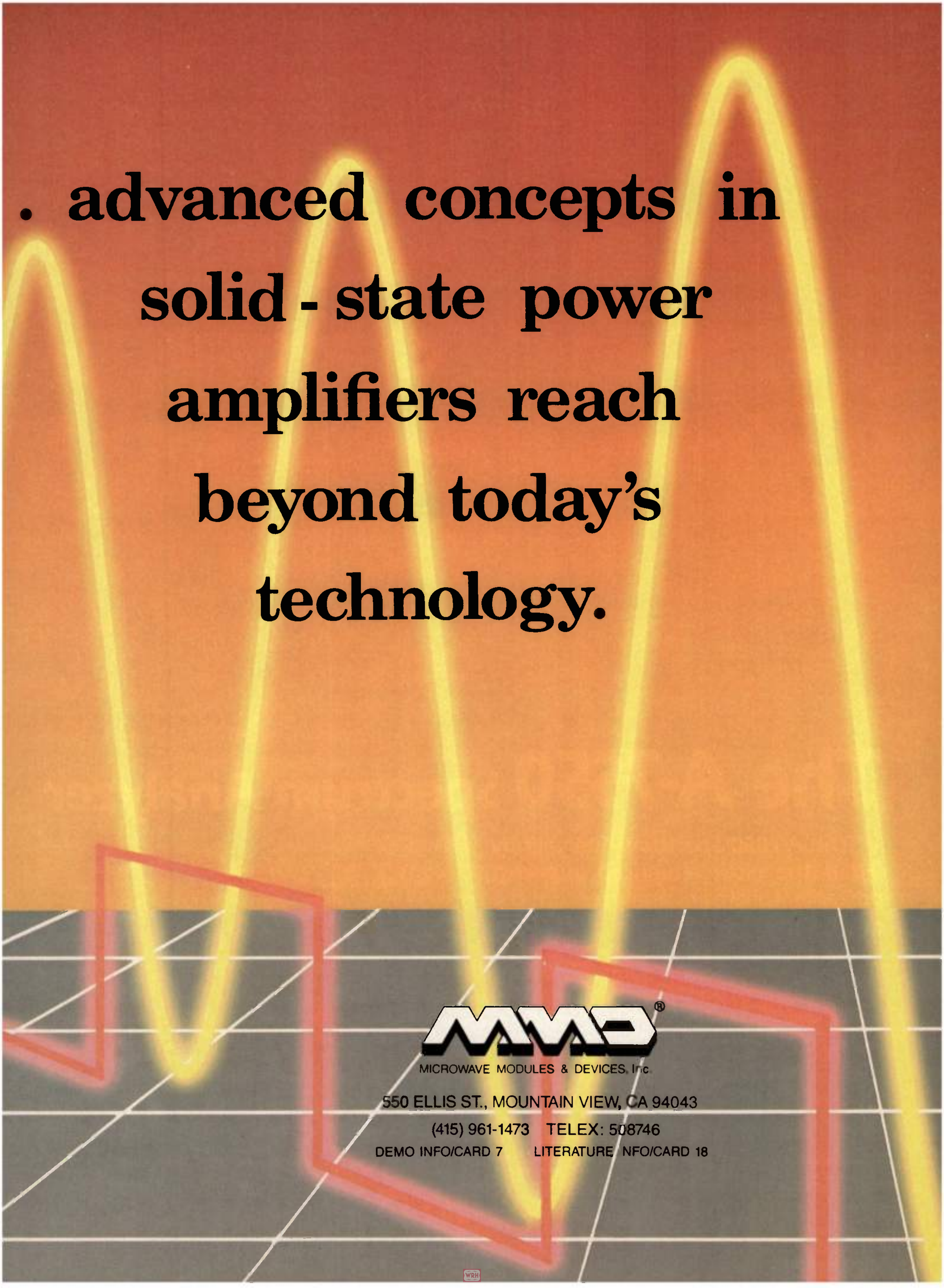

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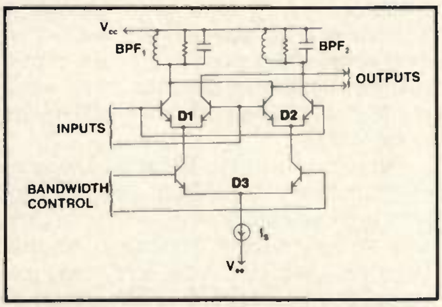
Variable Bandwidth IF Correction

Editor:

I have discovered an error in Figure 2 of my article, "Variable Bandwidth Intermediate Frequency Amplifier," published in the June issue of *RF Design*.

I regret the typographical error and enclose the correct diagram. *(Shown below — Ed.)*

Steve Kuh
Motorola, Inc.



Corrected version of variable bandwidth filter design.

Comment on Filter Design Definitions

Editor:

I thought Alan Tam's article an excellent introduction to microstrip filter design. It should be explained, however, that he elected to use a less common way of defining the cutoff frequency of his prototype. Usually the cutoff frequency of a Chebyshev filter is defined as the highest frequency where the response is ∈ dB down, where ∈ is the passband ripple. Mr. Tam's filter is designed to be 3 dB down at the cutoff frequency. This is a minor point unless someone happened to use the normalized coefficients given in the article to design another filter, which might result in an unpleasant surprise.

Methods for generating both types of coefficients (and others) are presented in *Handbook of Electronic Design and Analysis Procedures Using Programmable Calculators* by Bruce K. Murdock (Van Nostrand Reinhold, 1979). This book also contains much other information of interest to RF engineers.

John R. Moriarity
Wavetek San Diego

High-Temperature Superconductors: Excitement in Materials Research

The past half year has seen dramatic changes in the theory and practical use of superconductors. As a start, the first commercial product appeared on the market (from Hypres, Inc., see April 1987 *RF Design*, p. 21) using existing low-temperature technology. At almost the same time, news of high temperature superconducting breakthroughs began appearing in physics journals, then in the public press. Since then, every advance in research has been watched closely to see if it will be the one to bring superconductors into everyday use.

The use of superconductors in commercial applications made big news several years ago when IBM announced full-scale research into Josephson Junction (JJ) technology, with the intention of making a great leap forward in supercomputer performance. Difficulties in JJ development caused IBM to abandon its research, and superconductors were out of the news until Hypres' announcement of a picosecond-speed oscilloscope using technology based on the IBM research.

Early this year, researchers discovered new ceramic compounds that achieve superconductivity at temperatures above the 4 to 20 degrees Kelvin required for previously known superconducting materials. These materials are primarily rare-earth ceramics of the Yttrium-Barium-Copper Oxide family, which exhibit repeatable superconducting characteristics. Among the developments is the National Bureau of Standards development of a superconducting quantum interference device (SQUID) operating at 81K, above the 77K temperature of liquid nitrogen. The SQUID is the most sensitive device for measuring magnetic field, and operation using liquid nitrogen for cooling makes low cost, ultra-sensitive microwave detectors possible.

Evidence of superconductivity has been reported at temperatures as high as 280K (room temperature is 290K), although the results are not conclusive. Proof of superconductivity involves both vanishing resistivity and the Meissner effect, magnetic flux expulsion from the center of the object. In many of the recent experiments involving temperatures above 100K, the magnetic evidence (or lack thereof) suggests that the samples contain only small volumes of superconducting materials. This was reported by a group from the University of Houston, Lockheed's Palo Alto Research Lab and the National Magnet Laboratory, who observed vanishing resistivity in a ceramic oxide material at 225K. The effect survived thermal cycling over a two week period, another important test, but the small portion of the sample that was superconductive still needs to be isolated.

Superconductivity's RF applications include not only the SQUID detector, but also high efficiency magnets for oscillators and amplifiers (klystrons, magnetrons, etc.), dispersionless delay lines, low noise semiconductors, high efficiency power semiconductors and precision measurement standards.

RF Technology Assists in Plate Tectonics Measurements

Actual measurement of the movement of the earth's crust has confirmed the theory of plate tectonics, which explains how continents move in relation to one another. The June 12 issue of *Science* reports that radio telescopes located at Hawaii, Alaska and Japan have been used in a Very Long Baseline Interferometry (VLBI) experiment using distant quasars as "fixed" reference points. Part of the Crustal Dynamics Project, the team of radio astronomers has determined that Hawaii and Japan are moving away from each other at approximately 8.3 cm per year, and Hawaii and Alaska are being separated at a rate of 5.2 cm per year. The most remarkable aspect of the project is that results were obtained after only three years of measurements, indicating the accuracy of current VLBI techniques.

GE's Two Microelectronics Centers Consolidated

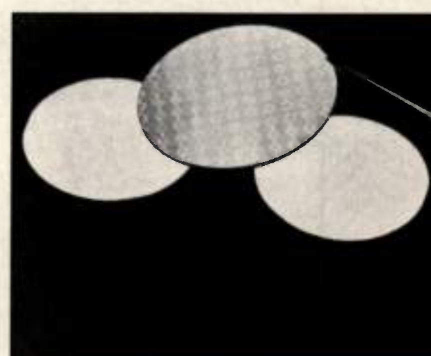
GE announced that its two microelectronic centers located in Research Triangle Park (RTP), NC, and in Somerville, NJ, are being consolidated at RTP. The move is expected to be completed by the end of the first quarter of 1988. The new GE Microelectronics Center charter will have a dual focus: to serve the application-specific integrated circuit (ASIC) requirements of GE's internal aerospace businesses, and to market its products and services with selected external military contractors and government agencies. The consolidated center will feature a complete ASIC capability, including design, CAD systems, and all the operational functions required to deliver qualified/classified parts, including customer program management and IC development.

Single Sideband Systems And Circuits

Single Sideband Systems and Circuits is a new book designed to bring radio communications equipment designers, electronic engineers and technicians up to date on the system and circuit design of single sideband radio communications technology. It brings together the expertise of twenty-three recognized authorities from Rockwell's Collins Radio Division to give readers the latest state-of-the-art design information, including audio and RF circuits, digital signal processing, synthesizer design, power amplifiers and many other areas. The book is edited by William E. Sabin and Edgar O. Schoenik. It is published by McGraw Hill Book Company, 11 West 19th St., New York, NY 10011. Price is listed at $49.95.

GTE Grows a Transistor

Researchers at GTE Laboratories have developed a way to *grow* a transistor. By combining and heating silicon and the tantalum disilicide, the researchers can simultaneously grow metal connections and silicon crystals, forming a transistor. The connections in the GTE transistor penetrate the entire device, providing a three dimensional form that permits the transistor to excel in high power applications such as pulse switching.



Grown transistors offer high power performance.

National Security Agency Endorses Rockwell

Rockwell International Corp. has received the National Security Agency's endorsement for a monolithic randomizer integrated circuit. The randomizer is the first device produced under the agency's overtake project in conjunction with its commercial COMSEC endorsement program (CCEP). The device is a digital, monolithic, binary, number generating device that can be used wherever a high speed, random data stream is required and small size and a single drive voltage are desired. It has been tested and found to have a zero/one distribution statistically unbiased making it appropriate for use in Type 1 products which secure unclassified US government information. More information can be obtained by calling Rockwell International Corp. at (714) 762-2622.

Applied Computation Electromagnetics Society (ACES)

Over the past ten years, computer modeling has matured as a problem solving tool in real world electromagnetic applications. Use of computer modeling has become so routine that sessions at the various professional society meetings deal primarily with new developments. As a result, information exchange is inhibited. ACES has been formed to foster information exchange among computer modelers in electromagnetics. Emphasis is put on computer application issues rather than research and development. Further information on ACES can be obtained from Dr. Richard W. Adler, Code 62AB, Naval Postgraduate School, Monterey, CA 93943. Tel: (408) 646-2352.

Hughes, MBB, and Aerospatiale Join to Bid on Air Defense Program

Derivatives of the battle proven Roland system have been entered by a U.S., French, and West German joint venture for the U.S. Army's Forward Area Air Defense, Line of Sight, Heavy program. Called the Paladin weapon system, the units will incorporate elements of the U.S. Roland air defense system and other components from the European Roland now fielded with the armed forces of France, West Germany and seven other nations. The Western Alliance Air Defense joint venture has been formed by Hughes Aircraft of the U. S., Messerschmitt-Boelkow-Blohm (MBB) of West Germany and SNI Aerospatiale of France to propose the Paladin. Plans call for 50 to 70 percent of the contents of Paladin to be built in the U.S. with the remainder coming from Europe.

Power MMIC Services

Microwave Semiconductor Corporation has announced the availability of GaAs custom circuit design and fabrication services. The services are tailored to meet the demands of customers requiring specialized microwave performance. The foundry services offered use the technology implemented in MSC's GaAs Power FET and standard MMIC line.

Electrospace and Chrysler Announce Merger

Chrysler Corporation and Electrospace Systems, Inc. announced that they have reached a merger agreement under which Chrysler will make an offer of $27.00 per share for 100 percent of the stock of the defense contractor. The total acquisition of the stock will cost approximately $376 million. Chrysler has been granted options by Electrospace Systems' four founding shareholders to acquire their approximately 38 percent of the company's outstanding shares. Electrospace Systems designs, develops and installs communications and electronic systems and equipment for military and commercial customers.

Watkins-Johnson Acquires Microwave Center

Watkins-Johnson Company has completed its acquisition of the Santa Barbara Microwave Center from Honeywell, Inc. W-J paid approximately $2 million for the manufacturer of millimeter-wave mixers and oscillators.

AMP and Micro-Coax Join Forces

AMP, Inc., of Harrisburg, PA., and Micro-Coax™ Components, Inc. of Collegeville, PA., have announced agreement to manufacture and market semi-rigid cable assemblies. The assemblies will utilize AMP's semi-rigid crimp Coaxicon™ connectors and Micro-Coax Components' UT™ semi-rigid cable. Available size range of the cable assemblies include cable diameters from 0.0865 inch to 0.141 inch with frequencies ranging from DC to 26 GHz.

Standard Oil Announces New Division

Standard Oil Engineered Materials Company announced the formation of an Electronic Ceramic Division, headquartered in Niagara Falls, NY, to focus on the development, production and marketing of products. The division will invest $8.5 million in two facilities to produce specialty materials for the microelectronic industry, specifically substrates and planar diffusion sources.

Esterline Sells Product Line

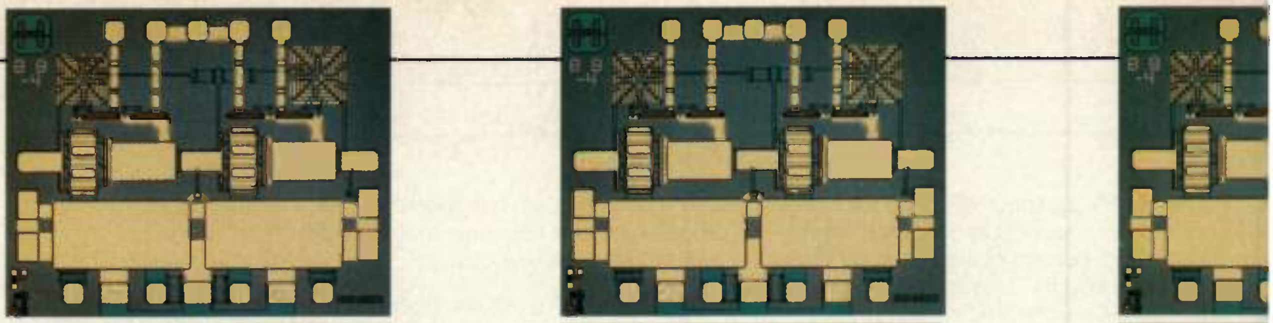
Esterline Angus Instrument Corporation, a subsidiary of Esterline Corporation of Connecticut announced the sale of its Minigraph® analog and event recorder product line to the Dickson Company of Illinois for an undisclosed sum.

General Motors and Siliconix Sign Agreement

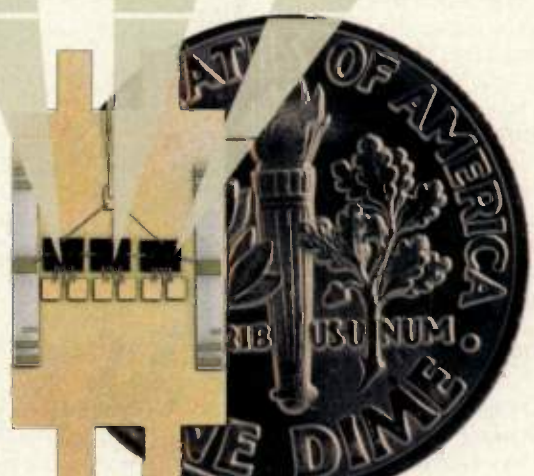
The Delco Remy Division of General Motors, along with General Motors Research Laboratories, has signed a contract with Siliconix to develop and produce a new semiconductor power technology. According to Siliconix, the significance of this technology may be compared to MOSFET technology. It is expected to be the basis of a whole family of new devices, both discrete and integrated circuits, promising major improvements and device efficiency at low cost.

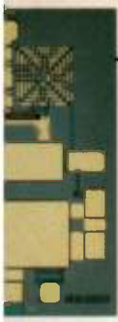
Shipboard DF System Delivered to Paramax

Electromagnetic scientists at Southwest Research Institute (SwRI) have designed and developed an advanced shipboard tactical direction finding system that is claimed to be faster than existing systems and is strong enough to withstand the stresses of prolonged service atop a ship's mast. The first electronic support measures (ESM) system, designated the AN/SRD-502 was recently delivered under subcontract to Paramax, Inc., a Canadian defense firm, for installation aboard a new class of Canadian Patrol Frigates. It consists of a 16 foot tall antenna, a control unit, an operator unit, and data processing equipment. rf



The no-gimmick MMICs: Cascadable, cost-effective, uniform GaAs gain blocks — available now from stock!

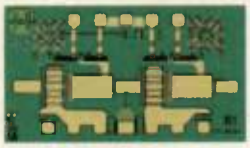




Small size, easy to use... lower cost than hybrid designs.

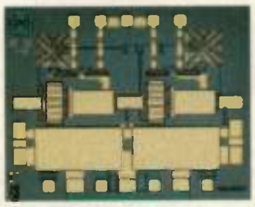
We think you will be amazed at how much our family of low-cost, gallium arsenide MMIC gain blocks can save in overall system design time and cost. And how they provide uniform performance over wide bandwidths. So you can drop them in wherever utility gain blocks are required.

Take our little HMR-10502 GaAs MMIC amp. It provides 10 dB typical gain and 10 mW output power from 0.5 to 5 GHz.



HMR-10502 MMIC

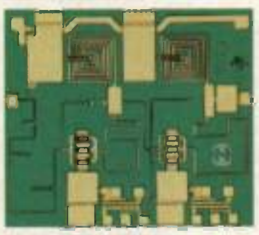
Or its companion, our HMR-10503. It provides 10 dB typical gain and 10 mW output power from 1 to 5 GHz and includes on-chip decoupling capacitors.



HMR-10503 MMIC

If you need more power and gain, the HMM-10610 is the right choice. It offers 75 mW output power from 2 to 6 GHz with 12 dB gain.

For higher-frequency applications, we offer the HMM-11810 — with 5 dB typical gain and 50 mW output power over the 6 to 18 GHz band.

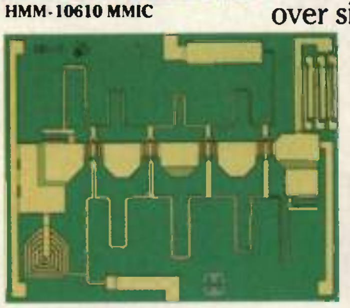


HMM-10610 MMIC

Since they're directly cascadable, you can combine multiple MMIC chips on the same carrier. They require no tuning, and minimal assembly.

Like all Harris GaAs products, these MMICs offer improved radiation hardness over silicon devices, and are well-suited to applications requiring Hi-Rel Qualification.

And, best of all — *they're available from stock!*



HMM-11810 MMIC

MMICs shown approximately twenty times actual size.

Consider the advantage of our MMICs in your next microwave system design.

Why wait? For GaAs MMIC amplifiers today, there's really only one choice — Harris Microwave Semiconductor. In U.S. phone 1-800-4-HARRIS, Ext. 1501, or (408) 433-2222. (TWX: 910-338-2247) In Canada: 1-800-344-2444, Ext. 1501.

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Harris Semiconductor: Analog - CMOS Digital
Gallium Arsenide - Semicustom - Custom

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INFO/CARD 13

rf calendar

August 25-27, 1987
9th Quartz Devices Conference
Westin Crown Center, Kansas City, MO
Information: Components Group, Electronic Industries Association, 2001 Eye Street, N.W., Washington, DC 20006; Tel: (202) 457-4930

September 1-2, 1987
Mountain States Electronics Expo
Denver Merchandise Mart, Denver, CO
Information: Darel A. Bennett, Midland Exposition Group, 3699 West 73rd Ave., Westminster, CO 80030; Tel: (303) 426-1634.

September 7-10, 1987
17th European Microwave Conference
Ergife Palace Hotel, Rome, Italy
Information: Microwave Exhibitors of Publishers Ltd., 90 Calverly Road, Tunbridge Wells, Kent TN12UN, England

September 15-17, 1987
Midcon/87
The Ohara Center, Chicago, IL
Information: Midcon/87, 8110 Airport Boulevard, Los Angeles, CA 90045-3194; Tel: (213) 772-2965, (800) 421-6816, inside California (800) 262-4208

September 21-22, 1987
1987 IEEE Bipolar Circuits and Technology Meeting
Hyatt Regency Hotel, Minneapolis, MN
Information: Janice Jopke, BCTM Secretary/Treasurer, 5016 W. 99th St., Bloomington, MN 55437; Tel: (612) 835-6742

September 22-24, 1987
Northcon/87
Portland Memorial Coliseum, Portland, OR
Information: Show Manager, Northcon/87, 8110 Airport Boulevard, Los Angeles, CA 90045-3194; Tel: (213) 772-2965

September 29-October 1, 1987
1987 OEM Design and Integrated Manufacturing Exposition
McCormick Place East, Chicago, IL
Information: Bill Little, Penton Exposition, 122 East 42nd St., New York, NY 10168; Tel: (800) 634-4639, in NY call (212) 867-9191

September 29-October 1, 1987
Ninth Annual Meeting and Symposium, Antenna Measurement Techniques Association
The Stouffer Madison Hotel, Seattle, WA
Information: James R. Otley, 1987 AMTA Symposium, 6682 South 191st Place, Suite E-105, Kent, WA 98023; Tel: (206) 655-7780

September 29-October 1, 1987
Fall National Design Engineering Show and Conference
Javits Convention Center, New York, NY
Information: Monica Viladegutt, Cahners Exposition Group, 999 Summer St., P.O. Box 3833, Stamford, CT 06905; Tel: (203) 964-0000

October 4-8, 1987
ISA/87
Anaheim Convention Center, CA
Information: Paul Albert, Instrument Society of America, P.O. Box 12277, Research Triangle Park, NC 27709

October 13-15, 1987
Scan-Tech 87
Bartle Hall, Kansas City, MO
Information: Don Anderson, AIM, Inc., 1326 Freeport Rd., Pittsburgh, PA 15238. Tel: (412) 963-8588

October 13-15, 1987
19th International SAMPE Technical Conference
Hyatt Hotel, Crystal City, VA
Information: Marge Smith, Business Director, P.O. Box 2459, Covina, CA 91722. Tel: (818) 331-0616

October 19-21, 1987
The Twentieth Annual Connectors and Interconnection Technology Symposium
Franklin Plaza Hotel, Philadelphia, PA
Information: Electronic Connector Study Group, Inc., P.O. Box 167, Fort Washington, PA 19034-0167; Tel: (215) 825-3840

October 26-30, 1987
FOC/LAN 87, Eleventh International Fiber Optic Communication and Local Area Networks Exposition
Anaheim Convention Center, Anaheim, CA
Information: Renee Farrington, Information Gatekeepers, Inc.,214 Harvard Avenue, Boston, MA 02134; Tel: (617) 232-3111

November 10-12, 1987
1987 ITEA Symposium
Park Plaza Hotel, Boston, MA
Information: Howard L. Graves, Raytheon Company, Public Relations, 141 Spring Street, Lexington, MA 02173; Tel: (617) 470-6027

R & B Enterprises
Tempest-A Detailed Design Course
September 14-18, 1987, Philadelphia, PA
Electromagnetic Pulse (EMP) Design and Test
October 5-6, 1987, Philadelphia, PA
November 17-18, 1987, Washington, DC
December 7-8, 1987, Philadelphia, PA
Electromagnetic Pulse Workshop
October 9, 1987, Philadelphia, PA
December 11, 1987, Philadelphia, PA
Understanding and Applying MIL-STD-461C
October 20-21, 1987, Philadelphia, PA
November 17-18, 1987, Washington, DC
December 14-15, 1987, Philadelphia, PA
MIL-STD-461C Praxis (Workshop)
October 20-21, 1987, Philadelphia, PA
December 16-17, 1987, Philadelphia, PA
Information: Greg Gore, Director of Training, R & B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428. Tel: (215) 825-1960

Norand Corporation
FCC, VDE, CISPR, and SAE Regulation and Design Criteria
September 1-2, 1987, Cedar Rapids, IA
Grounding, Bonding, Shielding and PCB Design for EMI/EMC
September 15-16, 1987, Cedar Rapids, IA
MIL-STD 461B/C and 462 Regulations and Design Criteria
October 13-14, 1987, Cedar Rapids, IA
RF Susceptibility and ESD Testing
November 3-4, 1987, Cedar Rapids, IA
Information: Bev Reynoldson, Norand Corporation, 550 2nd St S.E., Cedar Rapids, IA 52401; Tel: (319) 846-2415

Compliance Engineering
Compliance Seminars: EMI, Safety, ESD, Telecom
August 25-28, 1987, Atlanta, GA
September 29-October 2, 1987, Orlando, FL
October 27-30, 1987, Boston, MA
December 1-4, 1987, San Diego, CA
Information: Compliance Engineering, 593 Massachusetts Avenue, Boxborough, MA 01719. Tel: (617) 264-4208

Avantek, Inc.
RF & Microwave Semiconductor Design Solutions Seminar
September 15, 1987, Santa Clara, CA
September 17, 1987, Phoenix, AZ
September 21, 1987, Denver, CO
September 28, 1987, Kansas City, MO
October 2, 1987, Ft. Wayne, IN
October 5, 1987, Boston, MA
October 7, 1987, Ft. Washington, PA
October 9, 1987, Atlanta, GA
October 13, 1987, Orlando, FL
October 15, 1987, Dallas, TX
October 19, 1987, Burbank, CA
November 4, 1987, Albuquerque, NM
Information: Janice Little, Avantek, Inc., M/S 3G, 3175 Bowers Ave., Santa Clara, CA 95054. Tel: (408) 970-2139

The George Washington University
Frequency Hopping Signals and Systems
September 9-11, 1987, Washington, DC
HF Communications Technology
September 14-18, 1987, Orlando, FL
November 16-20, 1987, Washington, DC
Spread Spectrum Communication Systems
September 21-25, 1987, Washington, DC
Fiber Optics Technology for Communication
September 22-24, 1987, Washington, DC
Introduction to Modulators and Transmitters
October 5-6, 1987, Washington, DC
High Frequency Spectrum: New concepts and technologies
October 5-9, 1987, Washington, DC
Introduction to Receivers
October 19-20, 1897, Washington, DC
Modern Receiver Design
October 21-23, 1987, Washington, DC
Global Positioning System: Principles and Practice
November 4-6, 1987, Washington, DC
Wideband Communications Systems
December 7-11, 1987, Washington, DC
Information: Shirley Forlenzo, Continuing Education Program, George Washington University, Washington, DC 20052; Tel: (800) 424-9773, (202) 994-8530

Interference Control Technologies, Inc.
Practical EMI Fixes
September 22-25, 1987, San Diego, CA
MIL-STD-461/462
September 29-October 2, 1987, Washington, DC
Information: Penny Caran, Registrar, Interference Control Technologies, Inc., State Route 625, P.O. Box D, Gainsville, VA 22056; Tel: (703) 347-0030

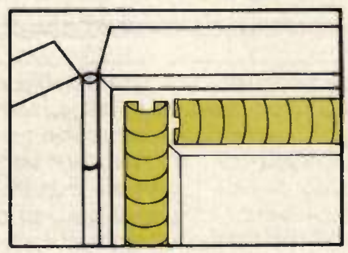
Integrated Computer Systems
Digital Signal Processing
September 22-25, 1987, San Diego, CA
October 27-30, 1987, Anaheim, CA
December 1-4, 1987, Washington, DC
December 8-11, 1987, Boston, MA
Machine Vision and Image Recognition
September 15-18, 1987, Los Angeles, CA
September 29-October 2, Washington, DC
October 20-23, 1987, Palo Alto, CA
December 8-11, 1987, Toronto, Canada
Fiber Optic Communication
September 15-18, 1987, Washington, DC
September 29-October 2, 1987, San Diego, CA
November 3-6, 1987, Los Angeles, CA
Hands-On Programming in C
September 22-25, 1987, Washington, DC
September 29-October 2, 1987, San Diego, CA
October 27-30, 1987, Boston, MA
Information: Marilyn Martin, Integrated Computer Systems, 5800 Hannum Avenue, P.O. Box 3614, Culver City, CA 90321-3614; Tel: (800) 421-8166, (213) 417-8888

New!

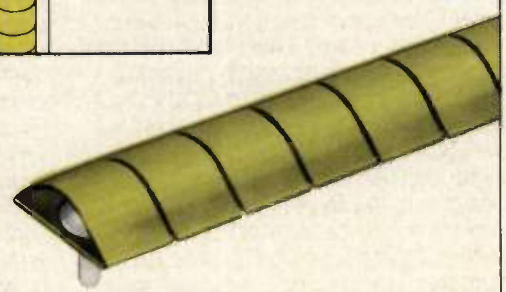
Symmetrical Shielding Strips (S^3) provide bi-directional engagement at severe shear angles!

These new symmetrical slotted shielding strips of beryllium copper permit continuous spring contact throughout their length, providing the perfect answer for a variety of shielding requirements.

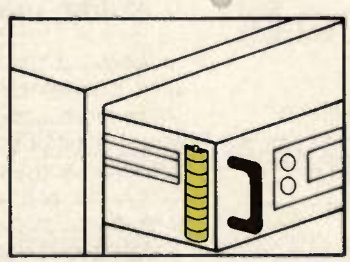
Three models are available: basic, rivet-mount and double-faced adhesive-mount designs. The basic design consists of low-compression, adhesive-mounted strips. A generous radius profile provides for the greatest incident engagement angle with the lowest force. As with all Sticky Fingers® shielding strips, the self-adhesive tape makes mounting easy and secure.



Adhesive-mounted strips for typical electronic enclosures.



The rivet-mount design incorporates the addition of an integral track, pierced for mounting with nylon push rivets. This configuration allows bi-directional engagement, and is specially designed for slide applications, PC board connections, etc.



Strips with integral mounting track* and nylon push rivets, for sliding drawer applications.

The third design also incorporates an integral track-mount design, but employs a double-faced adhesive tape instead of push rivets. This provides for fast, easy field replacement in military applications, especially where high frequencies do not permit the use of mounting holes.

Strips with integral mounting track* and self-adhesive strip for fast field replacement.

For complete information, including exact specifications, dimensional drawings, etc., on these and other Instrument Specialties shielding strips, use this publication's Reader Service Card. Or write to us directly at Dept. RFD-36.

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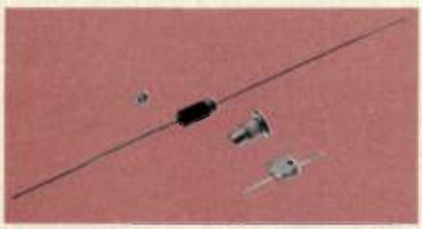

TYPICAL STANDARD MODELS	
NC 100 Series	up to 3 MHz
NC 200 Series	up to 500 MHz
NC 300 Series	up to 11 GHz
NC 400 Series	up to 50 GHz

ALL ARE IN STOCK

DROP IN MODULES FOR BITE

Self energized in TO-8
Ideal for self testing of receivers
50 ohms, 30 dB ENR min,
35 dB ENR typ.

TYPICAL STANDARD MODELS	
NC 501	up to 500 MHz
NC 502	up to 1 GHz
NC 503	up to 2 GHz
NC 504	up to 3 GHz
NC 505	up to 4 GHz
NC 506	up to 5 GHz

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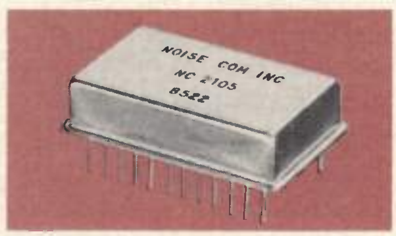
BROAD BAND AMPLIFIED MODULES

PLUG-IN, DUAL-IN-LINE
24 or 14 PIN, 150mv out



TYPICAL STANDARD MODELS	
NC 2101	up to 20 kHz
NC 2102	up to 100 kHz
NC 2103	up to 500 kHz
NC 2104	up to 1 MHz
NC 2105	up to 10 MHz
NC 2106	up to 20 MHz

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HIGH-OUTPUT:

+10 dBM, 50 ohms
SMA or BNC output

TYPICAL STANDARD MODELS	
NC 1101A	up to 20 kHz
NC 1107A	up to 100 MHz
NC 1108A	up to 500 MHz
NC 1109A	up to 1 GHz
NC 1110A	up to 1.5 GHz

Other frequency ranges
and output levels available

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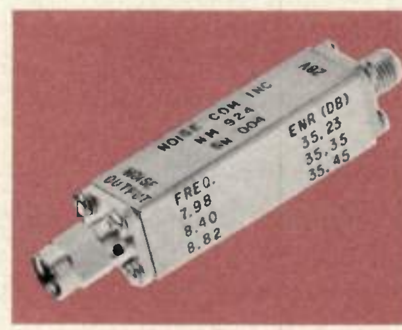
SMA, N, TNC Output Connectors



TYPICAL STANDARD MODELS	
NC 3100 Series	up to 18 GHz 15.5 dB ENR, noise figure meter compatible.
NC 3200 Series	up to 18 GHz 30-35 dB ENR, high noise output.

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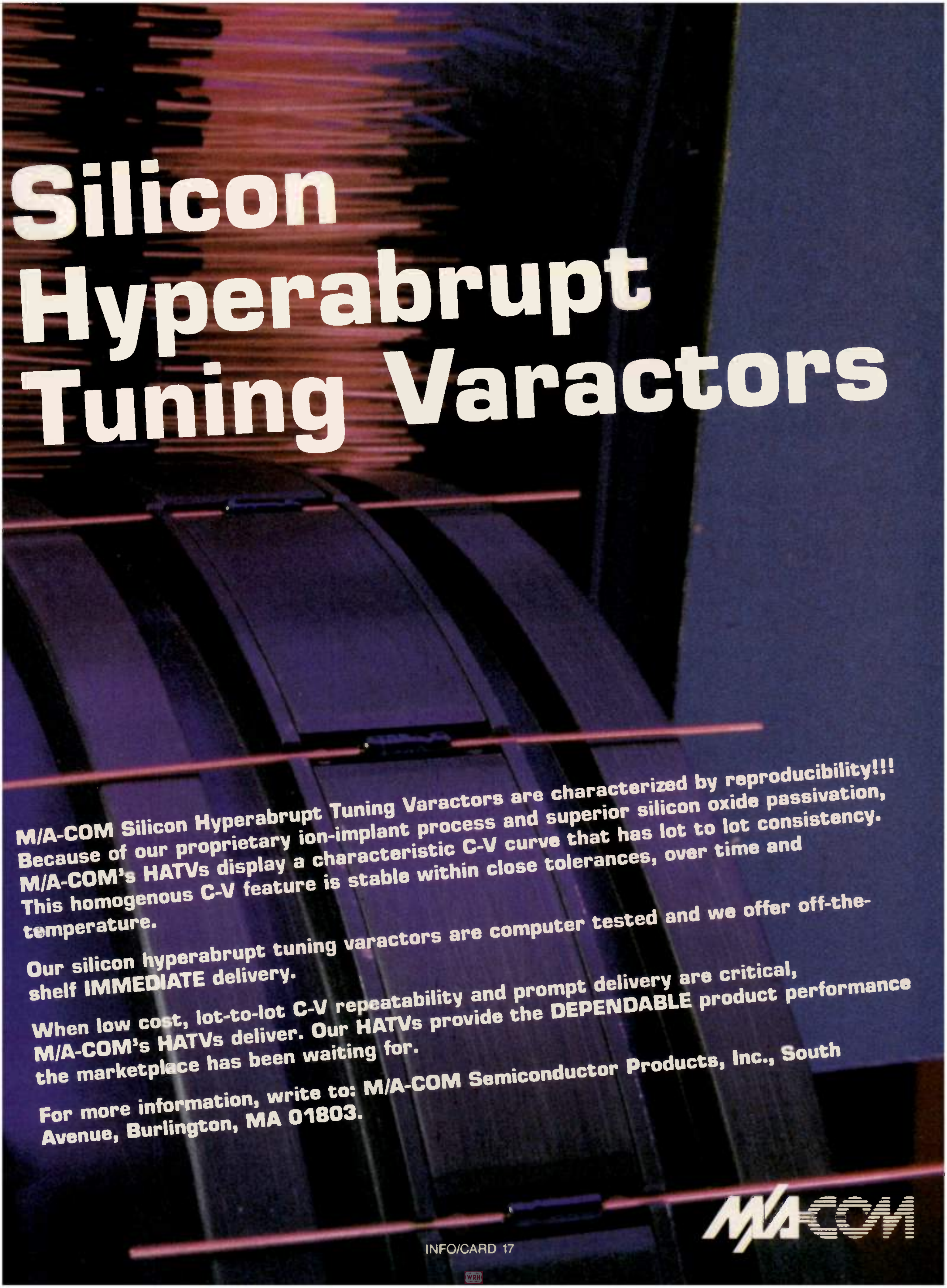
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M/A-COM Silicon Hyperabrupt Tuning Varactors are characterized by reproducibility!!! Because of our proprietary ion-implant process and superior silicon oxide passivation, M/A-COM's HATVs display a characteristic C-V curve that has lot to lot consistency. This homogenous C-V feature is stable within close tolerances, over time and temperature.
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INFO/CARD 17

Modules Deliver the RF Punch for PLRS

Assemblies, Boards and Hybrids — Three Levels of Modularity

The Automatic Position Location Reporting System (PLRS) is a UHF radio network consisting of a transportable Master Station with computers and situation display, in communication with up to 400 Individual User Units. These units may be deployed as manpacks or installed in aircraft and surface vehicles. The Master Station computes and continuously updates the position of each User Unit within 15 meters. The PLRS system is currently supplied to the Army and Marines.

Reliable communication of position data is realized by a unique combination of an anti-jam radio and a sophisticated net management algorithm. To support hundreds of users in real-time, the radio uses a spread-spectrum, pseudonoise, frequency-hopped waveform with error detection and correction. The net management algorithm monitors all radio links and maintains real-time information on the connectivity. This data is used to reconfigure the network when necessary, as a result of a broken link.

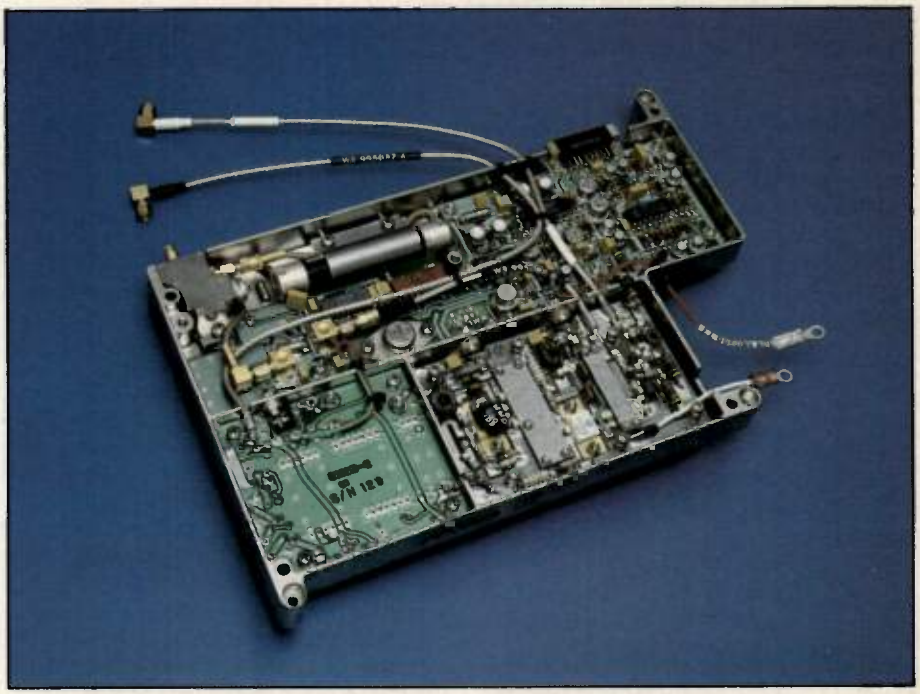
The 100 watt Transmitter Assembly used in the PLRS radio is made by Microwave Modules and Devices (MMD) for Hughes, the system manufacturer. The assembly is an excellent example of how modules and modular construction can be applied to high volume production military hardware. The Transmitter assembly built at MMD consists of three replaceable modules, each with a designated function:

- *Control Module* — This module selects appropriate power output with greater than 23 dB dynamic range, controls both the rise and fall time of the pulse, and protects the amplifier module.
- *Power Amplifier Module* — The UHF PA delivers 100 watts, or another selected level, over the full military temperature range. A PIN diode T/R switch is included in this module.
- *Driver Module* — This module delivers 10 watts of power to the PA module. It is constructed as a combination of TO39 thin film hybrids and a large thick film plug-in hybrid.

The modules represent an integration of thin film, thick film and printed board technology to achieve an optimum cost/performance tradeoff. Carrying the modular concept even farther, Hughes is able to use the assembly as a power amplifier in other radio systems operating in the military UHF band.

MMD supplies modular RF and microwave power amplifiers for defense electronics and commercial applications. They have delivered amplifiers for communications, radar, avionics and EW systems from DC to 4 GHz, operating from less than a watt to many kilowatts. Microwave Modules and Devices is located at 550 Ellis Street, Mountain View, CA 94043, tel. (415) 961-1473. rf

The driver subassembly combines thick and thin film technology.



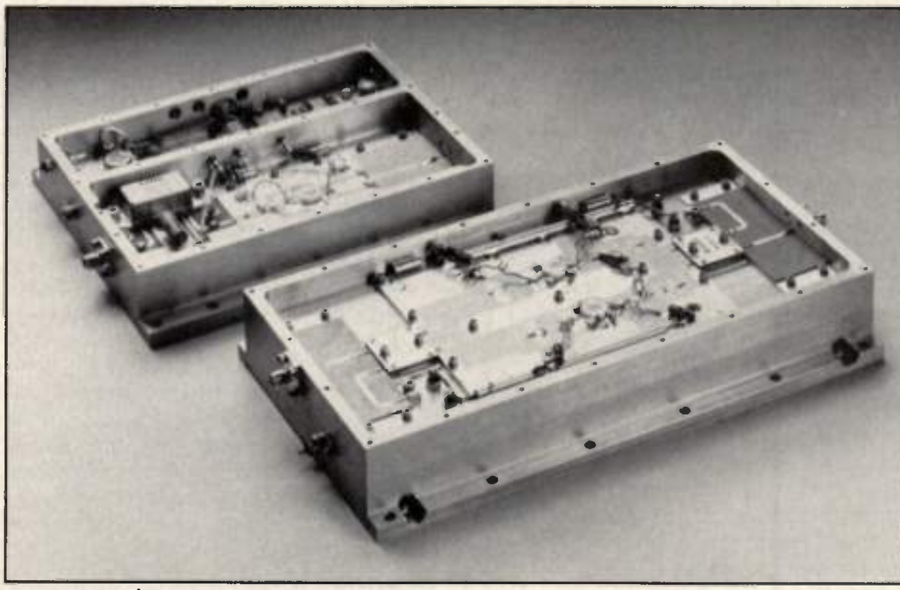
The amplifier assembly. At the top is the control module, lower left is the driver, and at lower right the power amplifier.

RF "Building Blocks" — The New Approach to Design

New Super-Components are Changing the Engineer's Role

By Gary A. Breed
Editor

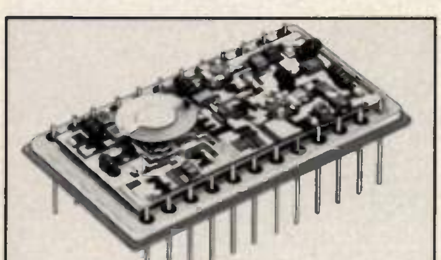
Modules, hybrids, subassemblies, board-level integration — whatever you call them, they are "building blocks" for RF systems and they are the hottest part of the RF industry right now. A look at the advertisements and new product announcements in this magazine (or any other electronics magazine) should prove that point. Although modular circuits have been around for a long time, they recently have become so widespread that engineers generally consider them as if they were individual components like resistors or capacitors.



Known best as a transistor and hybrid amplifier maker, TRW RF Devices is now manufacturing these UHF class A amplifiers.

This report is more of a news story than an update on technology. Many of the rapidly growing companies in the RF industry are in the business of making products best described as building blocks. It really doesn't matter whether their products are thick film hybrids, packaged circuit assemblies or board-level products. They represent functionally complete subsystems, and they are changing the way engineers design RF equipment.

One reason for recent growth in modular components is lack of available expertise. *RF Design* has reported the demand by RF companies for more engineers with analog design abilities (May 1987 issue, p. 57). With this current shortage of designers, companies often find themselves lacking the in-house capability to design certain types of circuits. When a new technology comes along, the problem is multiplied.



Oscillators are perhaps the most well known hybrid modules. This photo shows the construction of a VCXO from Reeves-Hoffman.

For example, surface acoustic wave (SAW) technology has matured in just the last few years. SAW device manufacturers agree that their greatest difficulty in attracting customers is that engineers lack adequate knowledge in SAW applications. Two companies, Andersen Labs and RF Monolithics, have specifically stated that a major reason they have undertaken modular assembly is to circumvent this problem. By providing their SAW devices in an assembly containing all interfacing circuitry, they have substituted their specialized expertise for the uncertainty of the customer's own engineering staff.

Performance is another major reason for the growth in modules. As RF technology has become more complex, a natural response is to create areas of specialization. Buying a modular assembly gives one company access to the specialized ability of another manufacturer. As another example, how many companies build their own precision oscillators? Not many. Instead, they buy them from one of the many oscillator specialists. The phrase applied here is certainly, 'Why reinvent the wheel?" In just the past two or three years, that principle has been expanded to include power amplifiers, noise sources, IF amplifiers, and entire receiver front-ends. The build-or-buy decision in RF is increasingly "buy."

Cost and Competition

Outside of consumer electronics, RF is not a mass market. The quantities of units produced by RF manufacturers are relatively small. For many years the attitude has been that quality and performance override all other concerns; that people buy equipment for those reasons. Add the desire for complete control over all design and manufacturing parameters and you have a completely engineering-driven sys-

Among the oldest modular components are filters, such as this product from TTE.

tem. For a long time, this system worked well, but there is a definite shift in economic climate that is forcing a change of attitude.

Last November, Hewlett-Packard introduced a new low cost spectrum analyzer. To create that product and sell it at a competitive price, H-P modified its historic 'engineering first" philosophy. The *marketplace* determined the price range and dictated the design goals for the product. Like another test equipment giant, Tektronix, had done a few years earlier with a new line of oscilloscopes, H-P engineers had to create an instrument within a well-defined framework of time, cost, and manufacturability.

There is another side to the cost equation: manpower. RF engineering salaries are high, and the required support equipment and facilities are expensive. As worldwide competition has grown, companies can no longer justify the cost of designing every circuit in that design. As a result, exercising control over every aspect of design and performance is more costly than ever. Fortunately, competition among module suppliers has developed to the point where quality is generally high in these system components.

Building Blocks Change the Designer's Role

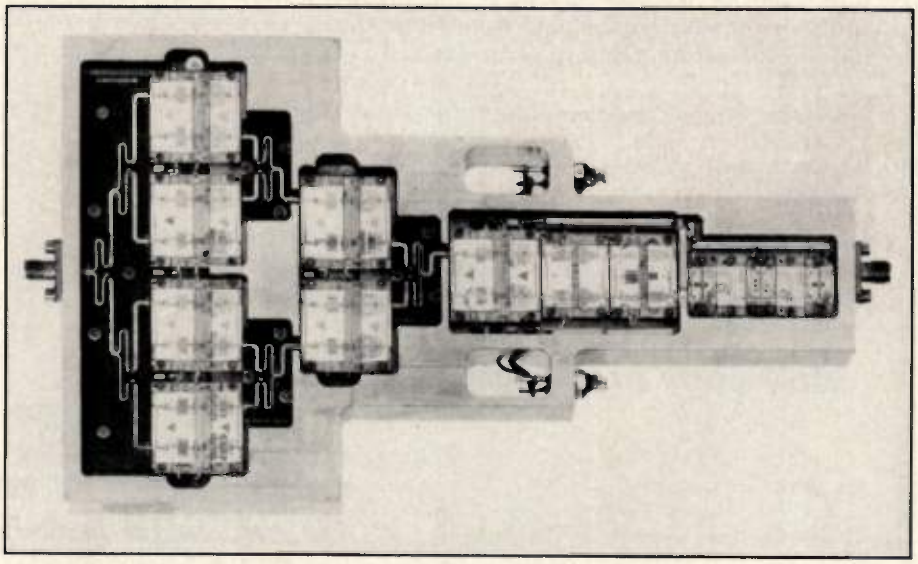
The ability to bypass component-by-component design of amplifiers, mixers, or oscillators changes the method of circuit design. The RF engineer needs sufficient understanding of these circuits to establish appropriate performance specifications, although he or she won't actually design them. Instead, that engineer must have top-notch ability to *integrate* various subsystems into a working whole. Formerly, the staff engineer had the opposite priorities: circuit design expertise with some system-level familiarity.

This design process is much less interactive, as it would be under the conventional arrangement where a circuit designer works under a project manager with authority over several subsystem teams. With outside vendors, the process needs to have far more advance preparation. Initially, specifications must be developed for selection of system components, including the compromises in performance that are usually necessary to meet budgets and timetables. Although the design process has always had these first steps, using outside sources for part of the system makes it very difficult to modify the system or explore different performance options as the project develops.

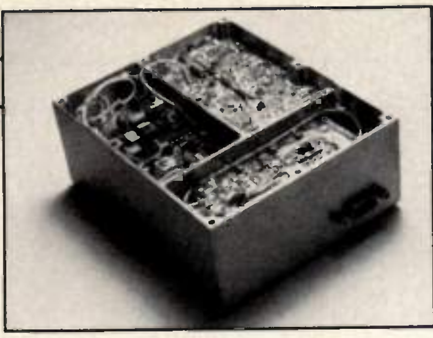
Product Knowledge is a Necessity

Besides the change in planning and specification of a design, modular components require that engineers at the lowest staff level be familiar with available products. If custom or semi-custom assemblies are needed, the capabilities of supplier companies should be well understood. The purchasing department may make the financial arrangements for procuring the modular components, but it is always the engineers who decide exactly what the specifications are, and which companies are most likely to be able to meet them.

This necessary awareness by engineers is in contrast with past practice. Designing with discrete components has involved "generic" resistors, capacitors, and semi-



M/A COM MPD has incorporated amplifier modules into a 20 watt S-Band power amplifier assembly.



This UHF receiver from General Services Engineering can be considered a "module" intended as part of a complete system.

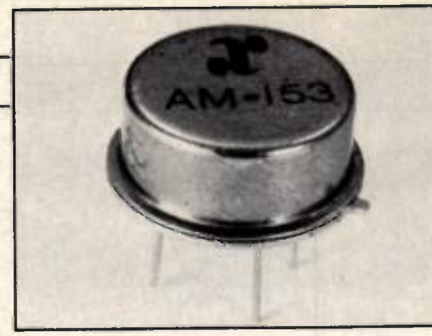
conductors. While preferences for certain manufacturers' products develop as a designer gains experience, these choices do not have to made for every project. The selection of amplifier, oscillator, synthesizer or mixer subassemblies has to be done "from scratch" every time. An engineer has to be aware of the differences in performance and manufacturing expertise among several potential suppliers.

Right now, the engineers' task is most difficult. The number of companies supplying modular components is growing rapidly, requiring a continuing effort to keep up to date on products and capabilities. Also, firms which manufacture discrete components are incorporating "value added" assembly of hybrids or boards based on their discrete products. A few examples include: Motorola, which is manufacturing an RF modem board; TRW, offering a line of hybrid and board-level power amplifiers; Piezo Crystal Co. continues to develop new oscillator modules; and Acrian is making UHF-TV and S-Band power amplifier assemblies. All of these companies, known best for their discrete components, have added modular products to their capabilities.

A Gradual Rise to Prominence

"Building block" design is not new. In particular, assembled oscillators, mixers and filters have been around for a long time. What is noteworthy is that the concept has rapidly expanded to include nearly every RF function over the past few years, to the point where modules are replacing discrete designs. The modest collection of modules available only five years ago has grown dramatically, to the point where they are a factor in *all* design decisions.

There is a negative side to the phenomenon, now that it is possible to build complete RF systems by purchasing modular assemblies, interconnecting them and applying the proper DC power. There is the danger that engineers will stop *designing* and just pick assemblies from a catalog and put them together in a system. RF engineers have to realize that the process of design should not be less rigorous because modular products are used.



Rather than design an amplifier, engineers have the option of using a broadband hybrid gain block like this one from the Anzac Division of Adams-Russell.

Like all new developments in product technology, the availability of these supercomponents offers outstanding time and convenience benefits. With proper system planning, maximum performance can also be achieved. But, also like any new development, users of the technology must understand the changes it brings to the process of engineering. rf

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Specifying High Power Filters

Important Considerations for Filter Design and Purchase Decisions.

By Dick Wainwright
QRS

There are still plenty of engineers who say, "Anyone can design filters, the textbooks are full of tables of element values." That is true, but there are many more pertinent specifications than just L and C values. Component ratings, not the values, are of fundamental importance in power handling devices. The old saying, "A little knowledge is dangerous," applies to high power filter design — resulting in a lot of smoke testing.

Take a moment to ponder the long list of key terms in the language of high power filter design. Electrical considerations include: Power, Q, selectivity, energy storage, modulation, peak-to-average, harmonic content, rejection, EMI, topology, dielectric strength, losses, and so on. Equally important are the mechanical and environmental aspects: heat generation, flow and sinking, contaminants, vibration, salt spray, connectors, altitude, plating, and many others. These terms are but a smattering of the flow of words that haunt every sensible designer of high power devices.

It takes an intimate knowledge and an awareness bordering on paranoia, along with considerable experience, to tackle this area of design. The same understanding is needed when specifying a filter for purchase from an outside vendor. More than one manufacturer has experienced the frustration of losing a bid because of exceptions prudently taken to allow for poorly defined specifications. Many times the user does not know or furnish such important information as:

a) *Harmonic content* of transmitter power output relative to fundamental power.

b) *Connectors* which may be incompatible with specified power and load conditions.

c) *Surface area* available for heat conduction/radiation and availability of cooling air. Assuming that cooling air is available, its rate of flow, pressure and temperature.

Harmonic Order	Level (dBc)	Harmonic Power W½kW (Fundamental)
2nd	−18	15.8
3rd	−12	63.1
4th	−21	7.9
5th	−18	15.8
6th	−22	6.3
7th	−21	7.9
(8-13th)		37.8 (total)

Total Harmonic Power = 154.6 watts per kW Fundamental

Table 1. Typical Amplifier Harmonics.

Selectivity 60 dB/3 dB	Nominal VSWR	Filter Design	Qul for a Given Loss	Energy Storage
1.25	1.2	Elliptic (0.01 dB ripple)	1000	20
1.5	1.35	Chebyshev (0.1 dB ripple)	650	15
1.7	1.2	Chebyshev (0.01 dB ripple)	460	12
—	—	Chebyshev (0.001 dB ripple)	290	—
2.1	1.2	Butterworth	200	10
4.2	—	Bessel	—	—

Table 2. Filter Type Comparisons.

d) Proper *shock and vibration* specifications. A vivid recollection concerns heavy shock and vibration specs along all three axes for an application which, under power, was fixed and indoors!

e) *VSWR* with realistic values. 1.1:1 is not the right specification for a filter which would,in practice, be operating into a load of 2:1 or 3:1, at almost any phase angle.

f) *Other mitigating relationships* which combine to specify an unrealistic design.

Harmonic Content

Typical solid state transmitters of recent vintage can be expected to yield harmonic power levels such as those listed in Table 1. Besides the filter requirements, the system designer may opt to use a ferrite iso-

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lator at the transmitter output to maintain a well-matched condition. However, most isolators are frequency sensitive, and the result may be excessive heating due to the harmonic energy. Burnout is one possible consequence, as is additional harmonic generation from operation of the ferrite material near its Curie temperature.

Connector Ratings

Most connector manufacturers don't know how much power or apparent power their connectors will safely handle under all possible operating conditions. Current ratings rather than voltage ratings are generally the problem area. Z_0 is of little importance in systems working with very high VSWR values (although, of course, they are related).

The fact is that most filters are reflective devices, producing attenuation by reflection of power back to the source, rather than by absorption. Absorptive filters are generally more expensive and considerably larger than reflective types. However, especially at UHF and higher frequencies, the use of harmonic absorptive filters should be considered.

Cooling Considerations

How much surface area should one allow for the cooling of high power filters? If cooling air is available, what is its pressure and rate of flow? First, we make the following assumptions: 1. The maximum power versus connector type is in the order of 2/3 of the rating of the cable attached, derated appropriately; and 2. A high power filter is normally designed such that the hot surface temperature does not exceed ambient plus 50C, with a heat sinking plate average temperature that is no more than ambient plus 10C (95C maximum). Cooling air, if available, should not exceed an effective temperature of 80C; hence, air speed may be an important consideration as the air approaches the filter hot spots.

In many cases, substantial size fins may be required, but fins are *not* effective in cramped air flow spaces. Convection air currents must be free to circulate if convection represents a substantial portion of the cooling means. Surrounding heat conducting surfaces may need to have rough textures to "wipe" the heat out of the circulating air.

Shock and Vibration

Heavy shock and vibration specifications along all three axes should be studied carefully. The strong G forces should be confined, if at all possible, to the smaller dimensions of the coaxial structure. Minimal forces of no more than 5G (preferred), or 10G maximum (11 m/s standard shock specification) should be applied on the length of coaxial filters of substantial size. In addition, the adequacy of the mounting and supporting hardware is essential.

Electrical Specification

Selectivity, time delay, energy storage, electrical (absorptive) losses and heat generation go hand-in-hand. Q, the ratio of *Energy Stored per Cycle* to *Energy Dissipated per Cycle* of the applied energy is a critical consideraton in the design of all filters in general, and of great importance in high power filters. For a given loss, the required ratio of unloaded Q/loaded Q is different for every filter design. It is not uncommon for certain designs to require inductor unloaded Q values in excess of 500-1000 and for capacitors, 3500-8000. Even with these values, the engineer may only eke out a responsive design where rejection bandwidths to low loss band edge ratios are small, e.g. much less than 1.2:1 for 40-60 dB rejection. The almost impossible Q values of 2000 or more for coils and over 10,000-15,000 for capacitors may be required, but are unobtainable in practice because of space, moding, or frequency limitations.

The Q of coils increases roughly as the square root of frequency, so high frequency filters generally yield lower losses for the same selectivity and available space.

For a given loss (see Table 2) the unloaded Q required increases substantially with passband ripple (VSWR), complexity (n) and type of filter (Elliptic, all-pole Chebyshev, Butterworth, etc.). Note that Table 2 indicates representative values, not absolutes.

As an example, a 0.01 dB Chebyshev (all-pole) filter required approximately (460/200-1), or 84 percent more Q than a Butterworth filter for a given loss. The Elliptic filter given has twice the energy storage indicating that voltages and currents are roughly 40 percent more than in a Butterworth filter.

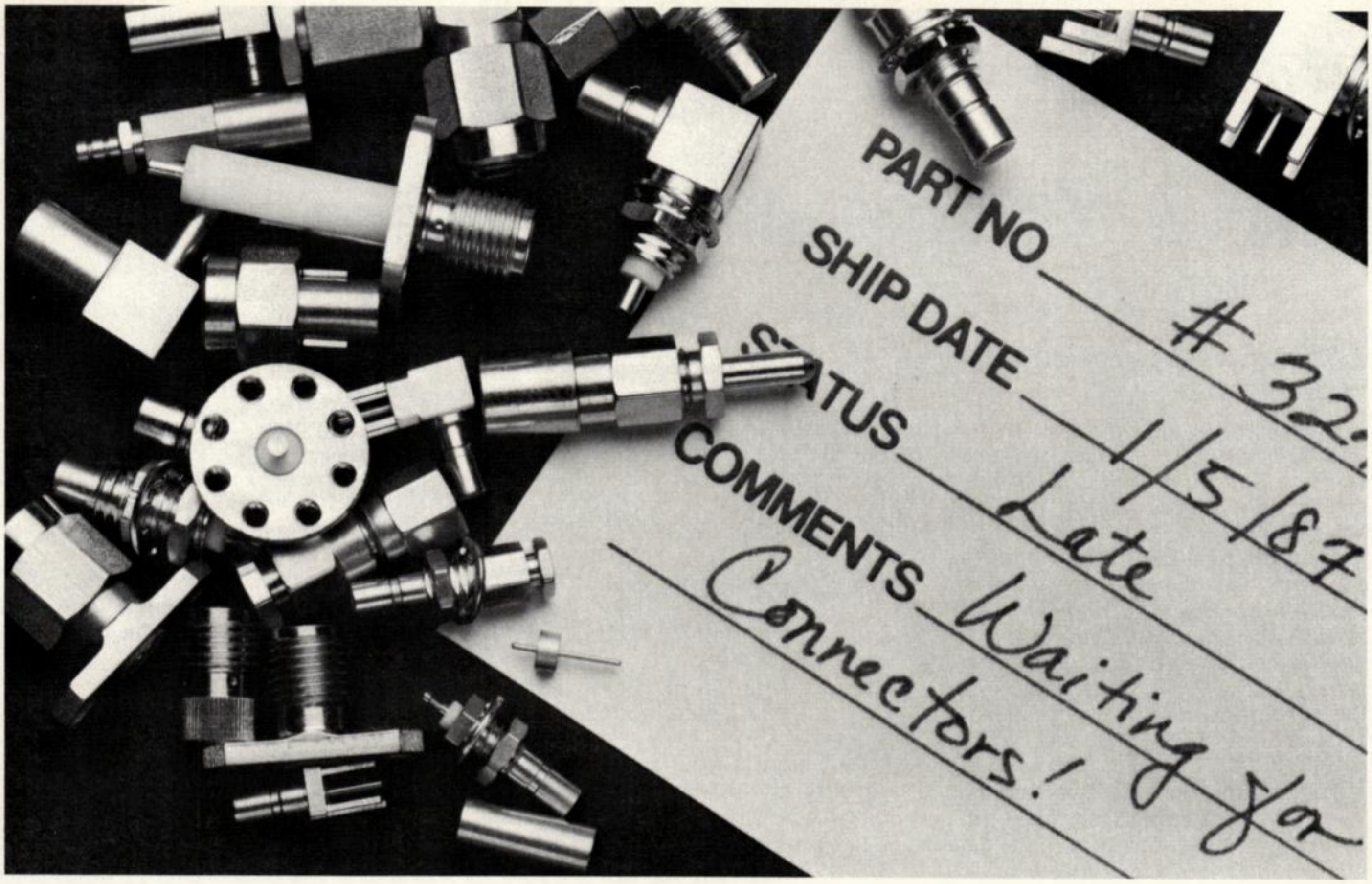
Other Factors

There are several factors that also require consideration in the specification and design of high power filters. These include phase linearity versus frequency in a single filter, or phase matching in filter groups. A ± 5 degree phase matching specification may double the price relative to a non-matching phase unit, to allow for extensive alignment and component selection. Additional work may be required in mechanical construction to assure matching under varying operating conditions.

Humidity is another concern. High humidity, especially when combined with condensation, can present substantial difficulties. Another environmental concern is altitude of operation. Derating may be necessary, and in difficult cases it may be best to pressurize the unit with dry nitrogen or sulfur hexafluoride. Of course, when pressurized, humidity ceases to be a significant problem. rf

About the Author

Dick Wainwright has many years experience in filter design as founder and Chief Scientist of Cir-Q-Tel. He is now practicing as a consultant. He can be reached at QRS, P.O. Box 116, Kensington, MD 20895.



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Phase Noise Calibrator

By Guy V. Love and Kevin Lindell
Norden Systems

The spectral purity of RF signal sources used in today's radar and communication systems is often the limiting factor in achieving the desired performance. Such spectral purity is usually specified in terms of phase noise, a measurement of the spectral distribution of the random (or regular) wanderings in phase of the ideal sinusoid, by which the source is characterized. The authors earned the runner-up prize of EEsof's Touchstone/RF in the second annual RF Design Awards Contest.

Source manufacturers often assemble their own test sets for measuring phase noise using a few items of standard test equipment, an appropriate source and a few in-house circuits which vary depending on the technique of choice.

In the procurement of low phase noise sources there is a need to assure that measurements made at the vendor's facility, for instance, on test set "A", can be duplicated in the buyer's lab on test set "B". A calibrator that can be used with any type of test set, whose performance is reliable and easily verified, and which is easily transported, has been developed. Its description, details of construction and application follow.

Technique

The basic idea, shown in Figure 1, is to introduce a general type of phase modulator ahead of the phase noise test set. The RF output of the source is switched between two lengths of coax, one of which is slightly longer than the other. This small change in electrical length appears to phase shift the source-under-test at the clock rate, producing a known phase modulation. The spectrum produced is also known, and provides the means of calibrating the phase noise test set.

The calibrator can be turned off to inhibit interference with the noise measurement of the source. The technique is inherently low loss and, being coaxial, is well shielded to assure negligible additive noise or interference. The approach is broadband, and one set of transmission lines can be used over several octaves. The phase deviation produced by switching between the two lengths of coax is related to the difference in coax lengths, ΔL, by the following equation:

$$\Delta\phi(pp) \text{ in radians} = 2\pi f\frac{\Delta L}{V_p}$$

where f = frequency of source under test
ΔL = difference in length of cables
V_p = phase velocity of coax cable used, at frequency f.

The phase shift is frequency sensitive varying linearly with frequency as long as phase velocity is constant. It is desirable to keep the phase modulation small so that the spectrum can be predicted from small index approximations and also to provide a calibration commensurate with the noise to be measured. At the maximum frequency of usefulness, determined by the transmission band of RF switches used, the coaxial cables should differ by less than 0.1 radian if small index theory is used.

Operation

In general, and specifically for large phase deviations, angle modulation is a non-linear process, producing an RF spectrum whose amplitudes are in terms of Bessel functions. However, if the modulation index is kept small (<0.1 radian), the following approximations to these functions can be made:

$J_0(\Theta)$ = carrier amplitude ≅ 1
$J_1(\Theta)$ = amplitude of first order sidebands ≅ Θ/2
and $J_2(\Theta) = J_3(\Theta) = J_4(\Theta)$, etc. ≅ 0

where Θ is the modulation index, which is equal to the peak phase deviation in radians, and J_n represent Bessel functions of the first kind and order n. Only the first order sidebands are significant, and they are related in amplitude to the carrier by

$$\text{dBc} = 20 \log \Theta/2$$

For example, if single frequency sinusoidal phase modulation is used, with 0.1 radians peak-to-peak: Θ = modulation index = 0.05 radians peak, and 20 log Θ/2 = −32 dBc. In the spectrum, single lines of this value would appear, spaced either side of the carrier by the modulation frequency.

The small angle approximation also permits superposition to be used to predict the spectrum produced by more complex modulation waveforms. Each of

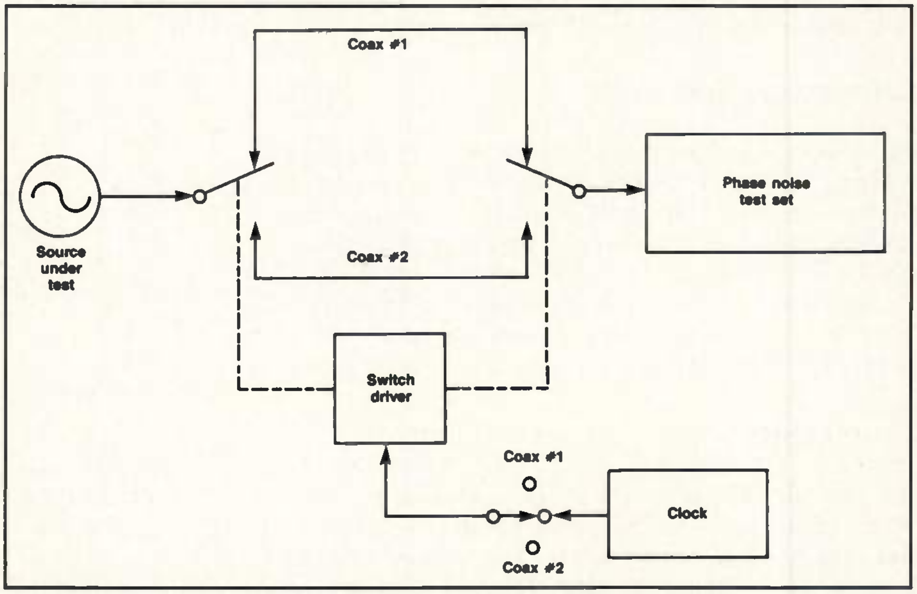

Figure 1. Phase noise calibrator — principle of operation.

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the Fourier components of the modulating signal then produces its own first order sideband pair around the carrier. For the case of a symmetrical square wave, only odd harmonics exist. The fundamental component (at f_m) produces a pair of lines $\pm f_m$ about the carrier; the third harmonic produces a pair $\pm 3f_m$ about the carrier, and so on for 5th, 7th, etc. The calibrator uses such a symmetrical square wave phase modulation, switching between the two coax cables whose phase difference is $\Delta\phi(pp)$. The Fourier components of the modulation function are given by:

$$\Theta(n) = \frac{\Delta\phi(pp)}{2} \cdot \frac{4}{\pi n} \quad \text{for n=1, 3, 5 . . . and zero for n=even}$$

The phase modulation sidebands are then given by:

$$\frac{\Theta(n)}{2} = \frac{\Delta\phi(pp)}{\pi n} \quad \text{for n = 1, 3, 5,. . .}$$

And, relative to the carrier level C, the single sideband levels L(n) are:

$$L(n)\ dBc = 20 \log \frac{\Theta(n)}{2} =$$

$$20 \log \frac{\Delta\Theta(pp)}{\pi n} \quad \text{for n = 1, 3, 5,. . .}$$

For the case $\Delta\phi(pp) = 0.1$ radians, the following sidebands are given

$$L(1) = 20 \log \frac{0.1}{\pi} = -29.9\ dBc$$

$$L(3) = 20 \log \frac{0.1}{3\pi} = -39.5\ dBc$$

$$L(5) = 20 \log \frac{0.1}{5\pi} = -43.9\ dBc, \text{etc.}$$

As expected, the sidebands fall as 1/n, equivalent to −6 dB/octave on a log-log plot of phase noise. The peak values of these line spectra are used to calibrate the plotter output when measuring the phase noise of an unknown source. The choice of clock frequency (fundamental) is not a factor in calibration, and is largely a matter of convenience. It should be high enough to avoid being demodulated by the phase locked loop commonly found in phase noise test sets. It should not coincide with line frequencies or their harmonics, which are often large. An acceptable value is a 100 Hz clock.

Calibration And Sources Of Error

In theory, a careful measurement of the difference in cable lengths, together with an accurate value for cable phase velocity, would yield a close value for $\Delta\phi(pp)$. However, added differential phase shifts in the RF switches, slight but invariable differences in construction, and the uncertainty of the phase velocity, all contribute to errors in this approach. A direct measurement of $\Delta\phi(pp)$ is possible using a network analyzer, or a vector voltmeter.

For use as calibrator, it is the spectral line amplitudes relative to the carrier (dBc) that must be known. As was shown, these vary directly with $\Delta\phi$. A 0.5 dB accuracy in spectrum magnitude requires better

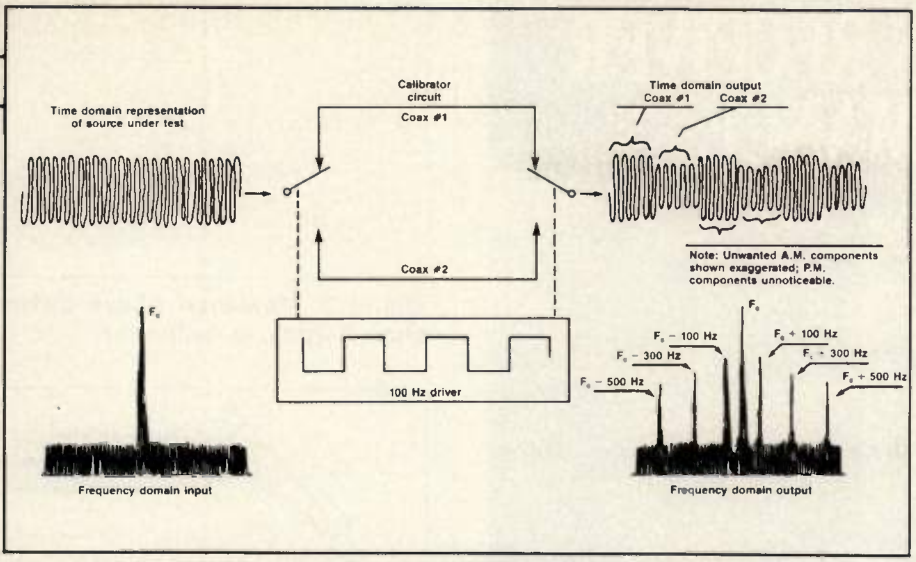

Figure 2. Signal representation in the phase noise calibrator.

than 6 percent accuracy in measuring $\Delta\phi$. If $\Delta\phi$ is 6 degrees, the measurement error should not exceed 0.36 degrees. Since $\Delta\phi$ is the difference of two larger phase shifts, the allowable percent error, in terms of either path length, must actually be much less than 6 percent. Fortunately, absolute phase shift is not needed, and the evaluation of $\Delta\phi$ allows systematic or offset type errors to be differenced out. Still, 0.5 dB accuracy requires considerable care. A 1.0 dB uncertainty in spectrum content is more easily achieved and may be adequate for many phase noise measurements.

An experimental model of the calibrator was built, and $\Delta\phi$(pp) evaluated using a network analyzer. The transmission phase angle was measured for each path, using the mode switch to select the path. Included in the path is any phase shift due to the RF switches. It is essential that these

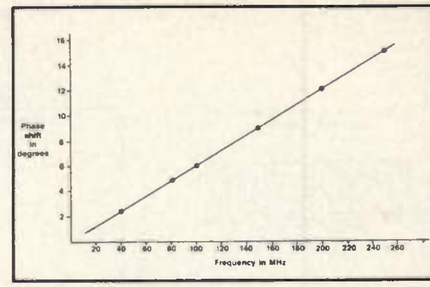

Figure 3. Measured phase difference, Δϕ(pp), in calibrator.

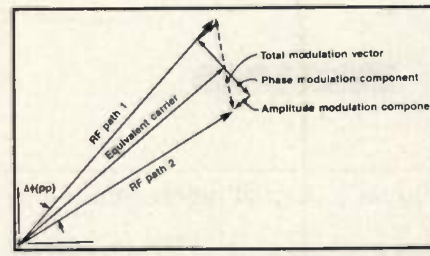

Figure 4. Vector representation of small index phase modulation plus amplitude modulation.

switches exhibit the same phase delay when switched statically as when driven by the clock. Since their phase shift was found to depend on drive level, the RF switches are always controlled by the same drive circuit (a TTL switch driver), the DC voltage (+5 V) is regulated, and mode switching is done ahead of the driver.

While the calibrator was intended for use in the 50 to 200 MHz range, the Δϕ value was measured over a somewhat wider range. No dispersion (variation in phase velocity with fequency) was seen, and the data points fell closely in a line, as shown in Figure 3. A best fit straight line averaged the data and facilitated interpolation of values of Δϕ at different frequencies. The measured value of Δϕ(pp) was found to be 6.1 degrees at 100 MHz, and the first order sidebands were expected to be −29.4 dBc. As a check, the modulated output of the calibrator was observed on a spectrum analyzer. All of the sidebands were greater than expected, with the first pair at −28 dBc. In looking for the discrepancy (about 1.4 dB), it was realized that the spectrum analyzer does not distinguish between amplitude and phase modulation, but measures the spectral energy distribution due to all causes. If AM was present, it could explain the increased sideband levels.

Figure 5 shows how the AM and PM vector components add to produce an increase in the total modulation content. The amplitude difference in the vectors (labeled RF path 1 and RF path 2) represents a difference in the insertion loss through the two paths (including switch losses), while the phase difference in these vectors is the measured phase modulation. Looking again at the network analyzer results, an amplitude difference of about 0.5 dB in the path losses was measured. The fractional amplitude difference, corresponding to ±0.25 dB, would be ±0.03 relative to a unit carrier vector. The measured phase modulation of 6.1 degrees pp translates to be ±0.053 radians. The total modulation vector is the quadrature addition:

$$\sqrt{(0.03)^2 + (0.053)^2} = 0.061$$

The total peak modulation vector, 0.061, represents about 1.2 dB increase over the expected 0.053 vector for phase modulation alone. This explains most of the 1.4 dB discrepancy in sideband energy as measured with the spectrum analyzer. The remainder is easily within the expected error of measurement. Confidence that the phase modulation component is close to the value that was expected, nominally −29.4 dBc, is important because a phase noise instrument is sensitive only to phase modulation (assuming proper alignment) and is insensitive to AM. An accurate measure of phase angle $\Delta\phi$(pp) throughout the band, therefore, should be sufficient to establish a useful calibrator.

Construction

Figure 5 is a schematic diagram of that model. IC1 is a clock generator, set to produce four times the desired modulating frequency. IC2 is a dual D flip flop which divides the clock frequency by four, assuring a 50 percent duty cycle square wave with which to drive the RF switches. IC2-b has its *Set* and *Reset* lines tied to a three position manual switch to permit selection of the toggling mode, or either coax line #1 or #2. This enables the coax lines and switch combinations to be characterized on a network analyzer. Also, the calibrator can be left in the test set circuit and disabled to permit phase noise measurements to proceed without calibrator interference.

SW#1 and SW#2 are pin diode type RF SPDT switches, whose passband largely determines the RF range and characteristics of the calibrator. The switches should have a reasonably fast switching time (a few orders of magnitude less than the modulating period) to assure nearly ideal modulation. They should also be closely matched in path loss, together with their coax lines, to prevent excessive amplitude modulation. Coax #1 and #2, constructed of semi-rigid (0.141 OD) 50 ohm coax, are of different electrical length to produce a small phase shift in the frequency range of interest. The switches used were fitted with SMA connectors to allow different coax lengths to be easily accommodated.

The measured value of $\Delta\phi$(pp) was 6.1 degrees at 100 MHz, as has been mentioned. Using a 100 Hz switching rate, the expected n^{th} order sideband levels are given by:

$$20 \log \left[\frac{\Delta\phi(pp)^\circ}{360^\circ}\right] \cdot \left[\frac{2}{n}\right] \text{for n odd,}$$

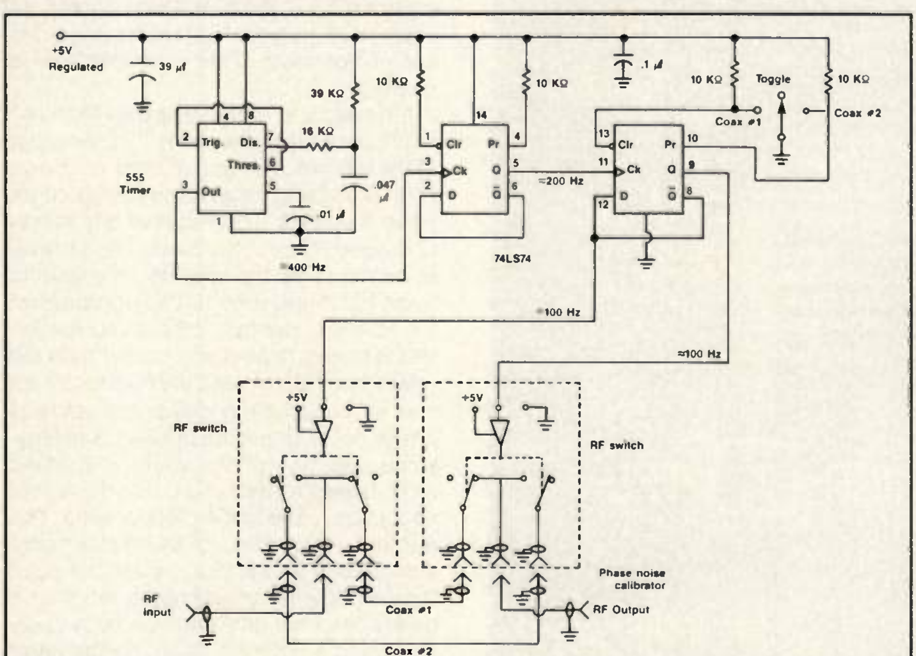

Figure 5. Schematic diagram of experimental calibrator.

and are:

−29.4 dBc at 100 Hz (n = 1)
−38.9 dBc at 300 Hz (n = 3)
−43.4 dBc at 500 Hz (n = 5), etc.

Applications

The calibrator can be inserted after either of the RF sources in a two-source type phase noise test set. Figure 6 shows the calibrator in series with the voltage controlled reference source (usually an internal component or synthesizer). The modulation rate (clock frequency) must be well above the phase-locked loop bandwidth, or the loop will act to demodulate the phase shift, reducing the spectral content and upsetting the calibration. This is true whether the calibrator is inside or outside the loop. In a discriminator-type phase noise instrument there is only one source (the unknown), and, without a locked loop, there is no such limitation on clock frequency.

The calibrator was used to check an HP 11740 phase noise test set, the plotter output of which is shown in Figure 7. A 100 MHz source was used and the expected calibration spectrum was −29.4 dBc for the first order line at 100 Hz offset, −38.9 dBc at 300 Hz offset, and −43.4 dBc at 500 Hz. Phase noise is defined in terms of the power density on one side (single sideband) of the carrier, so the above line levels should not be doubled (increased by 6 dB) to account for the double sideband nature of the RF spectrum.

As can be seen in Figure 7, agreement with expected values is quite close. The small scale of the plotter output precludes resolution better than 1 dB, and the accuracy goal of ±0.5 dB for the calibrator appears to be entirely adequate for the purpose. The higher order sidebands continue to fall 6 dB per octave, as is expected. The closeness of the lines on a log plot become so great beyond 1 kHz that the plotting routine never gets down to the source noise floor between lines. Ultimately, the analyzing bandwidth is inadequate and the plotter output beyond 4 kHz is meaningless. A possible source of misunderstanding is whether the calibration levels should be adjusted by 3 dB, just as it is assumed that a noise plot can be reduced 3 dB to account for equally noisy sources, each of which contribute one half of the observed phase noise. No such adjustment of the calibrator level is needed.

It is helpful to realize that the HP 11740 reads out total phase noise, including that of the reference source and the unknown source, making no assumption about relative noisiness. This requires any appropriate reduction in the plotted noise level to be made by the operator, depending upon his knowledge of the noisiness of the source-under-test. If the source-under-test is known to be much noisier than the reference, it dominates the measurement and no reduction in measured value of phase noise should be applied. Similarly, since only one of the sources is being modulated for calibration, no adjustment should be made to the plotted value. The number −29.4 dBc, for the first-ordered sideband is an absolute reference point for the detected phase noise, whether it arises because only one source is noisy or because both are noisy. In the latter case, only the noise plot should be adjusted downward to report the single

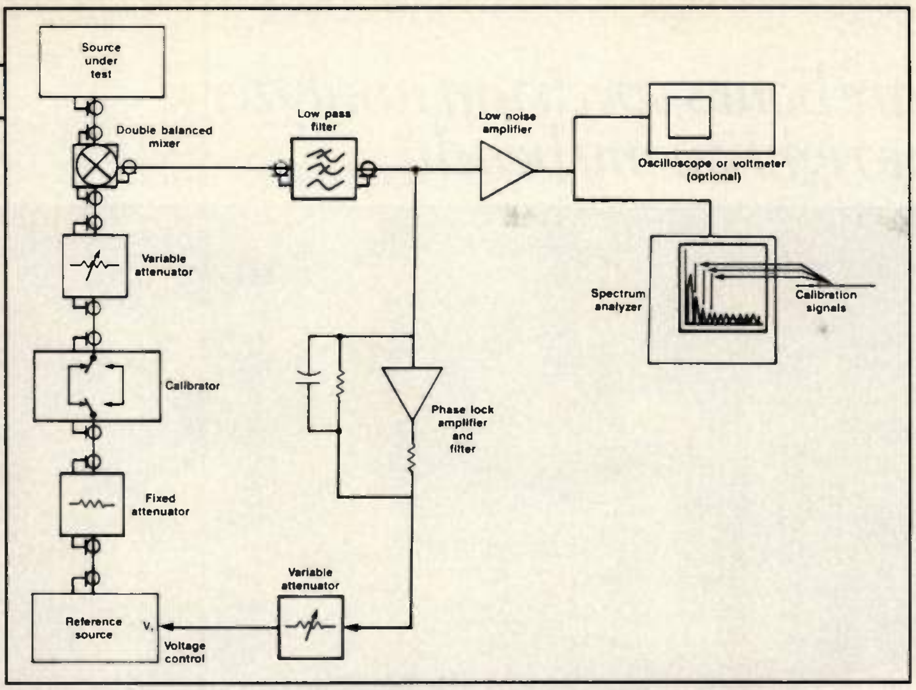

Figure 6. Application of calibrator to a typical phase noise test set.

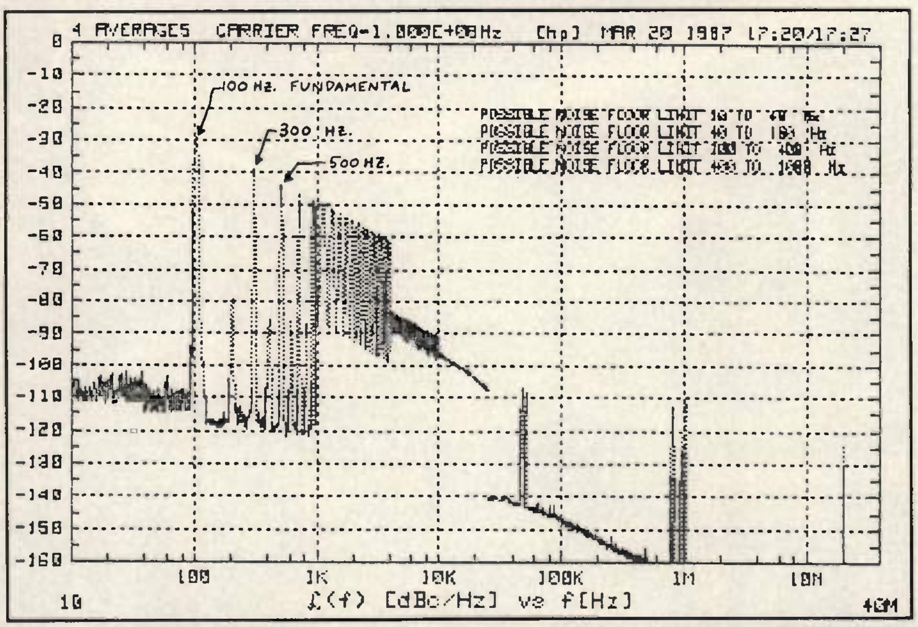

Figure 7. Line spectra produced by calibrator and measured with HP 11740 phase noise analyzer.

source phase noise, and not the calibration of the plot.

Summary

The calibration of phase noise measuring instruments can be established or confirmed using a simple phase modulator, built around the principle of switching between two short sections of coaxial cable. Such a modulator would be placed in series with a source to be measured, and, provided the line difference is less than 0.1 radian at the source frequency, the line spectra which result have a usefully small and easily determined value relative to the carrier. The amplitude of the line spectra can be used to establish the calibration of a phase noise test set to within ±1 dB. The technique can be applied over the entire frequency spectrum, subject to the availability of suitable components. Multiple calibrators can be cascaded to provide coverage of a wide frequency range with a single instrument. Norden Systems has filed for patent disclosure on this technique. rf

About the Authors

Guy Love is a senior design engineer and Kevin Lindell is an RF engineer at Norden Systems, Inc., Division of UTC, Norwalk, CT 06856. The authors can be reached at (203) 852-5000 for Guy, and (203) 852-5148 for Kevin.

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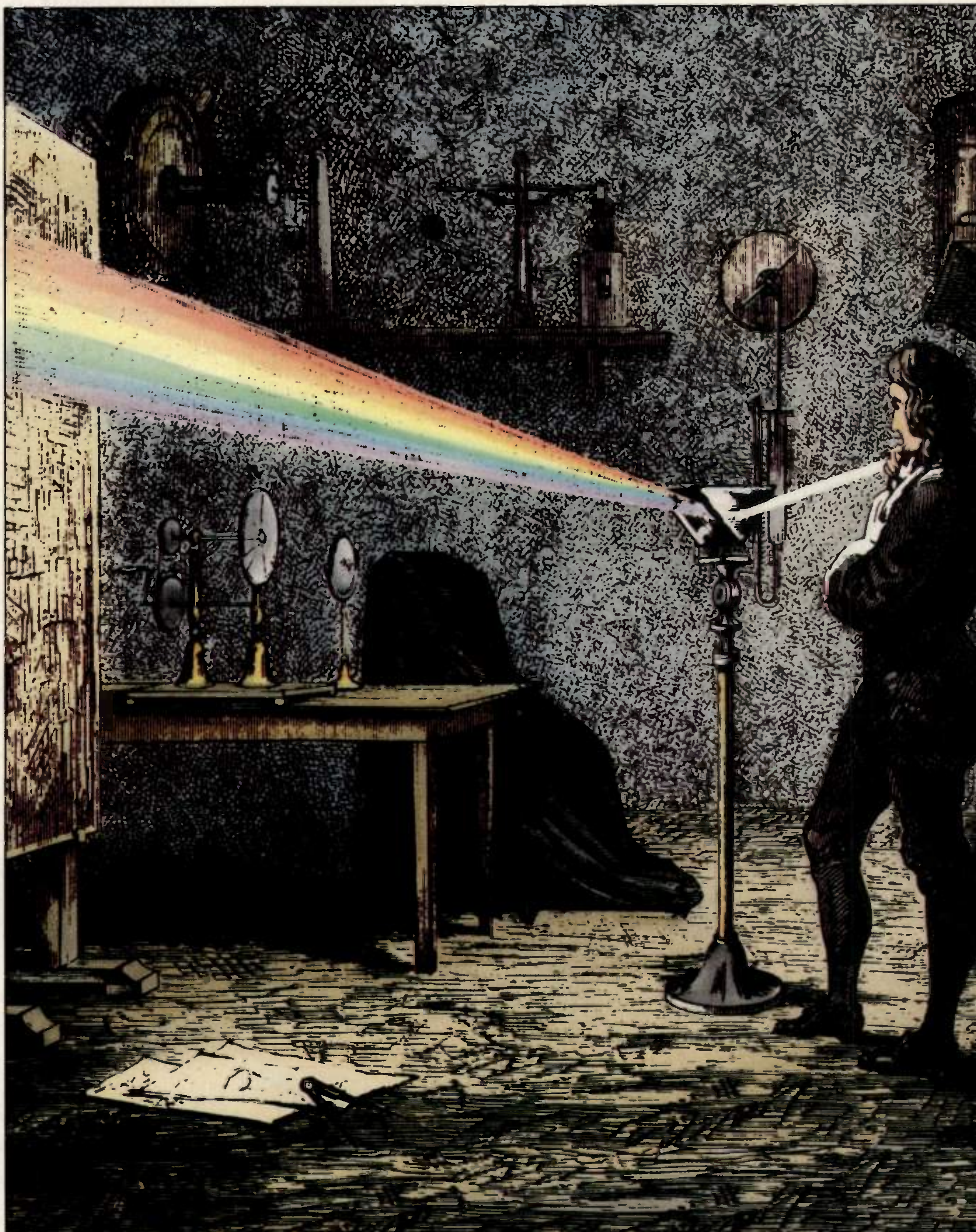

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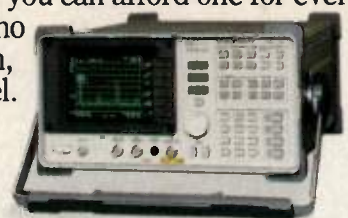

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Broadband Miniature Power Splitter

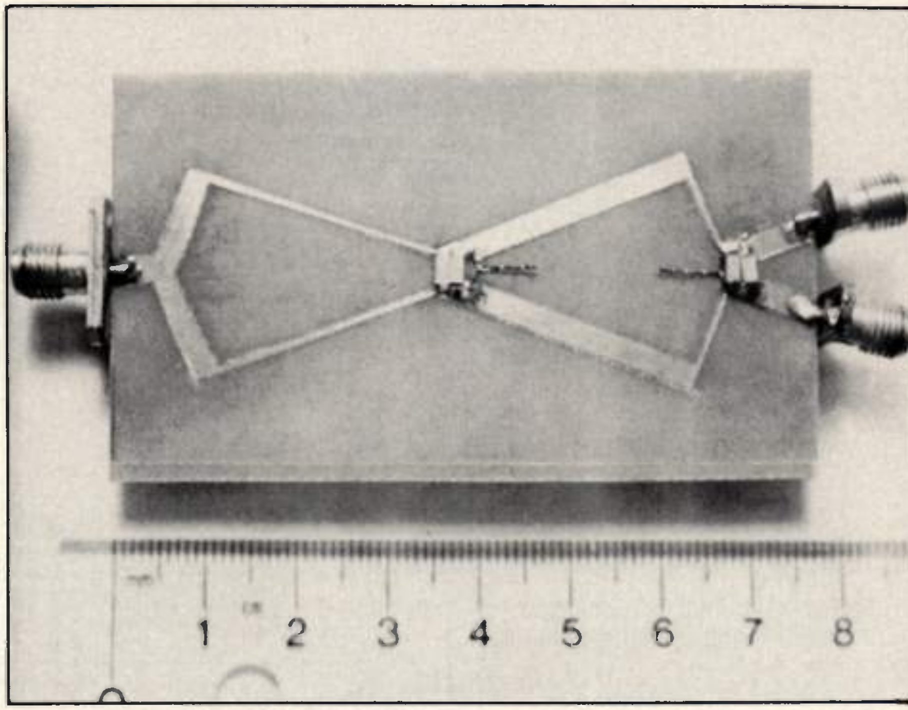
Space-Saving Microstrip Design is Contest Runner-Up

By Peter Vizmuller
Motorola, Ltd.

The frequency range between 500 MHz and 2 GHz presents a challenge for broadband power splitters. Those based on ferrite transformers become difficult to optimize above 500 MHz and broadband power splitters based on conventional microstrip techniques tend to be bulky below 2 GHz. The design in this article illustrates an inexpensive, compact microstrip power splitter that covers an octave bandwidth, yet is smaller than conventional microstrip realization. This design won Peter Vizmuller the Bird Model 4421 RF Power Meter in the RF Design Awards Contest.

The three most important design parameters for a power splitter are input match, output match and isolation. Other performance characteristics, such as amplitude and phase imbalance depend on circuit symmetry and are determined by construction techniques. The input match problem can be reduced to a 100 ohm to 50 ohm impedance transformation, as shown in Figure 1.

In a 50 ohm system, an equal in phase power split will occur if each of the output lines presents a 100 ohm load to the input line at A-A shown in Figure 1. This way the input line will see two 100 ohm loads in parallel, and a 50 ohm input match will be maintained. Each output line has to behave as a 100 ohm to 50 ohm transformer. The simplest impedance transformer is a quarter-wave length of 70.7 ohm transmission line, which forms the basis of the classical Wilkinson power splitter (1). The disadvantage of this impedance matching method is its narrow bandwidth. More sections of quarter-wave lines of varying characteristic impedances improve the bandwidth but make the transformer much longer.



The miniature power splitter.

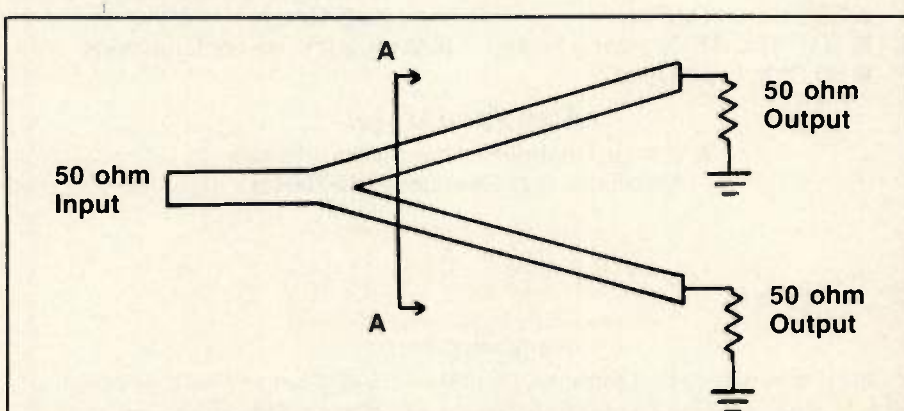


Figure 1. Simplified power splitter.

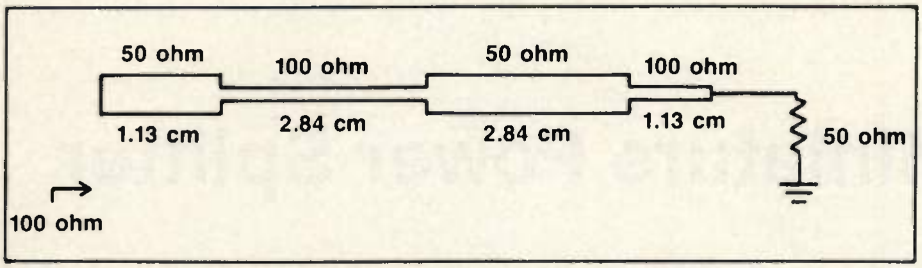


Figure 2. 100 ohm to 50 ohm nonsynchronous transformer.

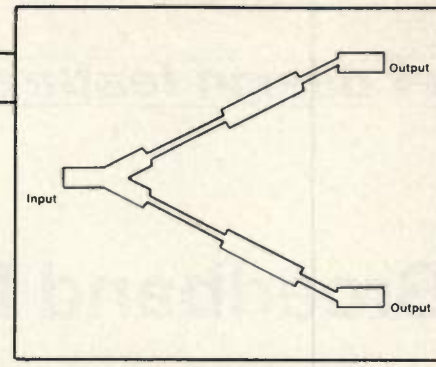


Figure 3. 50 ohm power splitter not corrected for output match and isolation.

Another approach to this impedance-match problem is the use of nonsynchronous transformers(2), where in matching 50 ohm to 100 ohm source and load impedances, sections of 100 ohm and 50 ohm transmission lines can be used to accomplish the impedance transformation. This is the approach taken for the proposed splitter.

A circuit analysis program was used to design a nonsynchronous transformer to operate between 450 MHz and 950 MHz on glass-epoxy circuit board as shown in Figure 2. The total length of this transformer is equal to the 70.7 ohm single-section tranformer, but it covers almost three times the bandwidth. Having obtained the required input match, the next step is to look at output match and isolation. Figure 3 shows the uncorrected power splitter. This splitter provides an equal power split from the input to the output in a 50 ohm system, but the output match and isolation is poor. To improve both, an isolation resistor can be added between the two outputs as shown in Figure 4.

The resistor isolation is accomplished the following way: Assume a signal is fed into one output, terminating the input in 50 ohms and looking at power coming out the other output. The signal that travels from one output to the other via the transmission lines is delayed by 180 degrees due to the quarter-wave length

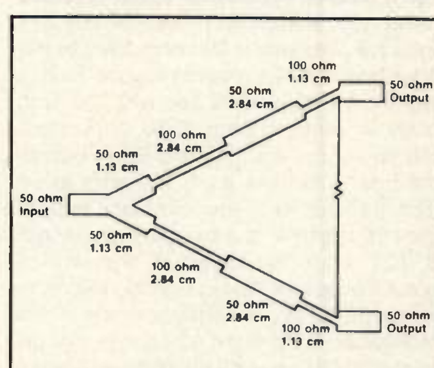


Figure 4. Power splitter with one isolation resistor.

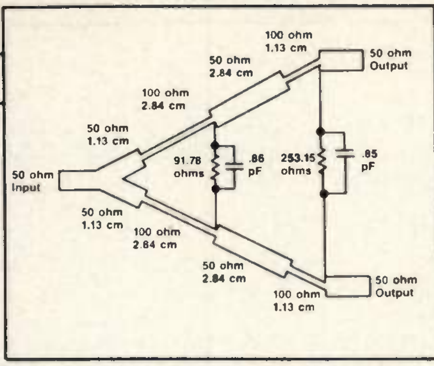


Figure 5. Final splitter configuration.

signals at corresponding points in the output lines are in phase (when the input is the signal source), and there is no potential difference across a component placed there.

The final resistor and capacitor values were obtained by a circuit optimization program, design criteria was better than 20 dB input and output return loss and better than 20 dB isolation over 450 MHz to 950 MHz. Figures 6 and 7 show the theoretical performance. The power splitter was then constructed on standard G-10 glass epoxy board, 1.6 mm thick. The transmission lines were folded at their junctions to allow the use of chip isolation resistors; 50 ohm lines were 2.7 mm wide and 100 ohm lines were 0.54 mm wide. Capacitors were realized as short lengths of twisted bifilar wire. Measured performance of this splitter is shown in Figures 8 to 12.

of each transformer, but the signal which takes the path through the resistor is not delayed, and therefore out of phase with the other signal. Selecting a proper value resistor ensures equal amplitudes for the two signals and therefore signal cancellation at the other output, accomplishing isolation.

Using one resistor achieves isolation over a narrow bandwidth, comparable to a conventional Wilkinson splitter. To increase the isolation bandwidth, two resistors are used as shown in Figure 5. The other resistor improves isolation at higher frequencies, since some of the signal going to the input is shunted to the other side by this resistor, decreasing the phase shift as required at higher frequencies, where the impedance transformers are longer than quarter-wave and would provide more than 180 degrees phase shift without the second resistor.

The splitter as constructed so far, has good input match, output match and isolation, but these parameters do not coincide exactly in frequency. Small capacitors added in parallel to the isolation resistors overcome this difficulty by shifting the output match and isolation curves in frequency, so that all three parameters become centered around a common frequency. Note that any components placed between the two output lines at corresponding points do not affect the input match or power split, since

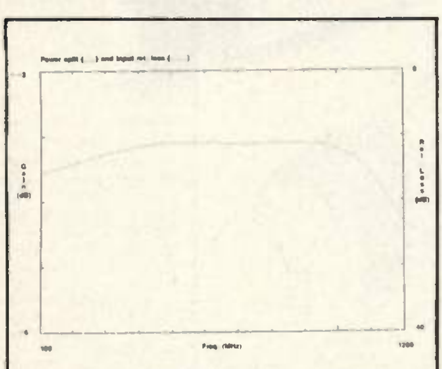


Figure 6. Theoretical performance of the splitter.

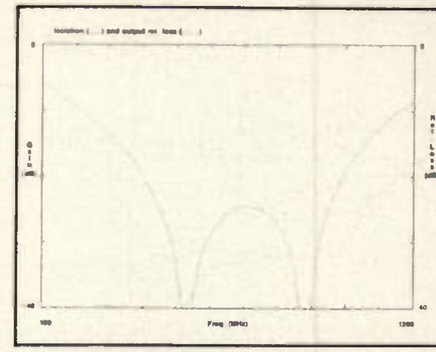


Figure 7. Theoretical performance of the splitter.

Figure 8. Measured input return loss.

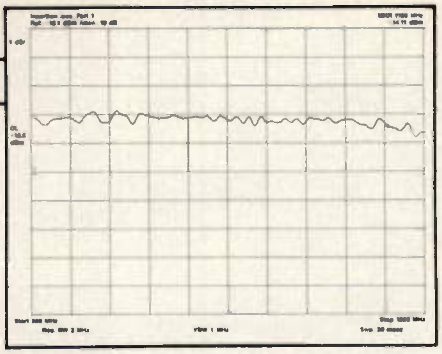


Figure 9. Insertion loss at Port 1.

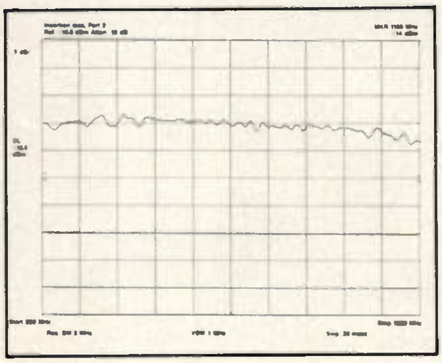


Figure 10. Insertion loss at Port 2.

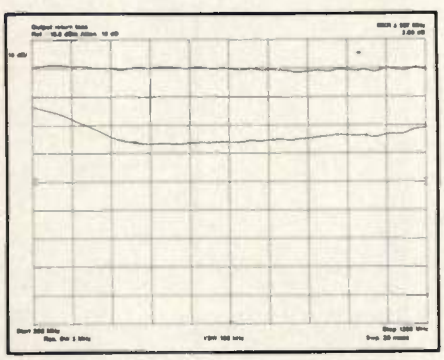


Figure 11. Output return loss.

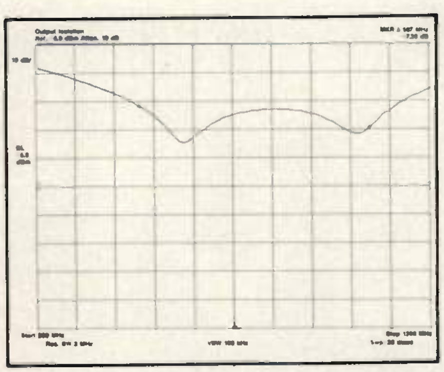
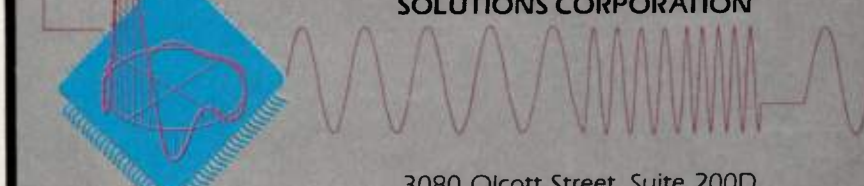


Figure 12. Measured output isolation.



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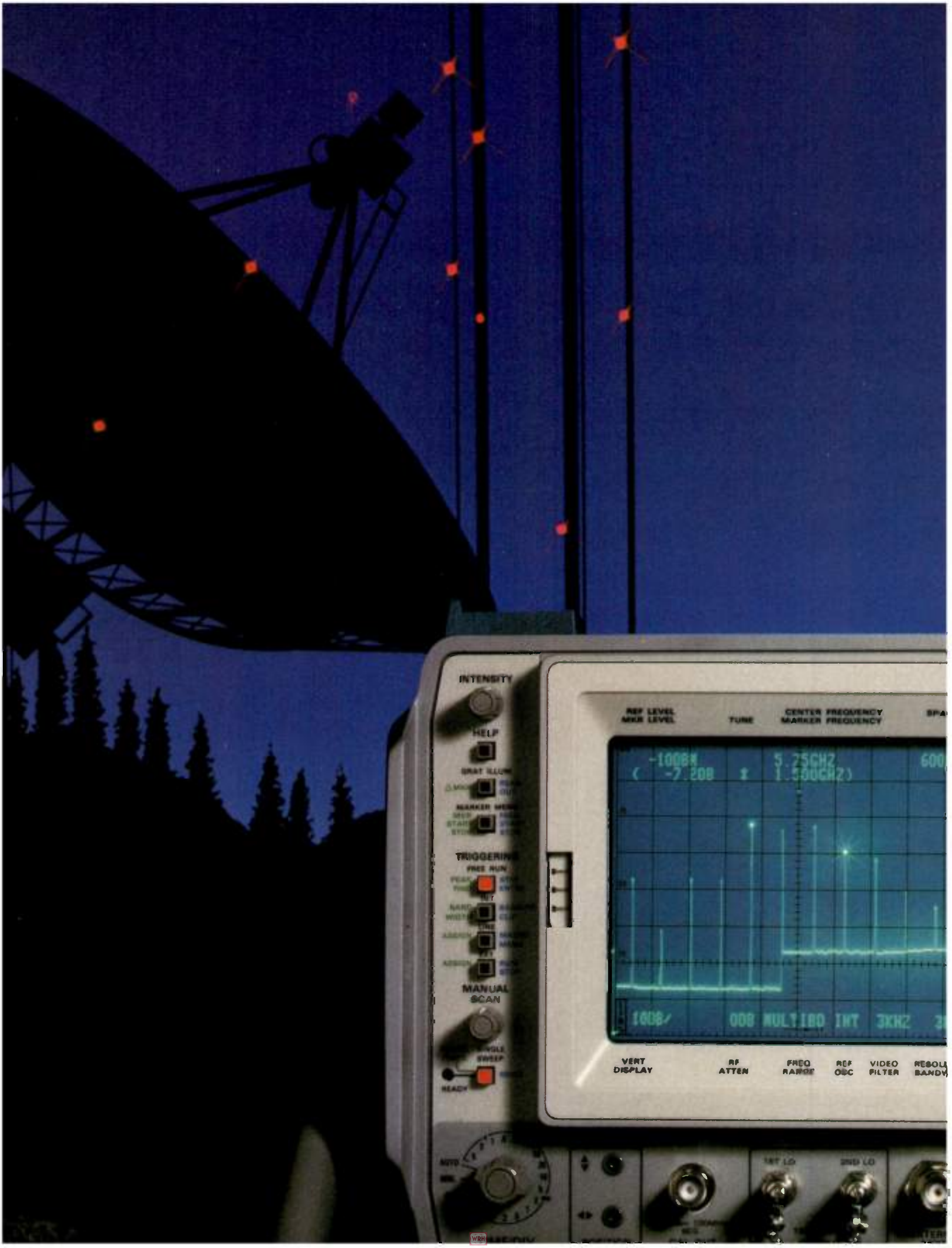
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Results

The design objectives of 20 dB return loss and isolation were achieved from 460 MHz to 1030 MHz, bandwidth performance being limited by the input return loss; output return loss and isolation covers a wider bandwidth. Maximum insertion loss measured was 3.4 dB at the higher frequencies, maximum amplitude imbalance was 0.2 dB. The measured prototype is shifted higher in frequency from the theoretical design, probably because in folding the lines at right angles, the high impedance lines are slightly foreshortened.

Table 1 outlines the performance of a Wilkinson splitter, the author's power splitter and a conventional two-section microstrip splitter of comparable performance (3), all realized on glass-epoxy circuit board, covering the same frequency band (results were obtained by computer simulation). The summary table shows

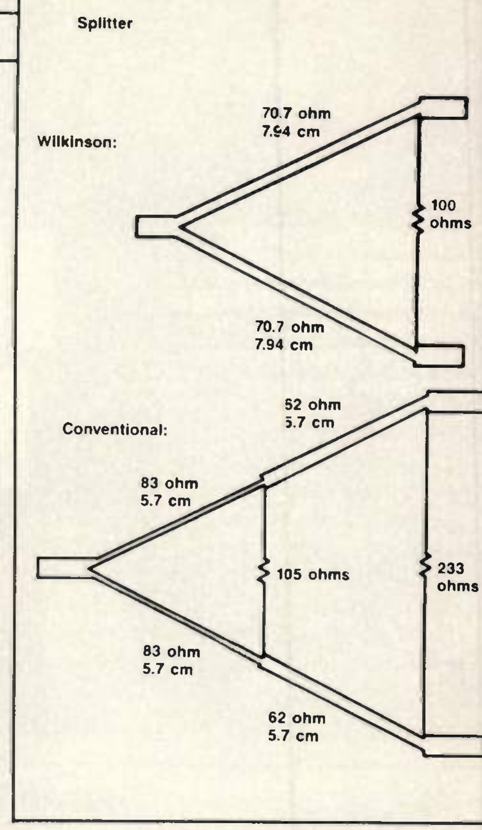

Table 1. Comparison between three splitters.

that the proposed power splitter is more broadband when compared to a Wilkinson of the same length and is 30 percent shorter than a conventional two-section microstrip version of slightly better performance.

Conclusion

This design illustrates how a fresh look at impedance matching coupled with understanding of basic circuit performance can advance the state-of-the-art in microstrip power splitters, to produce an inexpensive, practical broadband device.

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1. Howe, H., *Stripline Circuit Design*, Dedham: Artech House Inc., 1974, p.94.
2. Matthaei, G., L., L. Young, E.M.T. Jones, *Microwave Filters, Impedance Matching Networks, and Coupling Structures*, Dedham: Artech House Inc., 1980, p.334.
3. Howe, H. *op. cit.*, p. 105.

About the Author

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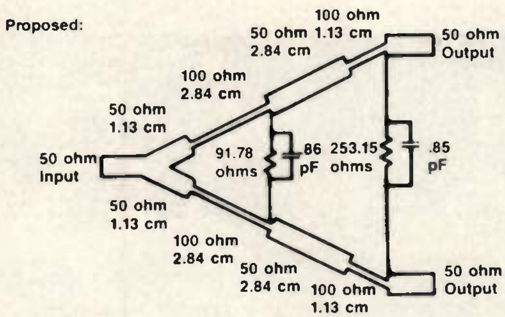
	Length (cm)	Bandwidth (MHz)	Bandwidth ratio
Wilkinson:	7.94	200	1.45
Proposed:	7.94	570	2.39
Conventional:	11.40	610	2.49



Conductive Plastic Composites Offer Shielding Solution

By Mark Gomez
Assistant Editor

Electromagnetic interference is an unavoidable aspect of design engineering. The search for cost effective methods of shielding has brought about various solutions to reduce interference problems. Conductive plastics offer one possible answer to this dilemma. However, plastics can only be used for new designs, while other products may be used to fix or improve existing systems. This article takes a look at a plastic shielding material developed by GE Plastics.

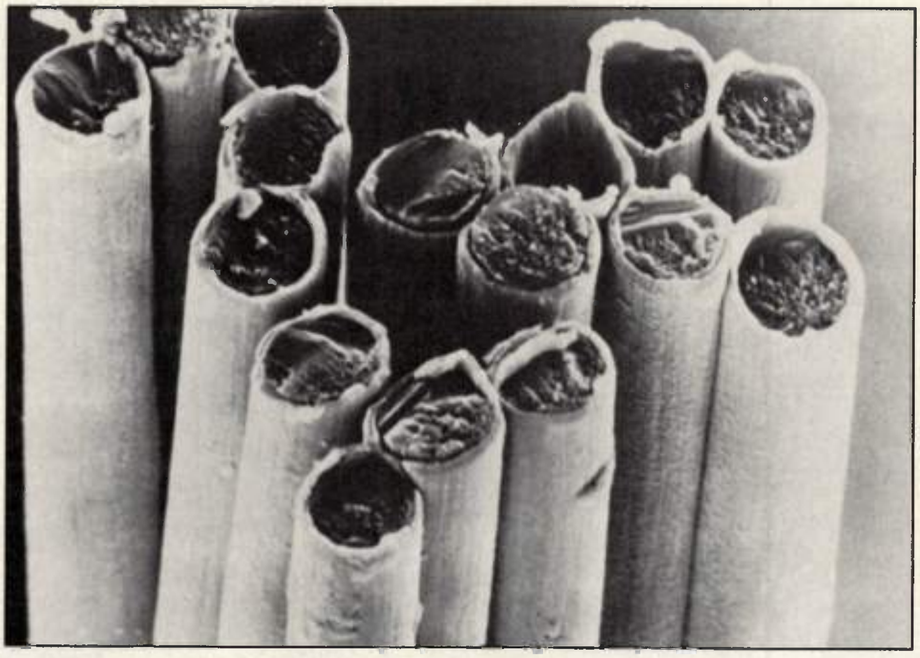
Shielding is defined as the ability of a material to reduce the transmission of propagating electromagnetic fields. It is continually being improved with the development of various fabrics, composite materials, and plastics. Conductive plastic composites are made up of polymer resins that contain electrically conductive additives.

Metal coatings such as metal filled paints and electroless plating have not proved to be effective since they are prone to flaking. Also, aluminum flake and stainless steel fibers used in shielding are relatively expensive and difficult to process. Plastics offer molded-in functionality and usually look better and weigh less than conventional methods.

High performance resins are easy to process and provide uniform and consistent inherent shielding without the need for costly secondary operations. Plastic materials which exhibit equivalent or superior shielding are generally more economical than nickel acrylic painting, electroplating, vacuum metalization or zinc arc spraying.

The Lexan® dB5000 resin series is a thermoplastic introduced by General Electric Plastics designed to provide shielding from EMI and RFI. The Lexan conductive polymer is a combination of bundles of nickel coated graphite fibers and pellets of Lexan resin. The bundles comprise of up to 12,000 quarter-inch-long fibers that become evenly distributed during the melt process, providing the desired shielding level.

A key advantage of the resin is the molded-in shielding for increased design freedom. Another advantage is that the mechanical and logistic problems associated with line of sight coatings are eliminated. Since the shielding is molded in, it will not flake or peel off.



Nickel coated graphite fiberts are combined with pellets of Lexan resin to achieve the desired shielding level.

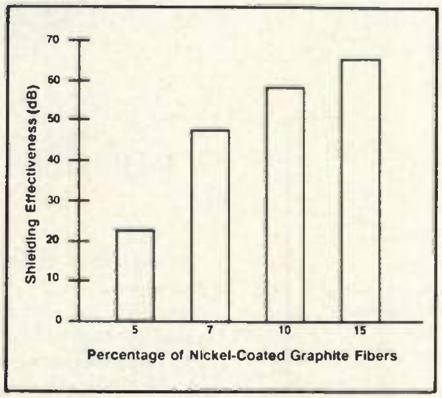


Table 1. Effects of nickel coated graphite fibers on shielding effectiveness.

Varying the loading levels in the Lexan resin/nickel-coated graphite fiber mixture gives the designer greater control over shielding levels, conductivity and cost. For example, a mixture of seven percent nickel-coated graphite fibers in Lexan resin has a shielding effectiveness of about 47 dB, which is greater than a coating of nickel acrylic spray. A 10 percent loading level of nickel-coated graphite fibers increases shielding effectiveness to 58 dB. Table 1 illustrates shielding effectiveness with respect to loading level of nickel-coated graphite fibers.

This method of shielding is fairly cost effective. One manufacturer has priced several shielding methods for an oscilloscope and has determined that at seven percent loading, nickel coated graphite fibers are less costly and provide better shielding than nickel acrylic paint.

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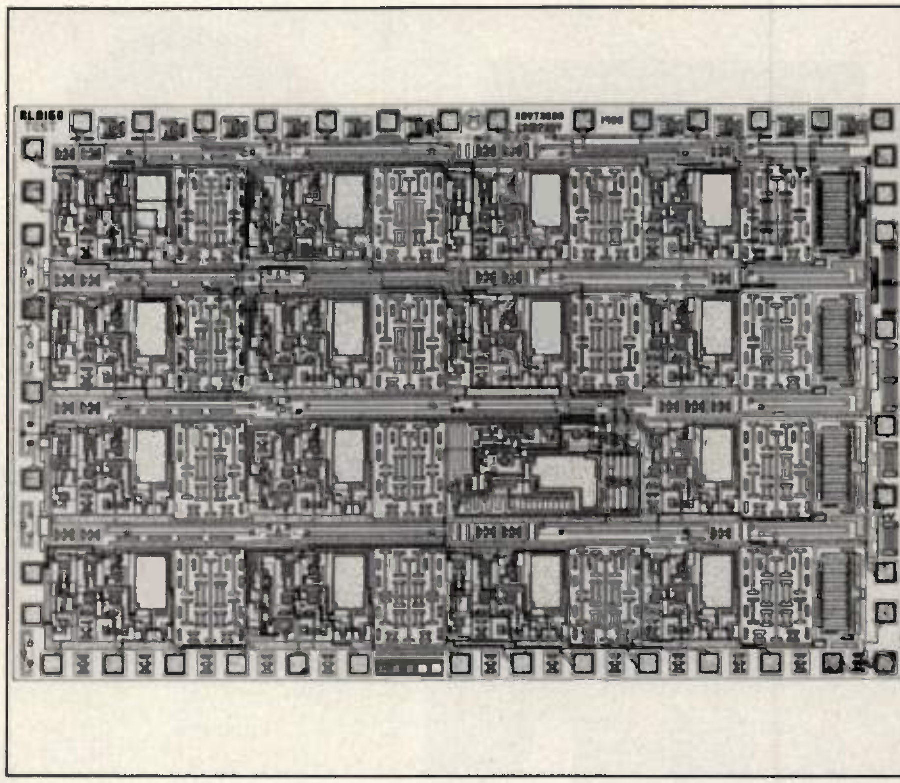
The thin film resistors are made by sputtering silicon-chromium onto the chip. All 240 resistors can track to an absolute temperature coefficient of 5 ppm with a typical tolerance of ± 5 percent each. All the resistors and transistors have double terminations permitting utilization of all the ICs macrocells and up to 80 percent of all individual transistors.

At unity gain, the slew rate is measured at 0.7 V/us and the bandwidth is 2.0 MHz. The input offset voltage is 1.0 mV while the input offset current is 1.0 nA. All the macrocells can be programmed for specific quiescent currents and AC operating conditions. Also sufficient gain can be obtained at specific frequencies which is a useful feature in the design of filters.



The price of the RLA160 is dependent on the package type, temperature range, cell utilization, and custom test requirements for specific applications. Kits are available from Raytheon to aid a prospective user in developing prototypes and are intended for designers who want to make a trial application of the RLA160 macrocells in an existing system. **Raytheon Company, Semiconductor Division, Mountain View, CA. INFO/CARD #220.**

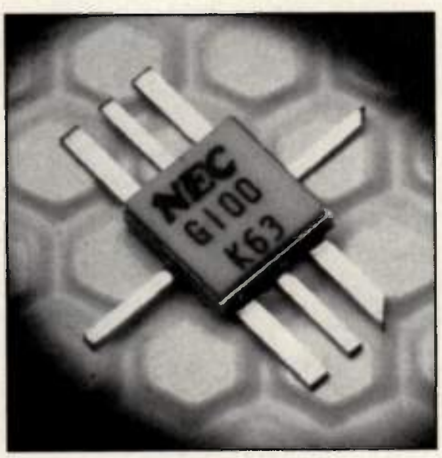
750 MHz IF Limiter Discriminator Introduced By RHG Electronics

The Model ICDX750 is a delay line IF limiter discriminator that operates at 750 MHz with a peak to peak bandwidth of 450 MHz while the minimum linear bandwidth is 250 MHz. The ICDX750's wide bandwidth and 20 nsec rise time enables it to handle FM demodulation of high speed pulsed carriers where substantial AM is present. It can also be used to measure the frequency of a pulsed carrier. The unit is rated for an input level of 0 dBm, but is usable down to −10 dBm. A delay line for demodulation, coupled with a constant phase limiter/driver for minimum degradation of pulsed waveforms is employed.

Designed for MIL-E-5400 and MIL-E-16400 environments, the limiter discriminator has an operating temperature range of −54C to +71C. It measures 3.53" × 1.50" × 0.47" excluding SMA connectors and weighs 3.7 oz. The specifications include a frequency accuracy of ± 12 MHz at 25°C and ±25 MHz above that temperature and a video sensitivity of 10 mV/MHz. The ICDX750 is priced at $1535. Other models are available with operating frequencies from 30 to 1000 MHz. **RHG Electronics Laboratory, Inc., Deer Park, NY. INFO/CARD #219.**

GaAs MMIC Amplifiers

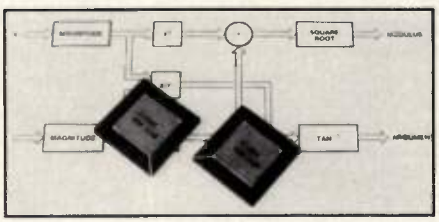
The UPG100 is a low noise GaAs MMIC and the UPG101 is a medium power GaAs MMIC. Both are internally matched to 50 ohms and operate in the .05 to 3 GHz range. The 100 has a gain of 16 dB with a maximum gain flatness of ± 1.5 dB, typical NF is 2.7 dB while the



power at 1 dB compression is 6 dBm. The specifications on the 101 include a gain of 14 dB, NF of 5 dB typical, and power at 1 dB compression is 18 dBm typical. The 101 maintains the same gain flatness as the 100. **California Eastern Laboratories, Santa Clara, CA. Please circle INFO/CARD #218.**

Pythagoras Processor

Plessey introduces a device that converts complex cartesian data into polar form magnitude and phase at a 10 MHz rate. Termed the pythagoras processor,



the PDSP16330 converts 16 × 16 bit two's complement or sign magnitude data into 16 bit magnitude and 12 bit phase format. The magnitude may be scaled in amplitude by powers of two. Its applications include radar, sonar and digital radio systems. **Plessey Semiconductors, Irvine, CA. INFO/CARD #217.**

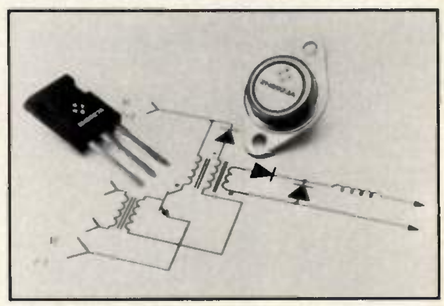
Digitizing Scope With TDR

The HP 54120T color digitizing scope has a 20 GHz repetitive bandwidth, a built-in time domain reflectometer (TDR), and four simultaneous acquisition input channels. The features include optional 6 GHz passive probing, 12 bit resolution, .25 ps timing resolution and a 10 ps tim-

ing accuracy. The TDR measures impedance, reflection coefficient and distance from a reference plane. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #216.**

Power Switching Transistors

General Semiconductors unveils a series of bipolar power switching transistors that offer a combination of 850 V (V_{CEV}) and a switching speed of 35 ns (crossover time). They also have a V_{CEO} of 400 and 450 V and a maximum saturation V_{CE} of 1 V. These devices are designed to switch the inductive loads characteristic of switching power supplies.



characteristic of switching power supplies.
General Semiconductor Industries, Inc., Tempe, AZ, INFO/CARD #215.

High Speed Power Driver

The UC3705 power driver uses a high speed Schottky process which allows it to interface between low level control functions and high power output devices. It is compatible with MOSFET and bipolar transistors. The device has a source/sink drive current of up to 1.5 A with a 40 ns rise and fall into 1000 pF. **Unitrode, Merrimack, NH. INFO/CARD #214.**

Tunnel Diode Pulse Generator

The TD-1110A produces an ultra fast pulse with 25 ps rise time, 240 mV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amplitude, 4 us duration, and 50 kHz repetition rate. It consists of a pulse driver unit and a remote TD pulser head. The unit costs $1950. **Picosecond Pulse Labs, Inc., Boulder, CO. Please circle INFO/CARD #213.**

2 to 6 GHz MMIC Amplifier Chip

Harris Microwave introduces a dual stage, 2 to 6 GHz, 0.5 micron GaAs medium power MMIC in die form. It is cascadable and intended for gain stage applications. DC blocking on the RF output and bypass functions are incorporated. The maximum input VSWR is 2:1 while the typical noise figure at 120 mA is 6 dB. **Harris Microwave Semiconductor, Milpitas, CA. INFO/CARD #212.**

GaAs Prescalar

The MFG-8000 Series is a family of dual modulus (1/128, 1/129) high speed GaAs frequency dividers. The devices operate up to 1.6 GHz with a maximum power dissipation of 50 mW. The maximum output current is –5 mA. **Mitsubishi Electronics, Sunnyvale, CA. INFO/CARD #211.**

Microwave Power Meter

Wavetek introduces its 8531 single channel microwave power meter. It is complemented by a broad family of sen-

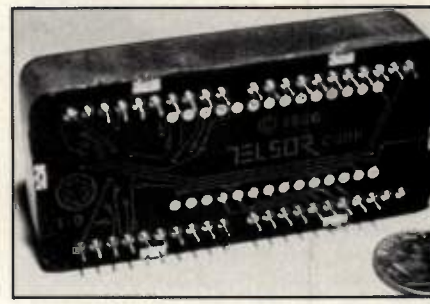
sors including thermocouple and diode sensors for high and low power measurements, low frequency sensors, 26.5 GHz sensors and 75 ohm sensors. The features include one button calibration, user controllable averaging of readings, and is programmable using GPIB format. Error is specified at ± 0.5 percent of full scale in the linear mode or ± 0.02 dB in the logarithmic mode. It can take up to 40 readings per second over the bus. **Wavetek Corporation, San Diego, CA. INFO/CARD #210.**

Portable Spectrum Analyzer

The Spectre 1050 spectrum analyzer offers portability through the use of self contained batteries that operate the instrument for three hours of continuous use. This 1 GHz unit has a line of options that include digital storage, tracking generator and a wideband video detector. **Texcan Instruments, Indianapolis, IN. INFO/CARD #209.**

Interface Reader Module

Telsor introduces an interface Model 2020 reader module. It is capable of multiplexing up to 8 addressable sensors which read 128-bit passive transponders



up to 12 inches away. The device measures 2.6" × 1.2" × 0.7". **Telsor Corporation, Englewood, CO. Please circle INFO/CARD #208.**

L-Band Modular Synthesizer

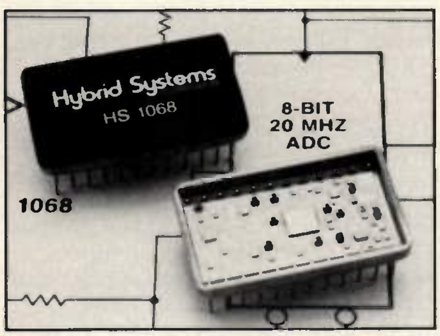
This OEM instrument is used to generate test frequencies of 1550 MHz to 1850 MHz in 1 MHz steps. Frequency control is provided by parallel TTL and CMOS input levels applied through a 25 pin D type connector. The specification include a phase noise of −85 dBc at 10 kHz, VSWR of 2:1, and a maximum settling time of 50 msecs. A sample of the reference frequency is available for coherent system operation. **Systematix, Lyndhurst, NJ. INFO/CARD #207.**

Quad OP Amp

NSC has released a quad operational amplifier that achieves a 140 dB dynamic range with less than 0.0015 percent distortion. The LM837 has a slew rate exceeding 8V/us, power bandwidth of 140 kHz and is able to drive 600 ohm loads. It has a low input noise voltage of 0.5 uV. It contains 4 amplifiers and is available in 14 pin dips and molded packages (SO). The price is $1.25 each in 25,000 unit quantities. **National Semiconductor Corporation, Santa Clara, CA. Please circle INFO/CARD #206.**

8-Bit A/D Converter

The HS1068 is a flash analog to digital converter that incorporates a wideband analog input amplifier, voltage reference and three stage output register into a 1.3"



× 0.77" 24 pin dual in line package. It is an eight bit parallel flash converter capable of digitizing at rates up to 20 MHz. A digital output register provides three state outputs for ease of microprocessor interface. **Hybrid Systems Corporation, Billerica, MA. Please circle INFO/CARD #205.**

GaAs Distributed Amplifier

Texas Instruments introduces a monolithic GaAs amplifier that operates in the 2 to 18 GHz frequency range. The TGA8300 has a typical gain of 6.5 dB with an output power of 18 dBm at 1 dB gain compression. The noise figure is less than 7 dB over the frequency range. It includes on chip metal insulator metal bypass capacitors for the biasing of the amplifier. **Texas Instruments, Inc., Semiconductor Group, Dallas, TX. INFO/CARD #204.**

Capacitor Evaluation Kits

Monolithic ceramic chip capacitor evaluation kits are available from the Delcap Division of American Precision Industries. Each kit contains 25 samples in a range of values and are available in COG and X7R dielectric construction. Standard chip termination is palladium silver with nickel barrier/solder available as an option. The rated voltage is 50 V. The kit costs $129.95 for palladium silver and $179.95 for nicker barrier. **American Precision Industries, Inc., East Aurora, NY. INFO/CARD #203.**

Synthesizer Receiver

Model SR500-F is a UHF synthesized FM receiver that operates at 420 to 470 MHz. The receiver is synthesized at 100 kHz channel spacings. Bandwidth is 360 kHz while the 12 dB SNR sensitivity is −95 dBm. The SR500-F is available with an analog or digital output. **General Services Engineering, Inc., Baltimore, MD. INFO/CARD #202.**

Low Frequency Active Transponder

The Eureka 411 is a RF read-write identification device for use in data collection and identification applications. Up to 115 alpha numeric characters may be read from or written to the tag at a range of up to 39 inches from the interrogating antenna. The activating field is continuous wave at 132 kHz. Data from the tag is transmitted on a 66 kHz carrier using phase shift keying. **Eureka Systems, Inc., Englewood Cliffs, NJ. Please circle INFO/CARD #201.**

Hybrid VCXOs to 100 MHz

Reeves-Hoffman introduces a line of high frequency sine wave VCXOs in a double dip hybrid package. The frequency range is 2 to 100 MHz with power output to 10 dBm. **Reeves-Hoffman Division, Carlisle, PA. INFO/CARD #200.**

30 MHz Measurement Receiver

The Model VM-7 is a 30 MHz receiver designed for applications where precise measurements of RF power ratio are required over a wide dynamic range. It provides measurements over a range of 0 to 127 dBm, a selectable resolution of 0.1, 0.01 or 0.001 dB and an incremental attenuation accuracy of .02 dB per 10 dB. It is priced at $15,000. **Weinschel Engineering, Gaithersburg, MD. Please circle INFO/CARD #199.**

Power Silicon MMIC Amplifiers

Avantek introduces two 100 MHz to 2 GHz Modamp™ cascadable gain blocks intended for use in narrow or broad bandwidth RF amplifier design. The MSA-0520 features +23 dBm power output at 1 dB gain compression and 8.5 dB gain at 1 GHz. The MSA-1023 features +27 dBm power output at 1 dB gain compression, +37 dBm third order intercept point and 8.5 dB gain at 1 GHz. **Avantek, Inc., Santa Clara, CA. INFO/CARD #196.**

Washable Trimming Capacitors

These miniature trimming capacitors feature internal "O" ring sealing which allow solvent washing. The TZ03 Series capacitance values are from 1.25 pF to 2.3 pF through 10 pF to 120 pF. The capacitors have an axle-less construction that contribute to its stable T.C. and small size. **Murata Erie North America, Inc., Smyrna, GA. INFO/CARD #195.**

SMT Capacitor Kit

NPO, X7R, and Z5U multilayer ceramic capacitor chips are furnished in Johanson Dielectrics' S-920 SMT prototype kits. It includes 550 capacitors of sizes 0805 and 1206 with nickel barrier terminations. It comes with a chip selector guide and a technical manual entitled *Understanding Chip Capacitors*. **Johanson Dielectrics, Inc., Burbank, CA. Please circle INFO/CARD #194.**

PTFE Laminate

Rogers Corporation introduces a line of woven glass reinforced PTFE laminates with dielectric constants ranging from 2.4 to 2.6 ± 0.04. Ultralam™ 2000 provides a highly uniform dielectric constant. **Rogers Corporation, Chandler, AZ. INFO/CARD #193.**

CMOS and D-MOS Data Book

This data book from Topaz Semiconductor features data sheets and application tips on lateral N-channel enhancement and depletion mode D-MOS FETs, high voltage vertical N and P-channel D-MOS FETs and high speed CMOS/D-MOS analog switches, multiplexers, and attenuators. It also provides a cross-reference and substitution guide for identifying alternate sources, high performance plug in compatible components plus information on replacing JFETs with D-MOS FETs for significant increases in performance. **Topaz Semiconductor, San Jose, CA. INFO/CARD #189.**

Software Literature

Compact Software has released literature on all its software products, including products formerly sold by Communications Consulting Corporation. Data sheets on Super-Compact revision 1.9 are available with details of all its additional capabilities. Data sheets on the company's line of microwave and RF, IBM PC, and Series 200/300 products called *CADEC 4* have been updated. **Compact Software, Paterson, NJ. INFO/CARD #188.**

Technical Note on Pulse Measurement

Pulse Measurements in the Picosecond Domain is a technical note that discusses measurement problems, particularly those with emphasis in the picosecond domain. Oscilloscopes, calibration standards, coaxial cables and connectors, and probes are discussed. Also included is a list of references for extended reading on the subject. **Picosecond Pulse Labs, Inc., Boulder, CO. INFO/CARD #187.**

Application Notes on Mixers

Synergy Microwave introduces a list of application notes and detailed information on surface mount technology for mixers. **Synergy Microwave Corporation, Paterson, NJ. Please circle INFO/CARD #186.**

Microwave Components Fact Sheet

Microwave Data Packet contains detailed fact sheets describing International Microwave Corporation's line of microwave components. Included are photographs, diagrams, descriptions and specifications for GaAs FET amplifiers, bipolar transistors and tunnel diode amplifiers, AGC and log video amplifiers, gunn diode and tunnel diode oscillators, broadband, narrow band and excess noise sources. **International Microwave Corporation, Stamford, CT. INFO/CARD #184.**

Oscilloscope Support Material

Tektronix had released a library of support material for its 2225 50 MHz oscilloscope. The material includes a demonstration video tape, brochure, a booklet entitled *The XYZ's of using a scope* and five technical briefs on oscilloscope measurements. The video tape demonstrates the 2225's dual channel operation, alternate horizontal magnification, 500 microvolt sensitivity and extensive triggering features. **Tektronix, Inc., Beaverton, OR. INFO/CARD #183.**

Surface Mounting Directory

IHS introduce a surface mount directory that enables the user to access over 30,000 devices which includes resistors,

rf literature *Continued*

capacitors, inductors, transistors, bipolar and MOS digital/linear ICs, data arrays, diodes, and memory devices. The directory is available in 24X microfiche and 16 mm microfilm cartridges. It allows search by manufacturer's name, part number, generic part number or generic component description. The annual subscription rate is $600. **Information Handling Services, Englewood, CO. INFO/CARD #182.**

Linear ICs Data Book

D.A.T.A. has released its 38th edition of *Linear ICs* which displays information for more than 15,000 linear ICs from 153 manufacturers. It has an expanded operational amplifier section with single, dual, triple and quad devices including programmable, ultra-low noise and BiFET types. Other devices in this book includes phase lock loop devices, amplifiers, sensor circuits, telecommunication devices, timers, transistor arrays, voltage comparators, and wideband devices. Two semiannual editions of this publication cost $110. **D.A.T.A., Inc., San Diego, CA. INFO/CARD #185.**

Linear Selection Guide

Linear Technology Corporation introduces a brochure called *Selection Guides.* Among the bipolar and CMOS integrated circuits listed are single, dual and quad precision operational amplifiers, switching and positive fixed voltage regulators, low drop-out voltage regulators, positive adjustable and negative adjustable voltage regulators, voltage references, monolithic switched capacitor filters and various other components. **Linear Technology Corporation, Milpitas, CA. INFO/CARD #180.**

Teledyne Microelectronics Offers Free Software

"RF Toolbox" is the title of a software package for everyday RF engineering calculations. Features include calculations for cascade noise figure and gain, resistive attenuators, inductive reactance and Q, capacitive reactance and D, resonance and tuning range, VSWR conversions, power level conversions and noise figure measurement. Also included are TSS calculations for DLVAs and TSS calculations with PD gain. The program is user-friendly and provides information on the equations used in the calculations. The software is free and users are entitled to free upgrades for one year provided they are registered with Teledyne. This promotional offer is intended to familiarize RF engineers with the custom hybrid development and manufacturing capabilities of Teledyne. **Teledyne Microelectronics, Los Angeles, CA. INFO/CARD #174.**

Synthesis and Analysis of Coaxial Transmission Lines

Microwave Software Applications introduces software that performs synthesis and analysis of coaxial transmission lines. *Cxline* performs synthesis of dimensions from impedance, analysis of impedance from dimensions, sensitivity analysis of impedance to incremental changes in inner conductor diameter, outer diameter conductor, and dielectric constant. The other functions performed include insertion loss versus frequency calculations for inner and outer conductor loss and dielectric loss effects. Higher-order mode cutoff frequency, capacitance and inductance per unit length, peak power handling of coax cross section and default values of each input parameter can also be calculated. **Microwave Software Applications, Inc., Norcross, GA. INFO/CARD #173.**

System Distortion Simulation

Designer of multichannel linear systems such as television repeaters, cable television distribution networks, microwave television links, and satellite transponders will find DPA-1000's distortion simulation useful in analyzing the interaction between signal to noise ratio and system linearity. DPA-1000 is ideal for frequency allocation studies as it can identify the source of intermodulation distortion in receivers. It calculates the second and third order distortion products arising from non linearity in multichannel systems. Version 1.1 of DPA-1000 read and writes data files compatible with BASIC, Fortran, and Pascal. It is priced at $3500. **Step Electronics, Inc., Campbell, CA. Please circle INFO/CARD #156.**

Spice Plus-DEC VAX Interface

Analog Design Tools has integrated its Spice Plus™ program with the DEC VAX. After designing with the Analog Workbench, the simulation can be sent to a remote VAX for the processing. This allows the designer to use his workstation for the interactive design task, yet free up the workstation for other uses while the VAX is performing the simulation. The price of the remote Spice Plus starts at $9,500 per MicroVAX. It will work in conjunction with Analog Workbench on Sun and Apollo workstations and with PC Workbench on IBM PC/AT. **Analog Design Tools, Sunnyvale, CA. Please circle INFO/CARD #157.**

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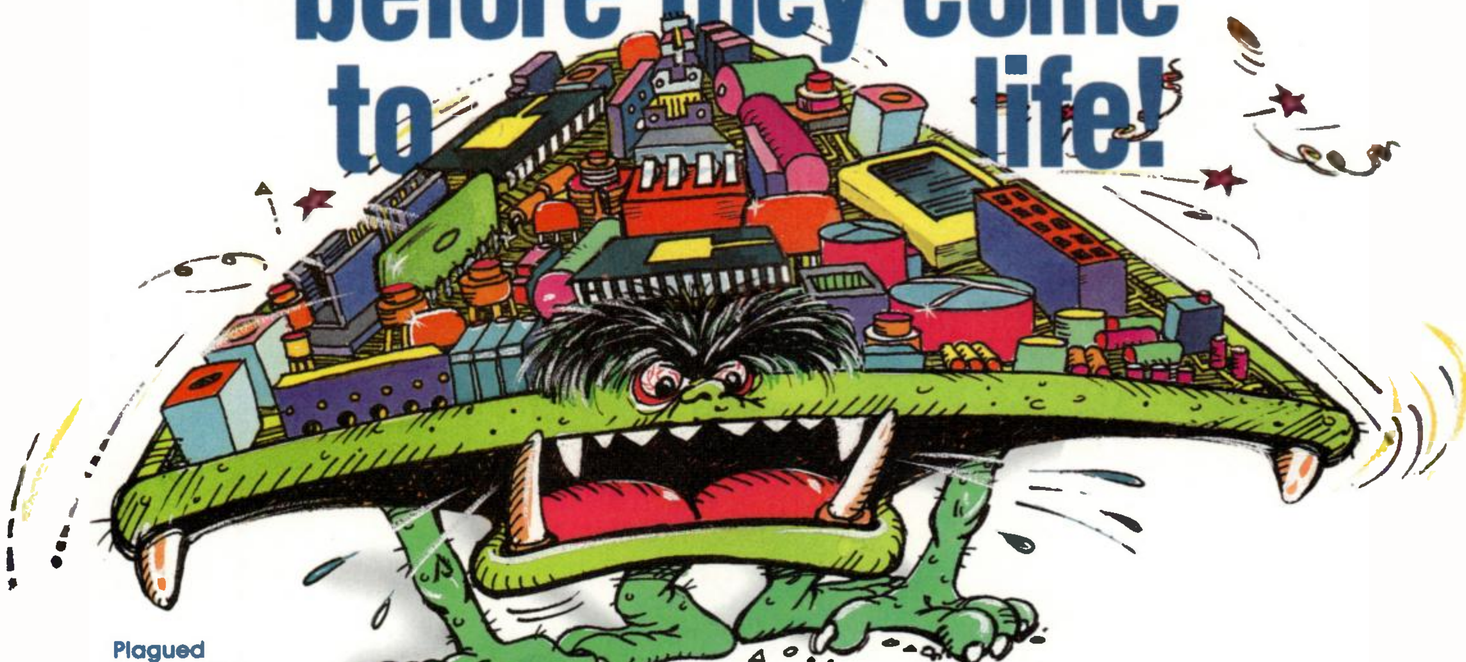
Toko coils and filters attack RF design problems before they come to life!

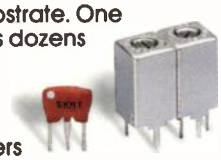


Plagued by parasitic oscillations, spurs, harmonics and feedback? The problem may not be your design, but the coils and filters you selected. Toko is the world's largest manufacturer of quality small coils and filters, with a selection so large, you're sure to find the right components to neutralize your rf design problems.

SUBMINIATURE ADJUSTABLE AND FIXED
Toko has what you need, so you won't need to compromise... subminiature adjustable coils and transformers, molded coils, radial fixed coils and fixed coils with axial leads. Toko high-Q coils are engineered in sizes from 5mm to 15mm, and inductance ranges from .02 µH to 500 mH.

CHIP AND ADJUSTABLE SMD
Need to reduce the size of your products or automate production? Toko solves these problems with a wide range of surface mountable coils and LC, ceramic and helical filters in fixed and adjustable configurations. Packaged for automatic insertion and available for reflow or solder dipping.

CUSTOM MODULES
Toko hybrid modules are a great way to simplify design and production tasks. With short lead time, Toko can develop compact custom modules utilizing a variety of components, surface mounted on a ceramic substrate. One module replaces dozens of components.



FILTERS
For i-f or tuned rf circuitry. Toko filters simplify attenuation of out-of-band signals, while cleanly passing your desired signal. Ultra-miniature ceramic and LC filters at popular i-f frequencies fit tight spaces and tight budgets. With frequencies up to 1.2 GHz Toko helical filters are the right choice for communications transceivers.

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Isn't it time to tame the design monsters before they bite back...call or write Toko today for a free coil and filter catalog or a quote on your needs. No matter what Toko coils and filters you choose, you can be assured of exceptionally high quality control at economical prices.

Quality and workmanship that add value and performance to your product.

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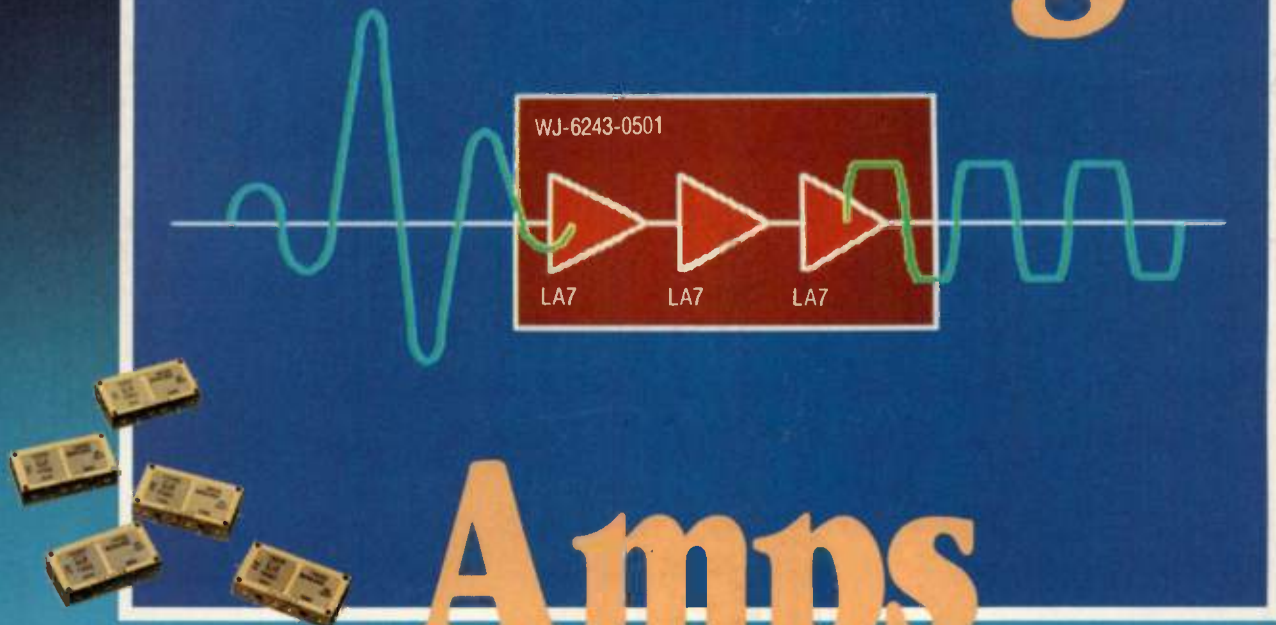
MULTIPAC™

Limiting Amps



- Cascade them to meet your own design needs
- Customized gain and limiting levels available
- Wide limiting range
- Unique design yields low harmonic distortion

Limiting Amplifiers (Guaranteed at +25°C)

Frequency (MHz)	Model[1]	Description	Gain (dB) (Min.)	Noise Figure (dB) (Typ.)	Power Output at 1-dB Comp. (dBm) (Min.)	VSWR In/Out (Max.)	DC Volts (Nom.)	DC mA (Typ.)
50-500	6242-0501	LA7/LA7	22.0	9.5	+7.0	2:1	15	108
	6243-0501	LA7/LA7/LA7	33.0	9.5	+7.0	2:1	15	162
	6243-0505	LA7/LA7/LA7	33.0	9.5	+7.0	2:1	15	162
10-1000	6242-0502	LA17/LA17	19.0	7.6	+5.0	2:1	15	110
	6243-0502	LA17/LA17/LA17	28.5	7.6	+5.0	2:1	15	165
	6243-0506	LA17/LA17/LA17	28.5	7.6	+5.0	2:1	15	165
1000-4000	6242-0503	LA45/LA45-1	21.0	10.0	+14.5	2.3:1	15	210
	6243-0503	LA45/LA45/LA45-1	30.0	10.0	+14.5	2.3:1	15	315
2000-6000	6242-0504	KLA62/KLA62	20.0	9.5	+10.0	2.3:1	12	140
	6243-0504	KLA62/KLA62/KLA62	30.0	9.5	+10.0	2.3:1	12	210

Note: 1. These models may be cascaded together for wider limiting dynamic range.

For more information on these excellent products, contact Watkins-Johnson Company, Components Applications Engineering, at (415) 493-4141, ext. 2626.

WJ WATKINS-JOHNSON

Watkins-Johnson Company, 3333 Hillview Avenue, Palo Alto, California 94304-1204

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