rf design

ideas for engineers

February 1986

Show Issue: RF Technology Expo '86

Special Report: Combining Amplifier Modules

Announcing RF Expo East, Nov. 10-12, 1986, Boston

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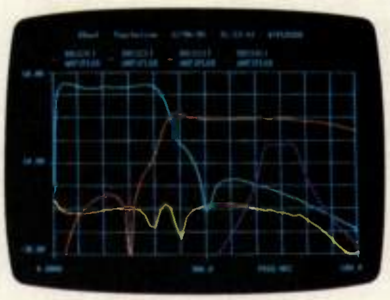
One look at Touchstone/RF will convince you. Call or write EEsof and we'll prove it.

A. Touchstone analysis of an active triplexer circuit with sampled output.

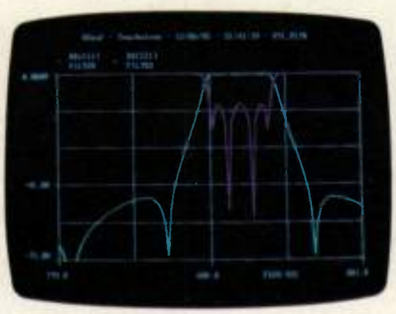
B. Insertion loss and return loss of crystal filter analyzed over its narrow pass band.

C. Schematic diagram of the active triplexer analyzed above.

D. A log axis can be used for displaying very broad frequency ranges. This feed back amplifier operates over nearly a decade bandwidth.



A.



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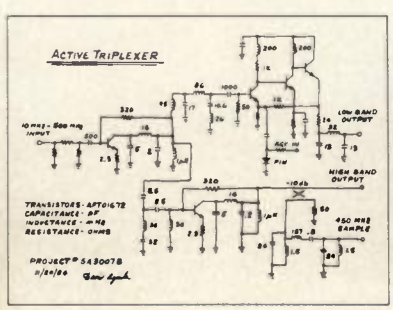
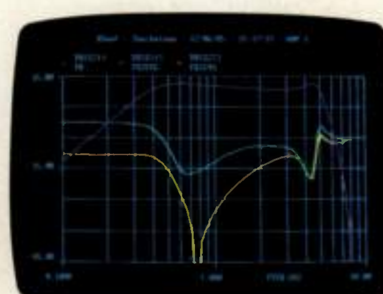


C.



D.

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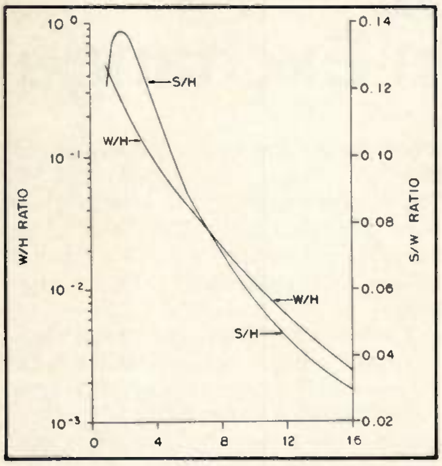
See us at the RF Technology Expo, booths #503, 505, 602 and 604.

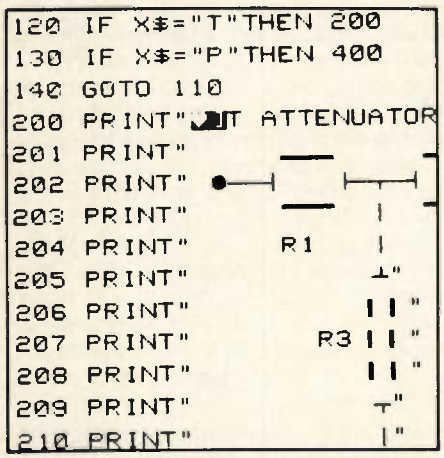
INFO/CARD 1

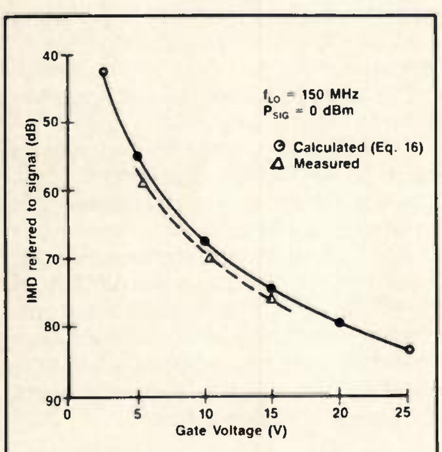
31194 La Baya Drive, Westlake Village, CA 91362 (818) 991-7530

rf design

February 1986







Cover

This month's cover features a new 600 watt FM amplifier module from Microwave Modules and Devices, Mountain View, Calif. Nine modules are successfully combined to create a 4,000 watt system for FM broadcast applications.

Features

Departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in August. February 1986, Volume 9, No. 2. Copyright 1986 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings Inc., 6530 S. Yosemite Street, Englewood, CO 80111 (303) 694-1522. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802, (1-800-346-0085). Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $22 per year in the United States; $29 per year in Canada and Mexico; $33 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $5.50 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.
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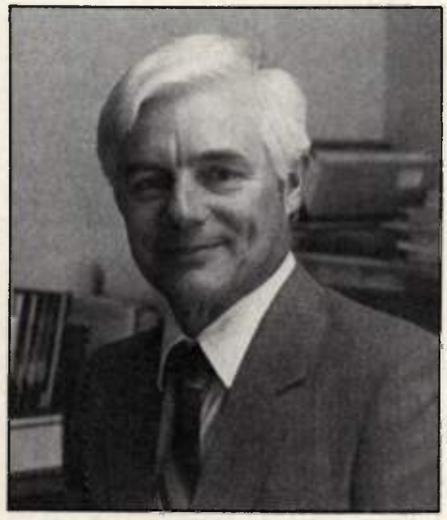
rf **editorial**

RF Technology Expo — An Information Exchange



By James N. MacDonald
Editor

We sometimes receive a letter in response to a technical article telling us that the design feature described in the article has been known for years. Usually, we also receive comments from others about how useful that same article was. To us, the fact that a particular problem was solved years ago does not lessen the usefulness of an article, even if the previous solution was better. A circuit design concept is only useful if it is known, and the more engineers who know about it the more useful it is.

The biggest problem we see in the RF industry is the difficulty of sharing information. Universities, the traditional institutions for passing on knowledge, generally ignore analog circuit design. Very few books are written on the subject. *RF Design* is the only magazine dedicated exclusively to the subject. Computer databases carry few references to work in the sub-microwave frequencies.

We have acknowledged before the significant contribution the amateur radio service makes in teaching and sharing information, but this too is a limited population. What has been lacking is a method of bringing together all the divers communities of RF designers: project team engineers, staff engineers, those helping to build new companies, consultants, instructors, authors and programmers, to share knowledge in all aspects of the discipline. This is the purpose of the RF Technology Expo and the reason it has been expanded to the East Coast. (See the announcement on p. 81.) It is also the guiding philosophy of *RF Design* magazine.

This issue of *RF Design* is significant in several ways. It is the show issue for the second RF Technology Expo, it begins our second year as a monthly publication and it is the largest issue in the magazine's seven year life. All three facts are evidence of the contribution *RF Design* is making to the electronics industry. We observe this not with a sense of complacency but with a sense of responsibility. The appreciation and encouragement we receive from our readers spurs us to increase our efforts to serve this community.

Most magazines strive to be interesting and attractive. Too few strive to be useful as well. This is the goal of *RF Design*. The promotional brochure introducing the magazine at the end of 1978 said, "In a world seemingly wrapped up in ones, zeros, minis, micros, and submillimeter wavelengths, it's easy to forget that nearly 50 percent of the plants listed in the D & B Electronic Marketing Directory manufacture communication equipment operating at RF . . . Never since Marconi started it all has there been a special place for the engineers who are making it happen to get ideas and exchange information. *RF Design* will be that place."

The basic philosophy of the magazine remains unchanged.

This issue begins my second year as editor of *RF Design*, a milestone more significant to me than to you. Let me take advantage of this milestone, however, to pledge my best efforts to continue to bring you the information you need. All of us on the *RF Design* staff are proud of the purpose the magazine serves. We will continue to pursue that purpose to the best of our abilities, and your suggestions and comments are appreciated.

James N. MacDonald

Introducing RF Expo East: November 10-12, in Boston

Keith Aldrich
Publisher, RF Design

In this issue you will find an announcement ad and a call for papers for a new event: *RF Expo East,* to be held for the first time at the Boston Marriott Copley Place, Nov. 10-12, 1986.

Assuming the success we expect for it, RF Expo East will be held every Fall in the Northeast U.S. Thus *RF Design* will present two convention events every year: RF Technology Expo, the first and still the only technical conference dedicated to RF engineers; and now RF Expo East, to serve RF engineers who may not be able to attend RF Technology Expo, which is held in mid-winter on the West Coast.

RF Expo East will feature two-and-a-half days of technical sessions of exactly the same sort that are presented at RF Technology Expo. That is to say, they will be original papers by and for RF engineers only, offering practical solutions to RF engineering problems on the boards today. In fact, it is likely that RF Expo East will repeat some of the more popular papers that were presented at RF Technology Expo. . .and certainly will repeat Les Besser's one-day course, "Introduction to RF Circuits."

Like the national show, RF Expo East will also have product exhibits by leading RF manufacturers. The first convention this Fall will have booth space for well over 100 exhibits. We have reason to believe they will all be sold out within a few weeks after this announcement.

The decision to hold RF Expo East each year in addition to RF Technology Expo was based quite simply on market demand. Whatever else is happening in the economy, the RF boom is continuing unabated. Engineers desperately need the information offered in the RF Expos, and it just isn't being offered anywhere else.

However, the engineers who need the information aren't necessarily in a position to pick up in mid-Winter and go to Southern California. *In a recent survey, we found that fully 85% of our readers in the Eastern U.S. cannot attend RF Technology Expo, for reasons of distance and expense. At the same time, we found that 85% of our readers in that same area would attend an* RF Expo East *in the Fall, should we decide to hold one.*

It is hard to imagine a more affirmative response. Since we have a concentration of 8,000 readers on the Eastern Seaboard, just from Pennsylvania north, the research would indicate a first-year attendance of over 6,000. Realistically, of course, we will be happy with 800 to 1,000. However, the research affirms the deep enthusiasm among our readers for a chance to attend a good RF Expo.

We are going to give them that chance. More. We are going to give twice as many authors a chance to present papers on the work they are doing, the breakthroughs they have made. We are going to stand in the gap. . .the tremendous *information* gap that prevails in RF technology. . .until the need begins to be filled.

See you in Boston.

Keith Aldrich

SMART SWITCHES.

Dow-Key Microwave introduces a line-up of INTELLIGENT RELAYS. Our multithrow SP8T - SP12T switches integrate the latest CMOS logic and MOSFET switch driver circuits with the simplicity and low insertion loss of electromechanical relays. Model 491 is a pulse latching SP9T with internal MIC terminations which accepts and decodes all binary or TTL compatible signals to select RF paths while actively deselecting all others. The multithrow switches are designed to be computer driven for switch matrix or automatic test equipment and are available with HPIB or IEEE 488 connectors. Frequency operation is DC to 12 GHz.

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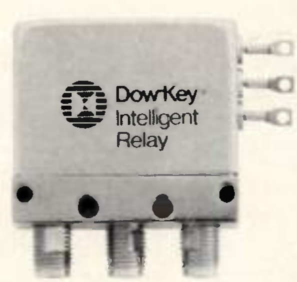
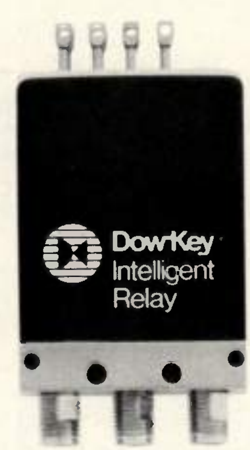


Model 403-230802C MOSFET Control



Model 401 TTL Control

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INFO/CARD 6

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For Literature Circle
INFO/CARD 8

For Demonstration Circle
INFO/CARD 38

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Our new teams are made up of dedicated people who represent the customer inside our factory. When the customer calls in he gets answers because the appropriate people are available; applications engineer, sales person, quality assurance rep, product control supervisor — and when necessary, any or all of the above.

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THE LONG LOOK.

Our continuing substantial investment in R&D is the only way to meet the long term needs of the market. At the moment, we're developing advanced silicon technologies, gallium arsenide products and vertically integrating our line with higher level assemblies.

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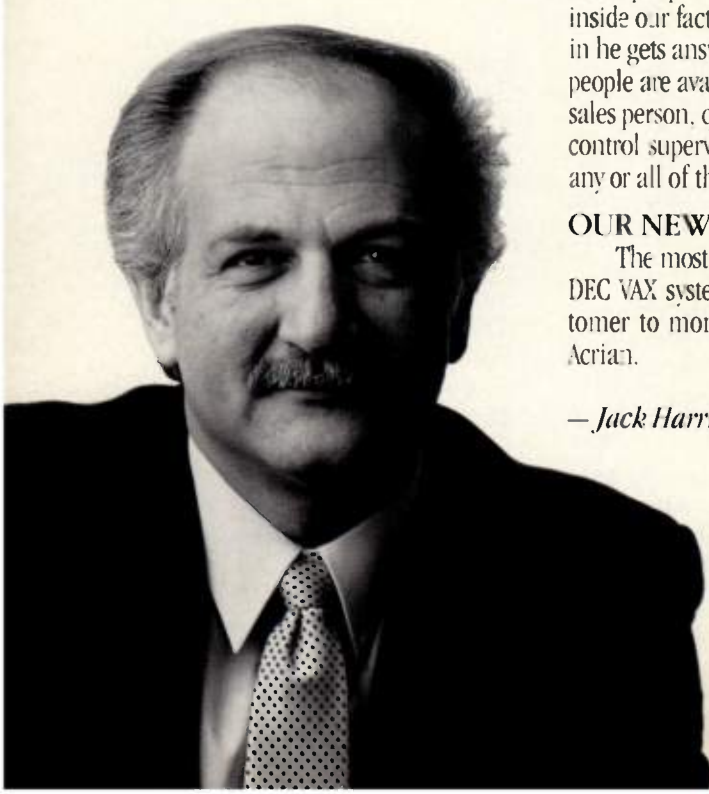
The true test of a company's strength is to make these investments and remain profitable. And few have demonstrated the strength of Acrian.

If we had pulled in our horns, we wouldn't be able to toot them now.

— Jack Harris, President



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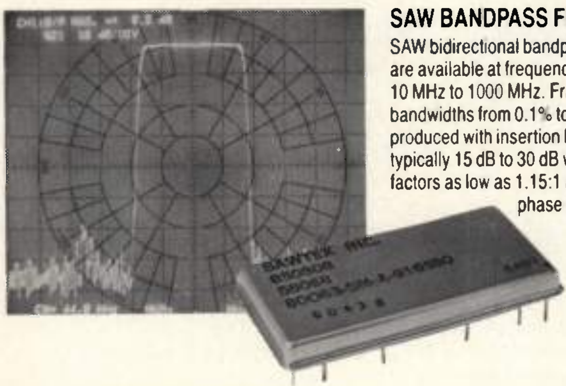
See us at the RF Technology Expo, Booths #702 and #704.
INFO/CARD 9

SURFACE ACOUSTIC WAVE TECHNOLOGY

provides performance advantages and design flexibility that have proven invaluable to engineers in need of reliable, reproducible components featuring linear phase, temperature stability, small size, or other SAW characteristics. Increasingly, SAW technology is meeting the exacting requirements of modern systems with high performance bandpass filters, resonator products, delay lines, and other state-of-the-art signal processing components. Sawtek offers the industry's broadest product line and provides the total engineering support needed to make the proper design trade-offs among key parameters in order to achieve the optimum performance available from SAW technology.

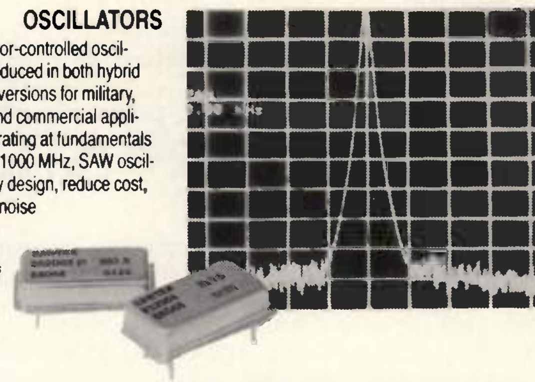
Sawtek produces hundreds of standard SAW products for both low and high volume programs in Cable Television, Satellite Communications, Modems, Radar, EW, and many other applications. In addition, Sawtek's custom design capability can provide technical assistance and rapid response to new design and production requirements at frequencies from 10MHz to more than 1GHz. Sawtek also designs and produces subsystems which incorporate SAW components. These include filter banks comprised of cascaded filters packaged in a single assembly, SAW resonator-controlled oscillators, and ovenized components.

Sawtek maintains a leadership role in SAW technology through the development and production of superior SAW components and a proven track record of delivering these reliable, high performance products on time and at a very competitive price. Product reliability for Sawtek's broad range of military and commercial parts is insured by a watchful quality control program that meets even the exacting requirements of military and space applications.



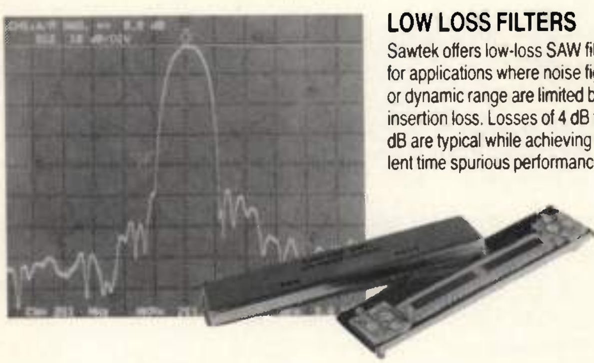
SAW BANDPASS FILTERS

SAW bidirectional bandpass filters are available at frequencies from 10 MHz to 1000 MHz. Fractional bandwidths from 0.1% to 65% are produced with insertion loss that is typically 15 dB to 30 dB with shape factors as low as 1.15:1 and linear phase response.



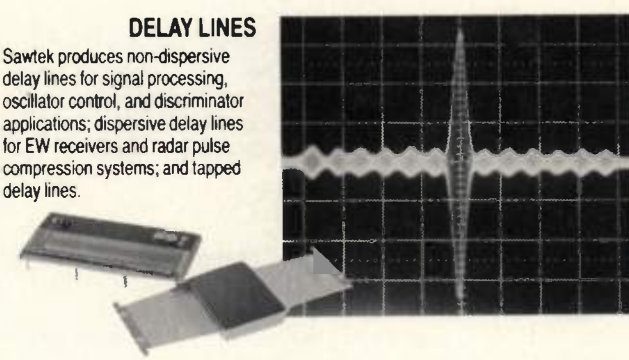
OSCILLATORS

SAW resonator-controlled oscillators are produced in both hybrid and discrete versions for military, aerospace and commercial applications. Operating at fundamentals to more than 1000 MHz, SAW oscillators simplify design, reduce cost, and improve noise performance through the elimination of multiplier stages.



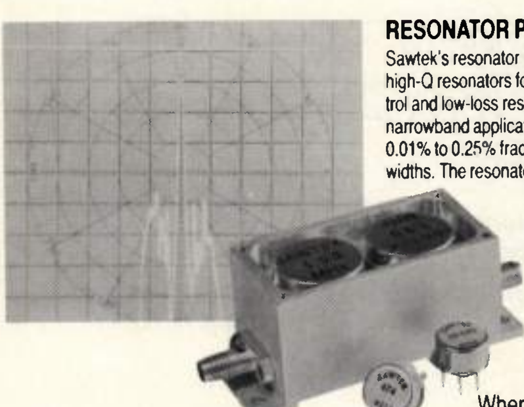
LOW LOSS FILTERS

Sawtek offers low-loss SAW filters for applications where noise figure or dynamic range are limited by filter insertion loss. Losses of 4 dB to 10 dB are typical while achieving excellent time spurious performance.



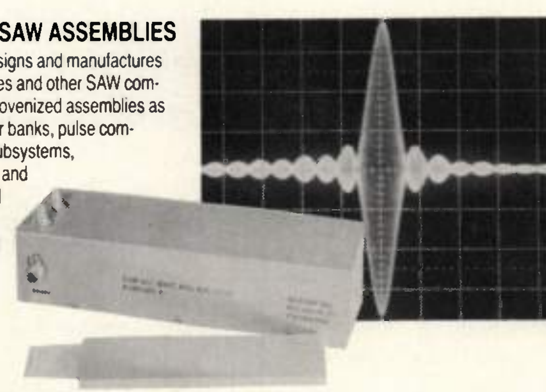
DELAY LINES

Sawtek produces non-dispersive delay lines for signal processing, oscillator control, and discriminator applications; dispersive delay lines for EW receivers and radar pulse compression systems; and tapped delay lines.



RESONATOR PRODUCTS

Sawtek's resonator products include high-Q resonators for oscillator control and low-loss resonator filters for narrowband applications requiring 0.01% to 0.25% fractional bandwidths. The resonator filters are provided in individual two-pole stages and in custom modules.



SAW ASSEMBLIES

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INFO/CARD 10

rf calendar

February 25-27, 1986
Nepcon West '86
Anaheim Convention Center, Anaheim, California
Information: Show Manager, NEPCON WEST, Cahners Exposition Group, 1350 East Touhy Ave., P.O. Box 5060, Des Plaines, IL 60017-5060; Tel: (312) 299-9311.

March 11-13, 1986
Automated Design for Engineering for Electronics West
Moscone Convention Center, San Francisco, California
Information: Show Manager, ADEE WEST, Cahners Exposition Group (see address above).

March 18-20, 1986
Southcon/86 High Technology Electronics Exhibition and Convention
Orange County Convention Center, Orlando, Florida
Information: Electronic Convention Management, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (213) 772-2965

March 25-27, 1986
IEEE Instrumentation and Measurement Technology Conference
University of Colorado Events/Conference Center
Hilton Harvest House, Boulder, Colorado
Information: Robert Myers, 1700 Westwood Blvd., Los Angeles, CA 90024; Tel: (213) 475-4571

April 8-10, 1986
Test and Measurement World Expo
San Jose Convention Center, San Jose, California
Information: Meg Bowen, Conference Director, Test and Measurement World Expo, 199 Wells Avenue, Newton, MA 02159

April 9-16, 1986
World Market for Electronics and Electrical Engineering '86
Hannover Fairgrounds, Hannover, West Germany
Information: Hannover Fairs USA Inc., PO Box 7066, 103 Carnegie Center, Princeton, NJ 08540; Tel: (609) 987-1202

May 5-7, 1986
36th Electronics Components Conference
Westin Hotel, Seattle, Washington
Information: Tom Pilcher, Electronics Industries Association; Tel: (317) 261-1592

May 13-15, 1986
Electro/86 High Technology Electronics Exhibition and Convention
Exposition Center, World Trade Center, Boston, Massachusetts
Information: J. Fossler, Electronic Conventions Management (see address above)

June 24-26, 1986
Military Microwave Conference
Metropole Convention Centre, Brighton, England
Information: Roger Marriott, Microwave Exhibitions and Publishers Ltd., Convex House, 43 Dudley Road, Tunbridge Wells, Kent TN1 1LE; Tel: 0892-44027

rf courses

The George Washington University
Electronic Warfare Systems: Technical and Operational Aspects
March 10-14, 1986, Washington, DC
July 14-18, 1986, Washington, DC

Spread Spectrum Communications Systems
March 3-7, 1986, Washington, DC

Synchronization in Spread Spectrum Systems
April 7-11, 1986, Washington, DC

Introduction to Receivers
March 17-18, 1986, Washington, DC

Modern Receiver Design
March 19-21, 1986, Washington, DC

Antennas and Arrays
March 17-21, 1986, Washington, DC

Information: Merril Ann Ferber, Assistant Director, Continuing Education Engineering Program, The George Washington University, Washington, DC 20052; Tel: (800) 424-9773

Besser Associates, Inc.
Introduction to RF & Microwave Circuit Design
March 19-21, 1986

Information: Ron Rose, Executive Vice President, Besser Associates, Inc., 3975 E. Bayshore Road, Palo Alto, CA 94303.

Virginia Polytechnic Institute and State University
Antennas: Principles, Design and Measurements
March 19-22, 1986, St. Cloud, Florida

Information: Ann Beekman, 1101 Massachusetts Ave., St. Cloud, FL32769; Tel: (305) 892-6146.

Interference Control Technologies
Grounding and Shielding
February 4-7, 1986, Orlando, Florida
February 18-21, 1986, San Antonio, Texas
March 18-21, 1986, San Diego, California

Tempest Design, Control, Testing
March 4-7, 1986, Washington, DC

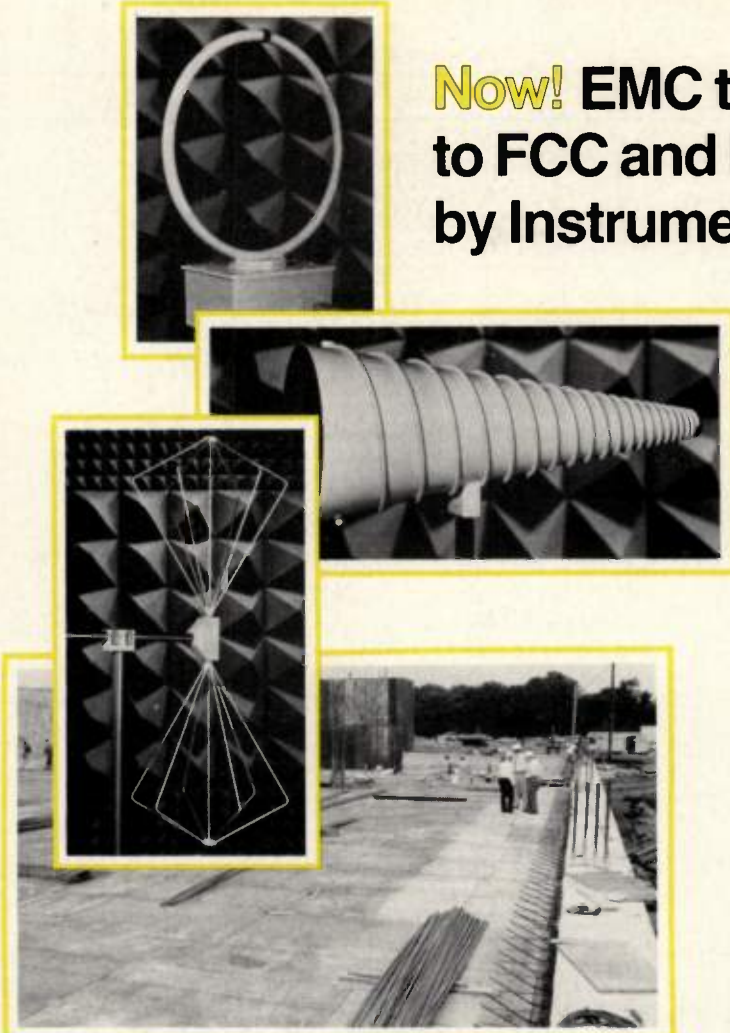
Practical EMI Fixes
March 24-27, 1986, Atlanta, Georgia

EMI Control in Computers and PCBs
February 4-7, 1986, San Jose, California

Information: Penny Caran, Registrar, Interference Control Technologies, State Route 625, PO Box D, Gainesville, VA 22065; Tel: (703) 347-0300

University of Mississippi
Dielectric Resonators
April 9-11, 1986, Oxford Campus

Information: Bruce Bellande, Continuing Education, University of Mississippi, University, MS 38677; Tel: (601) 232-7282



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Following testing, you'll leave our facility with the precise documentation you need. In the event you need help to meet required interference specifications, we can supply that as well. All this, from one qualified source!

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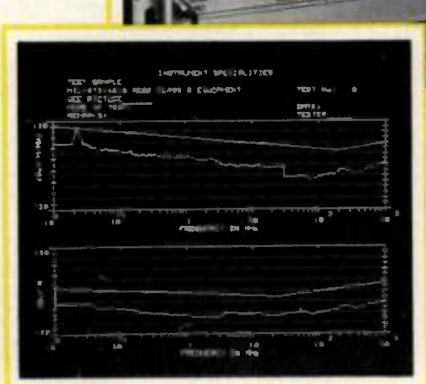

Editor:

Due to my return to Rio de Janeiro I was for a while cut from your magazine, *RF Design*, which I asked to be transferred to my new address here in Rio. Unfortunately I am still not receiving it, but I got a chance to see some comments on my paper published in the May issue. I was surprised about the response to the paper which seemed to be widely commented, mostly favorably. As to the comment from one person regarding the paper from Robert P. Arnold in Electronic Design, I could only say that the program is in Fortran, based on different algorithm and using arrays for storing data, the rest I leave for the judgment of the readers who know both programs. As it seems that there is requirement for such program, I would like to point out an error in line 1240 which should read I1 = I(2), which is obvious from conversion formulae. Further, I am enclosing additional lines which could be typed directly into the program and provide for a complete set of conversions, hoping that it may be of use to readers who liked the program.

Stanley Novak
Professor
Instituto Militar de Engenharia
Rio de Janeiro

(Transistor Parameter Conversion, May 1985, p. 49)
Addition to Parameter Conversion Program for all Conversions (double and triple):

```
440 DUAL CONVERSIONS
442 IF P$ = "Y" AND S$ = "A" THEN 470
444 IF P$ = "A" AND S$ = "Y" THEN 480
446 IF P$ = "H" AND S$ = "A" THEN 490
448 IF P$ = "A" AND S$ = "H" THEN 480
450 IF P$ = "S" AND S$ = "H" THEN 500
452 IF P$ = "H" AND S$ = "S" THEN 510
454 IF P$ = "S" AND S$ = "Z" THEN 520
456 IF P$ = "Z" AND S$ = "S" THEN 530
458 IF P$ = "S" AND S$ = "A" THEN 534
460 IF P$ = "A" AND S$ = "S" THEN 536
465 GOTO 2100
470 GOSUB 740
475 P$ = "Z": GOTO 200
480 GOSUB 960
485 GOTO 475
490 GOSUB 1160
495 GOTO 475
500 S$ = "Y": GOSUB 1360
505 P$ = "Y": S$ = "H": GOTO 200
510 GOSUB 540
515 P$ = "Y": GOTO 200
520 S$ = "Y": GOSUB 1360
525 P$ = "Y": S$ = "Z": GOTO 200
530 GOSUB 740
532 P$ = "Y": GOTO 200
534 S$ = "Y": GOSUB 1360
535 P$ = "Y": S$ = "A": GOTO 200
536 GOSUB 1960
537 P$ = "Z": S$ = "S": GOTO 200
```

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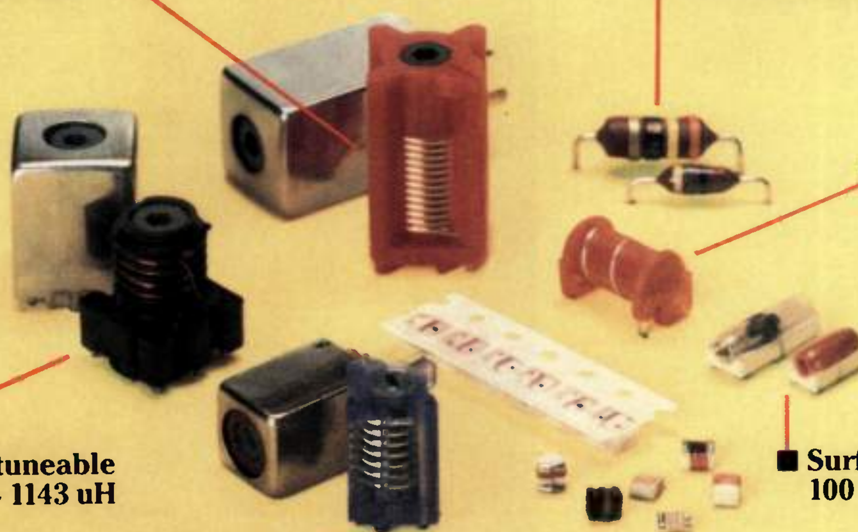

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Editor:

Though we have not yet seen your December issue, I suspect that we will be pleased with its editorial content in general and our input in particular.

This letter was written to inform you of a potential problem we foresee with the RF Design staff . . .

In the course of events, we have had reason to talk with Kathy Kriner, Kathi Walsh (who visited us here), April, Gary Breed, and other members of your staff. Some of these dialogs were convoluted and technical, while others involved detailed placement and printing instructions. In one case, we even asked for something that was apparently impossible (a booth at your sold-out Expo).

To date, everything we've asked for has been provided, and not one single problem has arisen. Your staff members have been remarkably cooperative and helpful, and we have yet to encounter reason for criticism. Hence this letter.

As the Boss, you're going to have to do something to lower that level of performance. Zero errors is not only too expensive to maintain, but eventually your market begins depending on it. Imagine our furor when we next discover a comma in the wrong place!

Henry Eisenson
Sciteq Electronics
San Diego, California

I wish I could take credit for this "problem," but I can't. April reports to Kathy Kriner, who is Convention Manager for Cardiff Publishing Company and, as you have seen, is boss of an outstanding staff. All I am to them is a nuisance. Kathy Walsh, like me, reports to our publisher, Keith Aldrich. We all thank you for your tongue-in-cheek compliment, Henry.
— editor

Editor:

I always look forward to each month's publication of *RF Design* and especially if the articles are accompanied with programs for the handheld computers such as the HP-41.

I understand some papers submitted to *RF Design* with programs for the HP-41 have been rejected. The apparent reason being that the editors have not taken a position on what program language the readers want.

Sorry to see this happening, especially if it happens to be a follow-up in a series such as "RF Amplifier Design" by Feeney and Hertling.

Keep up the good work, but don't let your HP-41 followers down!

Terry White
C-Cor Electronics, Inc.
Beaverton, Oregon

While we recognize that most of our readers use handheld computers, our selection of articles is based on their general usefulness. We do favor programs written in BASIC because we believe most engineers are familiar with that language. It is somewhat of a standard. We assume handheld computer users can convert BASIC programs for their computers more easily than microcomputer users can convert various handheld computer programs for theirs.
— editor

Bell Labs Builds Faster-Switching Transistor

The fastest semiconductor device ever built has been demonstrated by scientists at AT&T Bell Laboratories, Murray Hill, N.J.

The switch, designed and fabricated in collaboration with scientists at the National Research and Resource Facility for Submicron Structures (NRRFSS), Cornell University, can turn an electronic signal on or off in 5.8 picoseconds. The previously reported record was 8.5 picoseconds. Using circuit components as small as one third of a micron and exceptionally high quality control of materials, the scientists showed that submicron features can be integrated with larger elements to create ultra high-speed circuits. This technology will be useful in communications equipment, microprocessors and computer memories.

The work rivals a competing technology, superconducting Josephson junctions, which require the super-cooled environment of liquid helium (4.2° Kelvin) to operate. That technology has resulted in speeds of 4.2 picoseconds. The new device achieved 5.8 picoseconds (the time it takes light to travel a sixteenth of an inch) at the temperature of liquid nitrogen (77° K) and a near record 10.2 picoseconds at room temperature (300° K).

Researchers made test structures, called ring oscillators and frequency dividers, on multilayered wafers of gallium arsenide and impurity "doped" aluminum gallium arsenide, in work supported by the National Science Foundation and the Air Force Wright Aeronautical Laboratory.

"A competitive technology for the future requires not only high speed, but also low power," said Nitin J. Shah, a member of the Heterostructure Integrated Circuits Group at AT&T Bell Laboratories, who coordinated circuit fabrication and testing. "With this submicron-gate technology, we have demonstrated transistors which meet these requirements."

The basic units in these circuits are called Selectively Doped Heterostructure Transistors (SDHTs). The fundamentals of the SDHT technology were discovered in 1978 at Bell Laboratories. In the past few years, experimental devices and circuits have been developed under the guidance of Shin-Shem Pei, supervisor of the Heterostructure Integrated Circuits Group. Precise control over the quality of semiconductor materials used for these circuits was achieved with a method developed at Bell Labs called molecular beam epitaxy (MBE), according to Charles W. Tu of the Heterostructure Materials Group.

Shah, Pei and Tu collaborated with Richard C. Tiberio and his colleagues at the NRRFSS, a National Science Foundation-funded national research facility available to qualified personnel for exploratory experiments in submicron science and technology. Edward D. Wolf, director of the facility, said the submicron components were fabricated using direct-write scanning election beam lithography.

Recently, Bell Labs researchers also built the largest known SDHT logic circuit, a 4x4 bit parallel multiplier. This multiplier can complete a 4x4 multiplication in 1.6 nanoseconds, a considerable edge over other multipliers. Larry Vernerin, head of the Heterojunction Integrated Circuits and Materials Department at Bell Laboratories, said, "The switching speed record and the multiplier chip results open the way to a new generation of ultra high-speed electronic circuits."

Thomson-CSF Sells Socapex to Amphenol Products

Thomson-CSF, the French conglomerate headquartered in Paris, has signed an agreement to sell its Socapex subsidiary to Amphenol Products, an operating unit of Allied-Signal Inc. The purchase price totaled 199 million francs ($29.5 million U.S.), including 47 million Fr ($6.1 million) for shareholders' equity and 152 million Fr ($19.8 million) in assumed debt, according to Phillip W. Arneson, president of Amphenol Products.

Amphenol Products, a manufacturer of electronic connectors as well a electronic and fiber-optic components, considers the Socapex connector company to be a key factor in current plans for growth.

"Amphenol is interested in Socapex on several counts," Arneson said. "Socapex is already tooled to produce Amphenol Products' Bendix line of circular, environmental connectors, having been a licensee of Bendix connectors since 1960."

Socapex also manufactures a wide range of electronic and fiber-optic connectors for telecommunications, computer and industrial applications. Arneson said these products complement Amphenol's interests in those area. Amphenol was interested in Socapex's Technology and engineering expertise, especially since the two companies have complementary strengths in high-growth, high-technology areas, such as fiber-optic connectors.

Amphenol Products, headquartered in Lisle, Ill., has manufacturing facilities in France, West Germany, Great Britain, Italy, Canada, The United States and Hong Kong as well as affiliated companies in Japan and India.

Siemens, Motorola Agree on Surface Mount Optocoupler

Motorola and Siemens, two world leaders in surface mount components, have announced an agreement on a standard package profile and pin-out for small outline surface mount optocouplers. Spokespersons for both companies say the agreement is a major step toward establishing a worldwide industry standard and guaranteeing second-sourcing in a new fragmented marketplace.

"Motorola and Siemens have agreed on an SO-8 small outline IC footprint and package outline with a slightly larger package height of .125 inches for isolation purposes," said Larry Hayes, product marketing manager at Motorola Discrete & Special Technologies Group, Phoenix. "Pin spacing will be on 50 mil centers."

Brian Pottie of Siemens Optoelectronics said the agreement meets the needs of a marketplace characterized by a proliferation of packages.

"There are at least five non-compatible packages in the market right now," said Pottie, group marketing manager for infrared products at Siemens Optoelectronics Division in Cupertino. "Most current packages are standard 6-pin DIP with gull-wing leads. Our agreement guarantees the industry's first surface mount device (SMD) coupler second-sourcing through Siemens and Motorola, companies with considerable experience in development and introduction of surface mount devices."

Initial products include four product families with 13 different part numbers. These include standard (IOMA) and low-input (IMA) phototransistor couplers, rated 20, 50 and 100 percent current transfer ratios (CTR). Also, 100, 200 and 500 percent CTR low-input (IMA) Darlington and an AC input coupler will be introduced in the SO-8 standard package outline. The agreement also includes common part numbering with an IL prefix for Siemens and an MOC prefix for Motorola. Samples will be available later this year.

Both companies emphasized this agreement is a commitment to support surface mount design. "Siemens and Motorola are major players in the SMD arena, with years of experience and a broad range of surface mount products. We each have IC and active mount components with Siemens also manufacturing passive surface mount devices," Pottie said. "With the introduction of a stan-

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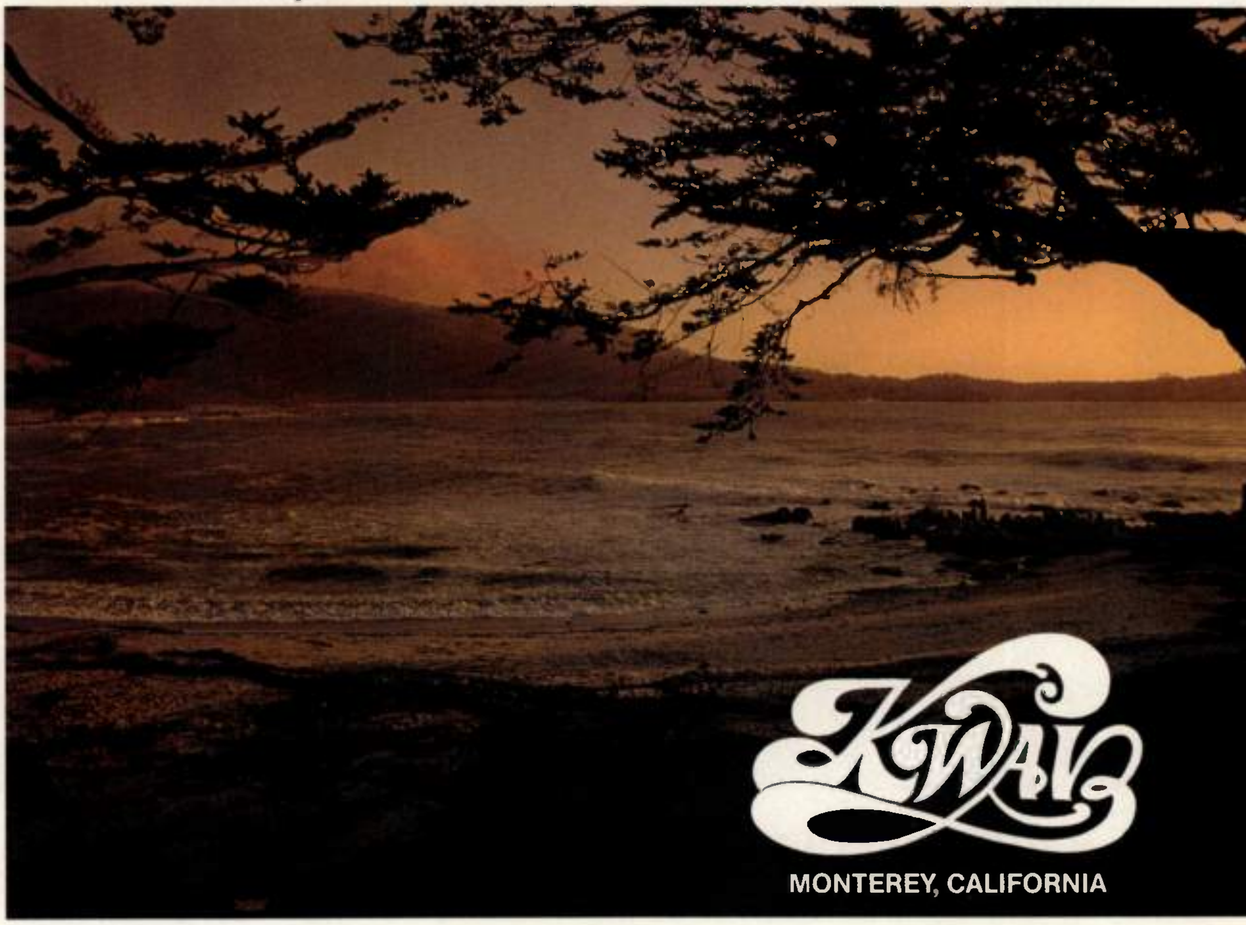

Ken Warren, Chief Engineer at KWAV reports that their 10 kW FM transmitter went on the air in November, 1972, equipped with EIMAC power tubes. The original tubes are still in operation after over 13 years of continuous duty!

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SPECIFICATIONS

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dardized coupler package to round out both our product lines, customers will now be able to realize the full benefits of surface mounting."

Hayes pointed out that, "similar to other surface mount devices made by both Motorola and Siemens, the new opto products would be available in tape and reel options in conformance with EIA standard RS481A."

For further information, please circle Info/Card #133.

'No Hands Road Map' Helps Pilots

A new electronic "road map" will let military pilots fly low over unfamiliar territory at near supersonic speeds without having to wrestle with flight charts. Hughes Aircraft Company has been selected by the U.S. Air Force to complete the development of a system that will constantly update terrain data, which pilots can display at the touch of a button.

The Integrated Terrain Access and Retrieval System (ITARS), under development at the company's Radar Systems Group, will display color-coded surface features and man-made structures. Pilots can elect to see the information in look-down or look-ahead views or on the head-up display. The system marks a new era of avionic development in which the use of stored terrain information will make possible greater pilot survivability and improved mission effectiveness, according to Donald M. Small, Air Force project engineer at Wright-Patterson AFB.

ITARS automatically will share its stored data with other systems aboard the aircraft to aid in navigation, terrain following and terrain avoidance, weapon delivery, sensor blending, mission planning and threat avoidance.

Hughes' modular design makes ITARS flexible enough for a variety of applications, ranging from helicopters and small tactical fighters to strategic and reconnaissance aircraft, depending on the mission, the aircraft, and the branch of service. ITARS will enable military pilots to "pre-fly" a mission in a simulator to acquaint them with the terrain and location of probable threats, and to permit them to plan their routes to limit exposure to detection and enemy fire.

"The system's modular design will make it possible to tailor it to the needs of the user, with the initial version supporting up to 10,000 square miles of terrain data," Small said. "If the mission requires it, and the aircraft can accommodate it, the system can be expanded to include terrain data covering 250,000 square miles."

Digital map information being incorporated in the system by Hughes will come from a data base produced by the Defense Mapping Agency, St. Louis, Mo.

New Microscopic Details Magnetic Structure of Surface

NBS researchers have developed a new technique for observing — simultaneously — both the magnetic and physical structure of a surface over dimensions as small as 100 angstroms (10 nanometers). New, compact electron spin analyzers developed at NBS are used to measure the spin vectors of secondary electrons produced by a scanning electron microscope. The instrument measures the magnitude and orientation of the magnetic structure of materials with a resolution many times better than the best current instruments, while simultaneously producing a conventional topographic SEM image of the surface. The new technique is expected to find wide application in fields such as the development of high-density magnetic recording media, the search for new strongly magnetic alloys for use in high-efficiency electric motors, as well as development of new RF-related magnetic materials.

New Publications

Monolithic Microwave Integrated Circuits

Monolithic Microwave Integrated Circuits has been published by the IEEE PRESS, the book publishing division of the Institute of Electrical and Electronics Engineers, Inc. The 512-page volume, edited by Robert A. Purcel, was prepared under the sponsorship of the IEEE Microwave Theory and Techniques Society. *Monolithic Microwave Integrated Circuits* contains 82 key papers by experts in the field of MMICs. The book also includes a comprehensive tutorial introductory paper written expressly for this volume by the editor. The reprint papers are arranged in four main sections covering all phases of MMICs from design to testing. The titles of the sections are: 1) Design Considerations; 2) Materials and Processing Considerations; 3) Monolithic Circuit Applications, and; 4) CAD Measurements and Packaging Techniques. The applications section is subdivided into these categories: low noise amplifiers and receiver circuits; power amplifiers; broad-

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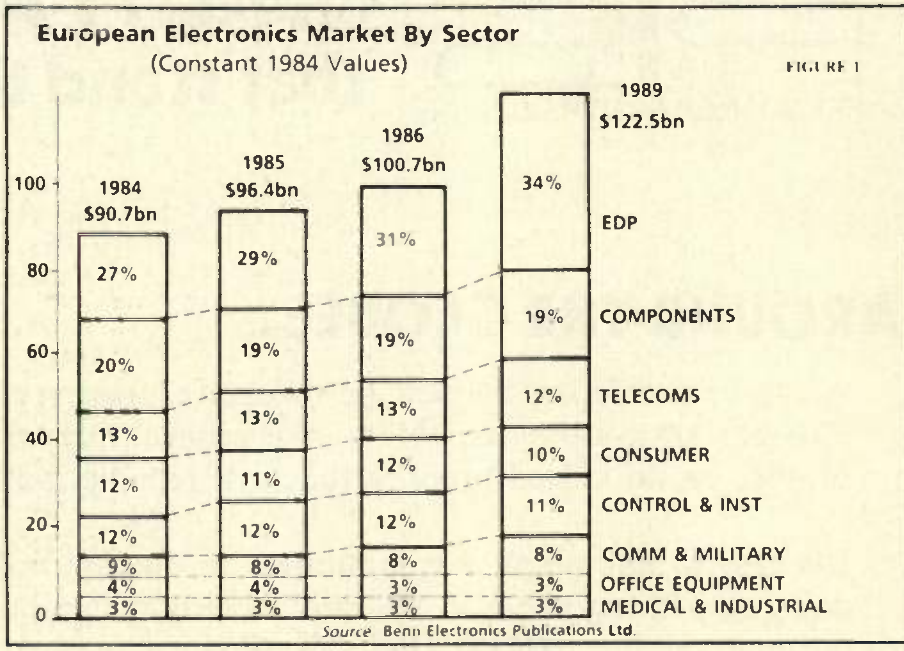
band amplifiers; transmit/receive modules; miiimeter wave circuits; and special components and circuits. Each section and category is preceded by a short introductory summary.

This book is an excellent source of information on materials and device processing for microwave engineers and graduate students in physics, chemistry and related technical fields. Specialists in research and development programs considering the inclusion of MMICs in their future projects will find this book a valuable guide.

The editor is a consulting scientist at the Raytheon Company, where he has been a senior staff member of the Research Division since 1955. His research has encompassed both theoretical and experimental studies of most microwave semiconductor devices, especially their signal and noise properties. During the last seven years he has been heavily involved in the field of MMICs.

Monolithic Microwave Integrated Circuits (PCO1867) is available for $69.95 ($41.95 for IEEE members). For ordering information, INFO/CARD #143.



Yearbook of West European Electronics Data 1986

The total West European market for electronic equipment and components will reach $96 billion in 1985, according to the 13th Edition of the yearbook of West European Electronics Data 1986, produced by Benn Electronics Publications Ltd. (BEP). This represents an increase of 6.4 percent over the 1984 total of $91 billion at constant 1984 values. The rate of growth is forecast to slow to 4.4 percent in 1986, when the European electronics market will top $100 billion at constant 1984 values, but then to recover to give an annual average growth rate of 6.7 percent in real terms over the period 1986-89 to reach $122 billion in 1989 (Fig. 1).

In their review of economic prospects contained in the report, BEP predicts that growth of the world economy will be slower in 1986 than in 1985, but that Europe's rate of economic expansion will be higher than that of the USA. The performance of the European electronics market 1984 showed growth of only 6 percent over 1983, at current prices and exchange rates, but the increasing strength of the U.S. dollar against European currencies masked the true growth rate, which at 1984 constant prices and 1984 exchange rates was around 13 percent (1983 prices adjusted using GDP inflator).

The active component sector grew particularly strongly in 1984, with a true rate of growth of over 30 percent, mainly due to the increase in the market for integrated circuits. However, BEP predicts that the European active components market will fall by 3.7 percent in 1985 but then revert to a growth market in 1986 and show substantial growth of over 9 percent per annum over the period 1986-89. The fastest growing European market sector continues to be electronic data processing (EDP), covering mainframe and personal computers, word processing systems and computer peripherals, with an average forecast growth of 9.9 percent per annum in real terms over the period 1984-89, taking the European EDP market to $42 billion in 1989.

The European Consumer electronics market is expected to be particularly slow moving, with an overall projected growth at an annual average rate of 1.9 percent over the period 1984-89. The only product showing significant growth prospects is compact disc players, with an average growth rate in value terms predicted of 55 percent per annum. The BEP Yearbook estimates that over 2 million compact disc player units will have been sold in Europe by the end of 1986. The market for video recorders grew very strongly in the early 1980s, but has now stabilized and is projected to grow at an average rate of only 5.4 percent per annum up to 1989. In the U.K., VCR sales dropped appreciably in 1984 from 2.4 million units in 1983 to only 1.6 million units in 1984 as the rental boom subsided.

Other sectors covered in the BEP Yearbook 1986 are Control and Instrumentation, which is expected to expand at 5.0 percent per annum 1984-89, Telecommunications Equipment, which is predicted to grow at 4.8 percent per annum, Communications and Military Equipment forecast to increase at 4.5 percent per annum and Passive and Audio Components with growth rates of 4.5 percent and 3.0 percent per annum respectively.

Of the major European countries, West Germany and the U.K. are forecast to grow a little faster, at 6.9 percent per annum and 6.4 percent per annum respectively over the period 1984-89, than Italy and France (5.6 percent and 5.5 percent per annum respectively), thus increasing their share of the European market. The U.K. will enjoy the highest growth in 1985 of any of the countries surveyed but will then falter in later years. The reverse is the case for France where 1985 is expected to be a very poor year but which is forecast to recover in 1986.

The 13th Edition of the Yearbook of West European Electronics Data 1986 is $495 per copy. For ordering information, please circle INFO/CARD #141.

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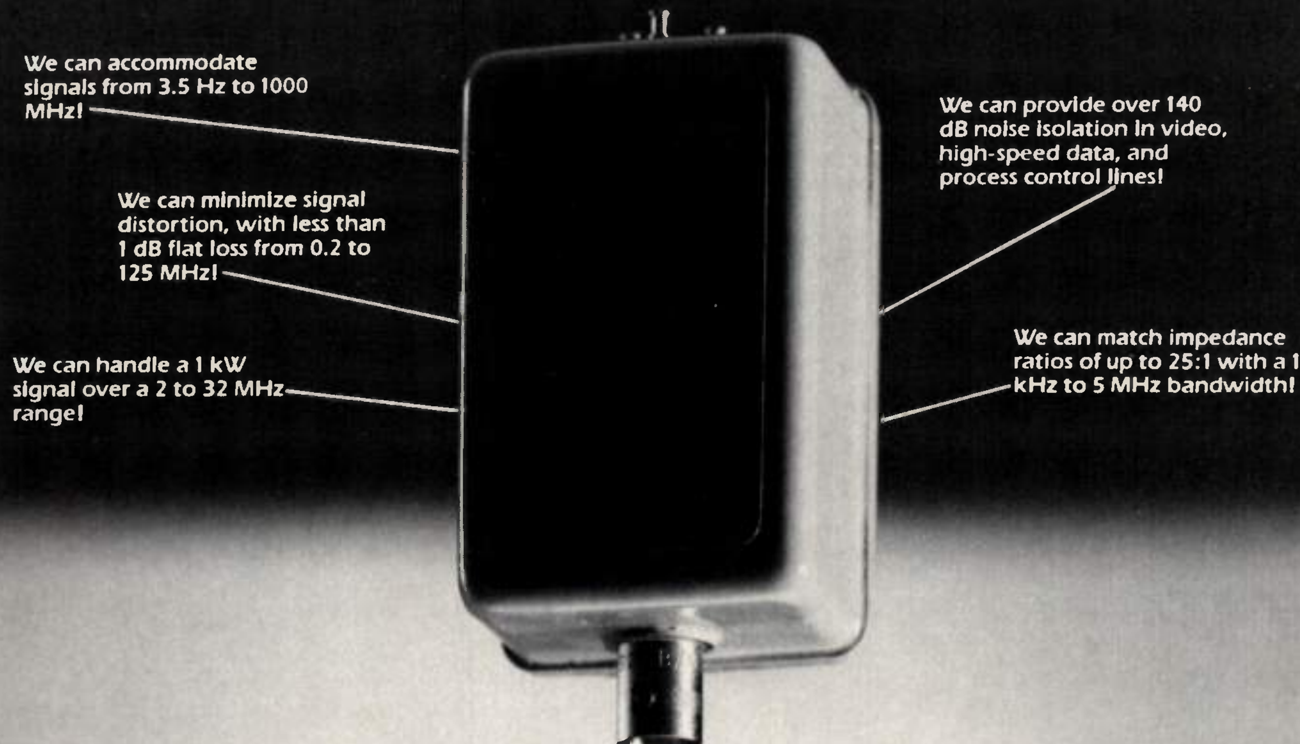

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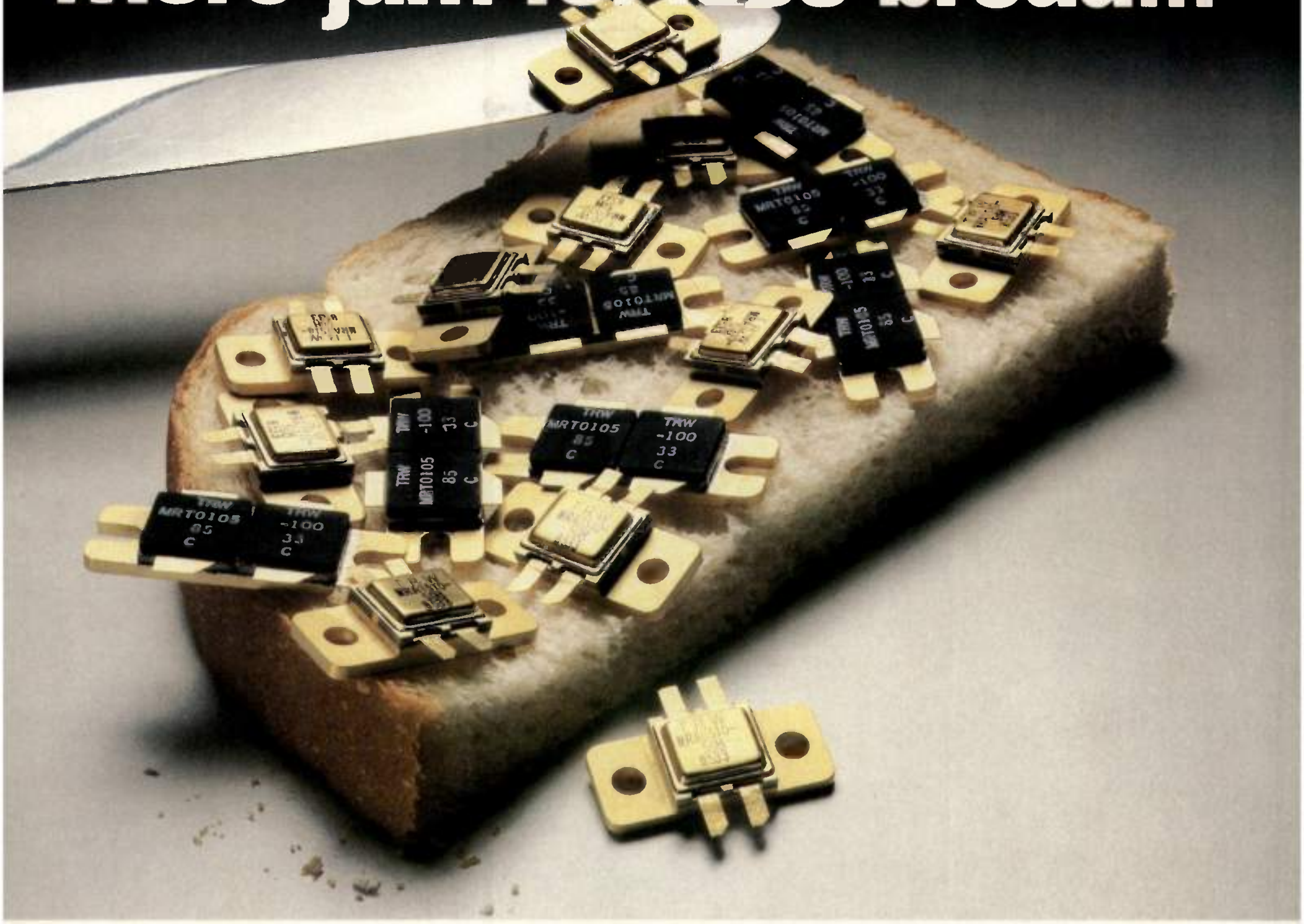

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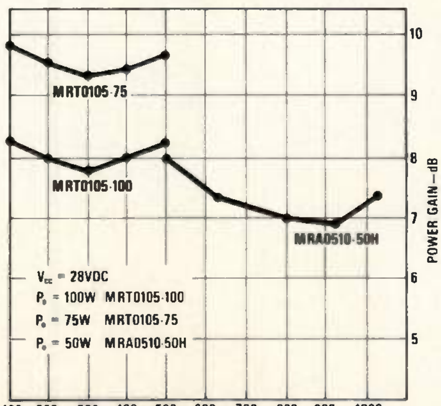

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INFO/CARD 26

See us at the RF Technology Expo, booths #313 and 315.

This course consists of eight video cassettes with a corresponding syllabus and the popular new *MOSPOWER Applications Handbook*.

Over ten hours of in-depth power MOSFET applications information is presented on the video tapes. Topics include practical switchmode power converter circuits and design tips, MOSFET structures, MOSFETs as charge-controlled devices, MOSFET thermal design, safe-operating area, dV/dt turn-on, MOSFETs as rectifiers, paralleling MOSFETs, and radiation effects on power MOS circuits. The accompanying syllabus contains a complete set of copies of the material shown in the video presentation with space for taking notes.

The *MOSPOWER Applications Handbook* is provided as a supplement to the video course. This 512-page technical reference was first offered to the public earlier this year. The book includes more than 70 articles and application notes contributed by 32 recognized industry experts on power MOSFET applications.

The course is designed to provide detailed circuit information and practical solutions to power MOSFET design problems. The $625 package — including one set of tapes (standard VHS format), five syllabi, and five handbooks — is available for immediate delivery. For further information circle INFO/CARD #140.

Kalman Filtering: Theory and Application

Kalman Filtering: Theory and Application, edited by Harold W. Sorenson, has been published by the IEEE PRESS, book publishing division of the Institute of Electrical and Electronics Engineers, Inc. (IEEE). This 464-page volume in the IEEE PRESS Selected Reprint Series was prepared under the sponsorship of the IEEE Control System Society.

Kalman Filtering: Theory and Application explains state-of-the-art applications and fundamental theories behind this methodology. Among the 45 papers, assembled from world-wide sources, are those covering a broad range of Kalman filter applications, from spacecraft orbit determination to the demographics of cattle production. Included with the application and theoretical papers are penetrating tutorials emphasizing the major contributions discussed in the reprinted papers.

The volume is divided into two parts and seven sections: Part 1 — Theoretical Beginnings; Historical Survey; Theoretical Foundations; General Application Considerations; Model Errors and Divergence; Divergence Control and Adaptive Filtering; Computational Considerations; Smoothing; Part 2 — Applications.

The extensive applications covered in this volume focus on: orbit determination; phased array radar tracking; polar coordinates for bearings-only tracking; maneuvering target trajectories; high-performance GPS Navigation; techniques for terrain-aided navigation; a recursive terrain height correlation system; design and analysis of a dynamic positioning system; dynamic ship positioning; real-time prediction of aircraft carrier motion at sea; aircraft track recovery system; bathymetric and oceanographic applications; natural Gamma Ray spectroscopy; instantaneous flow rate; estimation and prediction of unmeasurable variables in the steel mill soaking pit control system; dead time processes; nuclear power plant instrumentation; power station control systems; and demographic models.

Harold W. Sorenson is chief scientist, United States Air Force, Washington, D.C. He has published over 70 papers dealing with Kalman filtering, estimation theory, identification, optimization and control of stochastic systems. He is author of the book *Parameter Estimation: Principles and Problems,* a past president of the IEEE Control Systems Society, and a member of the IEEE Board of Directors.

Kalman Filtering: Theory and Application (PCO1859) is available for $58.95 ($35.95 for IEEE members). For ordering information, INFO/CARD #142.

RF Design to Hold Two Expos in 1986

Responding to numerous requests from East Coast readers, *RF Design* will hold an Expo in that region similar to the one held in Anaheim, Calif., each year. The East Coast show, called RF Expo East, will be held in the Boston Marriott Copley Place, Nov. 10-12, 1986.

RF Design publisher Keith Aldrich said the decision to have an East Coast show was made after a survey of 1,000 readers in the Northeast U.S.

"The returned questionnaires showed an overwhelming interest in such a show," Aldrich said. "Eighty-five percent said they probably or definitely would go to an Expo in that region."

Most respondents picked Boston as the preferred location. Surprisingly, of the few respondents who said they were planning to attend RF Technology Expo 86, in Anaheim, almost all said they would also attend RF Expo East. Aldrich said such response indicates that RF Expo East can serve East Coast engineers without decreasing attendance signficantly at the RF Technology Expo. Only 12 percent of the sample, which represented nearly 8,000 readers, said they would go to the West Coast show. Most respondents said it was too far to travel.

Aldrich said RF Expo East is not intended to be "just an East Coast version of the RF Technology Expo" and certainly is not intended to replace that show.

"Our primary show is the RF Technology Expo, and the third one is scheduled in Anaheim again, early in 1987," he said. "On the other hand, the East Coast show may be as big as the Anaheim show because of the large engineering population there."

A call for papers has been issued for RF Expo East and RF Technology Expo '87 (see announcement on p. 81). Exhibit space at both shows is coordinated by April DeBaker, Cardiff Publishing Company, 6530 South Yosemite Street, Englewood, CO 80111. The telephone number is (303) 694-1522. For information circle INFO/CARD #132.

FM Broadcast 88 to 108 MHz 4,000 Watt Amplifier Subsystem

By Lee B. Max
Microwave Modules and Devices

During the last five years, ultra high power solid-state transmitters have truly come of age. A variety of multikilowatt, all solid-state systems have been developed. Initially, military systems, where more dollars were available, were developed using ultra high power solid-state transmitters. The more cost conscious commercial applications remained tube systems. Today, however, the technology and economics have reached the level where one of the most cost sensitive commercial applications is being converted to solid-state. The FM broadcast transmitter (88-108 MHz) market has already converted to wide band, solid-state, driver amplifiers for power levels through 1,000 watts. But even beyond this, the performance, initial cost, operational cost, and reliability considerations have made solid-state transmitters the choice of a new FM broadcast market.

As a result of an interest in the FM radio station business, the Federal Communications Commission (FCC) has taken the following actions:

1. Relative to the presently licensed high power FM radio stations, the FCC, has adopted to "use it or lose it" policy. Meaning that a time limit has been set when a radio station whose license allows for more "effective radiated power" (ERP) than it is presently delivering must either increase its ERP level or be relicensed down to its present ERP level.
2. After the "use it or lose it" cut-off date, the FCC will begin issuing new licenses for FM radio stations to fill in the open areas.
3. Approximately 700 new licenses for FM radio stations will be issued for 3,500 watt transmitters.

In response to the creation of this entirely new 3,500 watt "low power" transmitter market opportunity, complete 3.5 kW solid-state transmitters are already being built.

Microwave Modules and Devices (MMD) has developed a 4,000 watt subsystem for use in these low power FM broadcast transmitters. The major features of this subsystem are:
- 4,000 watt output
- electrically self-protected
- mechanical rugged
- 50 watt input
- low cost
- high efficiency
- rack mounted

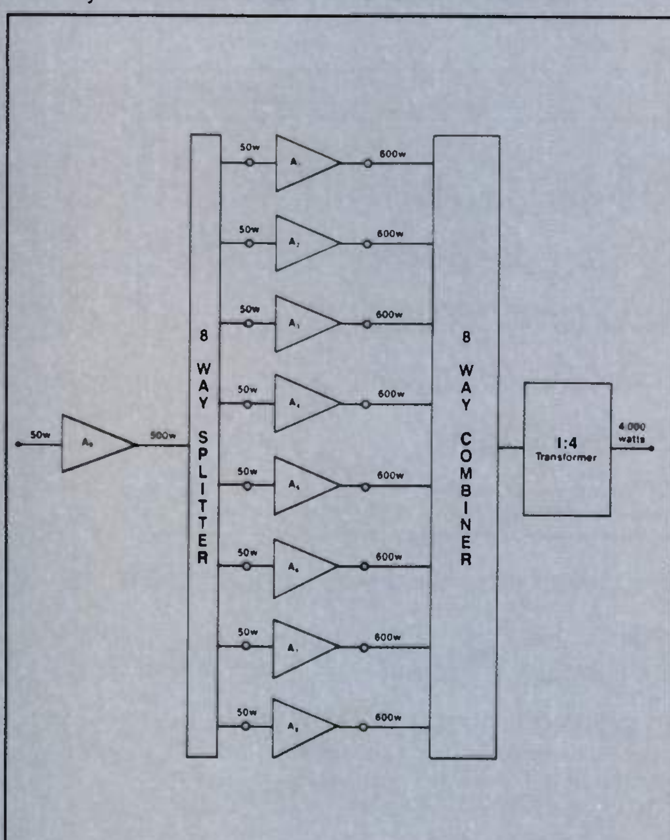


Figure 1. 4,000 watt amplifier chain

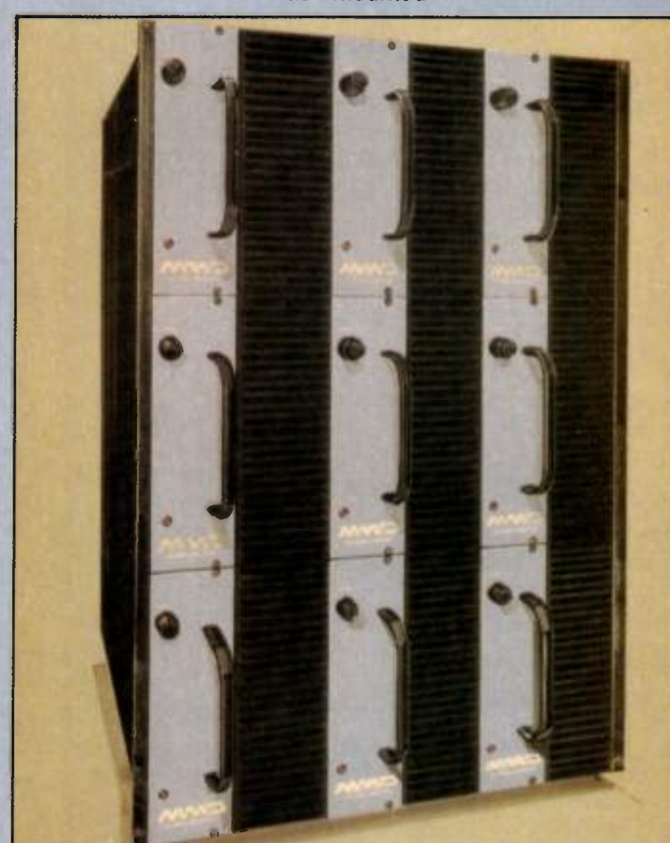


Figure 2. 19" rack-mounted subsystem

The most crucial requirement is that the unit be totally self-protected and virtually indestructable.

Subsystem Architecture

The 4,000 watt subsystem (Figure 1) is modular in construction. It uses nine identical 600 watt amplifier modules in a one driving eight configuration. The mechanical structure consists of three rows of three modules per row (Figure 2). All nine modules are plug-in replaceable from the front of the cabinet. The subsystem is also designed to allow for "hot replacement" (i.e., a module can be removed and replaced without turning the transmitter off). This helps maximize the stations "up" time. The subsystem is cooled using forced air with each 600 watt module having its own self-contained blower assembly.

600 Watt Self-Protected FET Amplified Module

The heart of the 600 watt module is the RF amplifier section (Figure 3). The unit uses eight 125 watt silicon FETs. The die are similar to those used in the Motorola MRF-174 transistor. These die are mounted in special high performance MMD packages. Since high temperature reliability was critical and small size was not a driving consideration, MMD's module was targeted for minimum thermal density (Figure 4). The unit easily delivers the rated 600 watts of power with eight FETs operating at well under 140°C even during worst case environmental conditions.

The eight thermally individually packaged transistors are binarily interconnected through three levels of combining. To end up with the maximum combination of benefits, each level of combining uses a different technique. At the first level, a pair of transistors is combined in the simplest possible way, i.e., in phase or parallel combined. Isolation resistors are used across the pair to smooth out slight amplitude or phase imbalances. The next level of interconnecting uses 180°, i.e., push-pull combining techniques. An optimally designed transmission line trans-

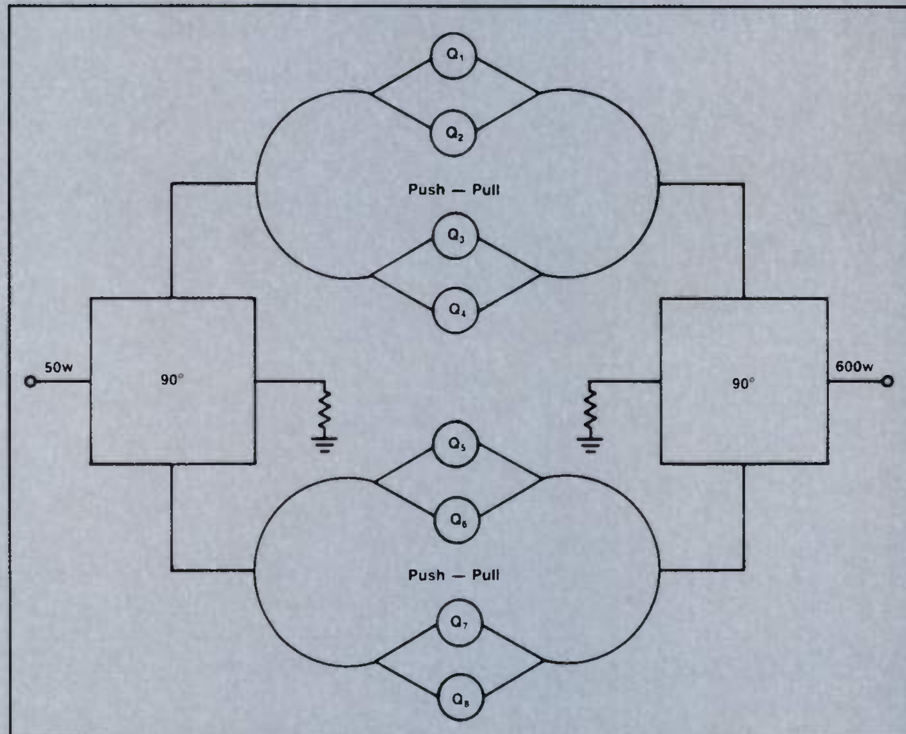


Figure 3. 600 watt FET module amplifier architecture

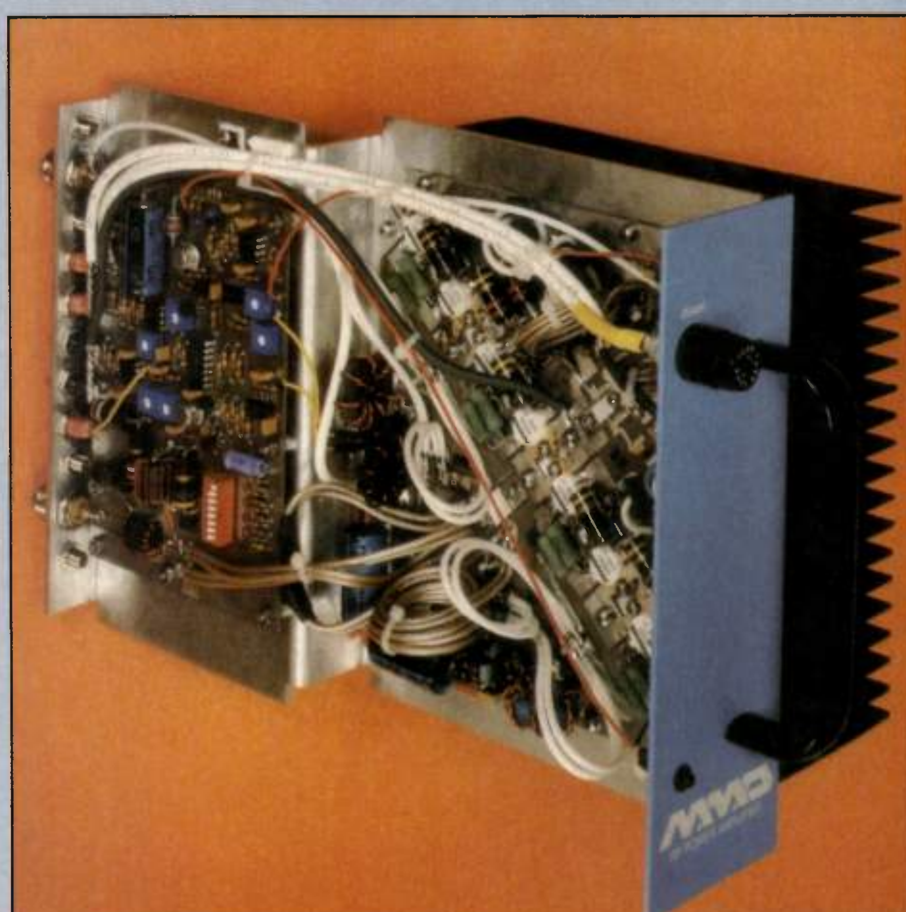


Figure 4. 600 watt building block amplifier module

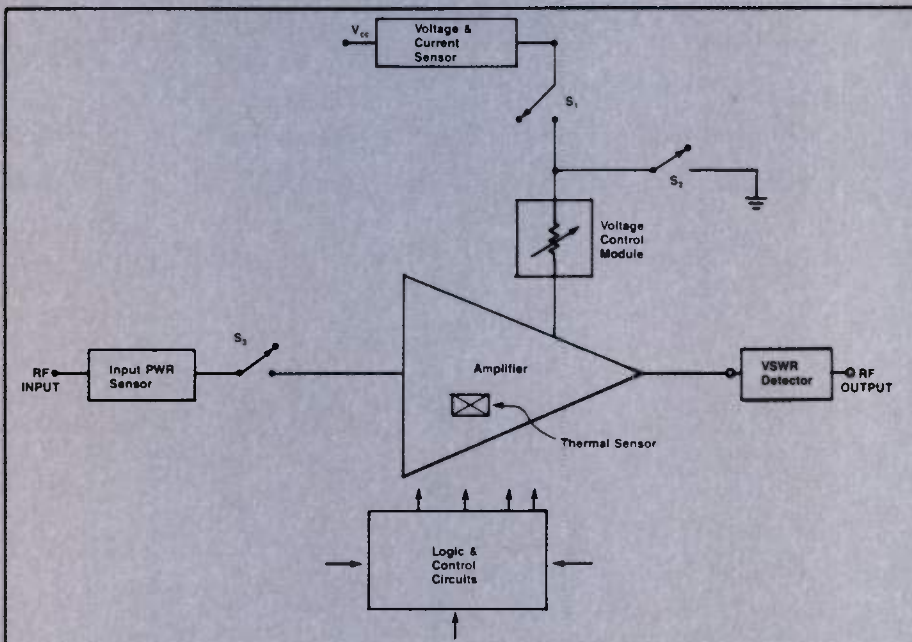


Figure 5. Self-protected 600 watt module

former structure accomplishes this. The push-pull combiner is an ultra-wide bandwidth structure that provides very predictable impedance transformation, even harmonic attenuation, as well as efficient power combining. The third and final level of interconnection uses a special 90° combiner. This combiner is the key to making the 600 watt module a true building block unit. Use of the 90° (or Quad) combiner produces a module with the following advantages:

- 1.5:1 VSWR input and output
- Improved forward power delivery into a mismatched load
- Improved back IMD
- Reduced 3rd harmonic levels
- Sub-module isolation
- Improved efficiency into a mismatched load

Since it is crucial that the 600 watt building block module be indestructable, sophisticated protection circuitry is built in. As seen in Fig. 5, the module contains both an input power sensor and a load VSWR detector. The critical parts of these sensors are the special, low-loss, bidirectional couplers used to pick off forward and reflected power samples that are then rectified and converted into DC reference levels. The 600 watt module also contains DC voltage, DC current, and baseplate temperature monitoring circuits. If abnormal conditions appear, the unit can automatically reduce the DC voltage to the module, or crowbar the supply to the ground, depending on what is required. The entire 600 watt module can be shut down in less than 2 milliseconds.

When any module shuts itself off after sensing an abnormality, it must wait a preset time (not more than 2 seconds) before resetting itself and trying to come back on line. Each 600 watt module has a slightly different preset time so that if the entire 4 kW subsystem shuts down, all nine modules will not try to come up at the same instant and overload the power supply.

4,000 Watt Combiner

The low-loss, 4,000 watt, 8-way combiner is critical to the system performance and reliability. As seen in Fig. 6 it is constructed using eight 71 ohm, 1¼ inch cables assembled in a ring configuration on both the input and output of the combiner. The circular structure allows for the balancing terminations to be conveniently mounted on the input, and the high power combining to occur with the minimum loss to the output. It should be noted that the output impedance of the combined eight large coaxial cables is 12.5 ohm. To transform from here to 50 ohm, a low loss 1:4 transformer made from a 25 ohm, quarter wave length transmission line is used. The entire combining system has less than 0.2 dB insertion loss. Furthermore, the eight isolation resistors, rated at 500 watts each, provide a minimum of 20 dB isolation between any one module and its neighbors. Measurements have shown that if a module fails or is removed, none of the remaining seven modules sees a load VSWR any worse than 1.5:1. Thus, if one module fails or is removed, the subsystem can still deliver over 80 percent of its full power capability.

The eight way low power splitter used on the input (not described in detail) is a conventional in-phase Wilkinson structure.

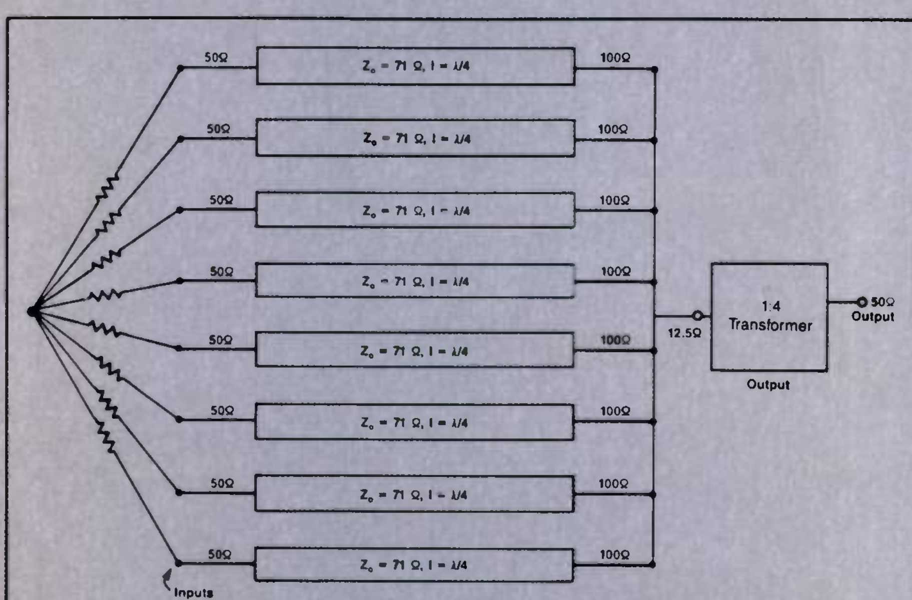
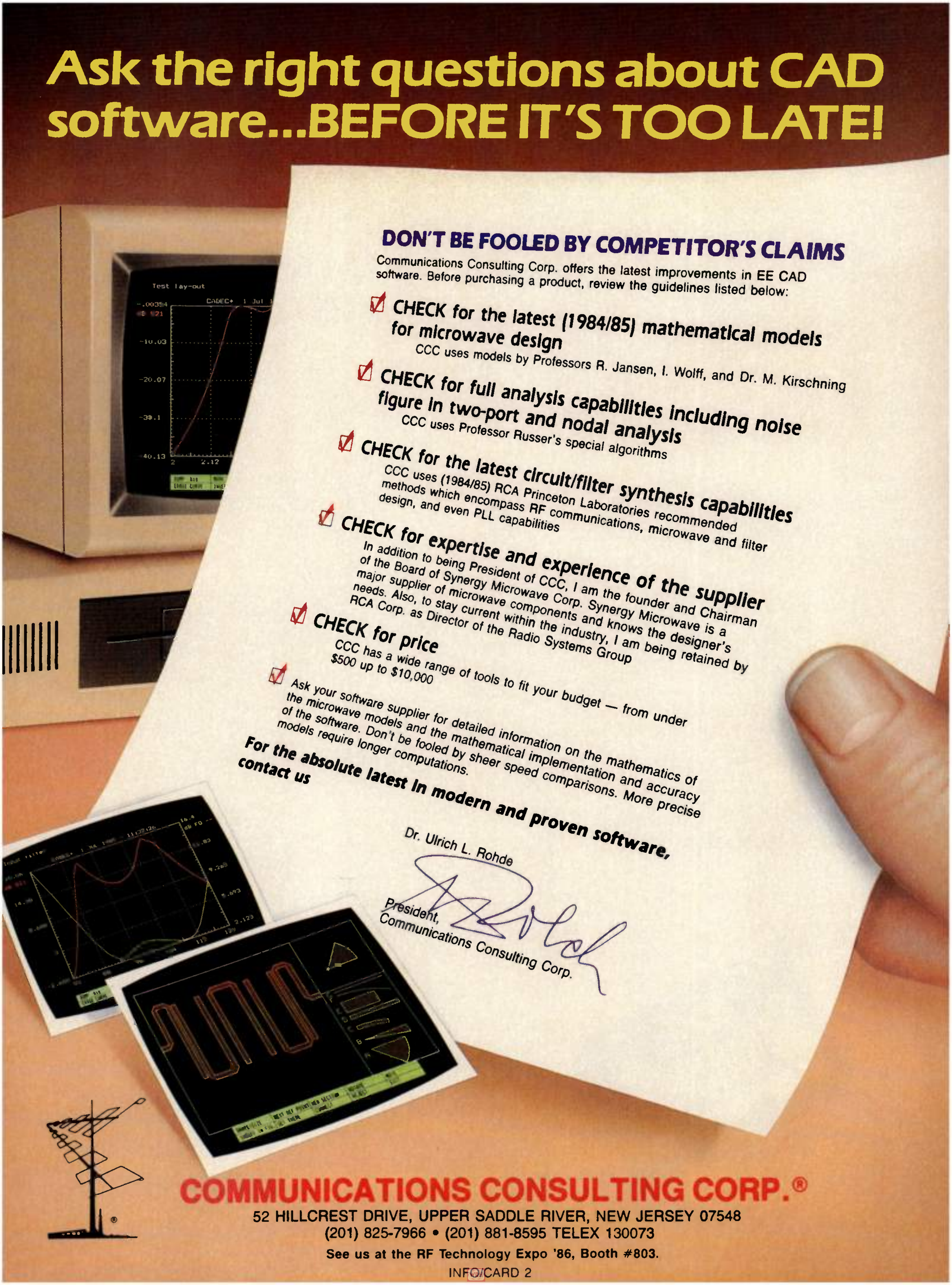


Figure 6. 4 kW output combiner

About the Author

Lee Max is vice president of Microwave Modules and Devices, 550 Ellis St., Mountain View, CA 94043. His telephone number is (415) 961-1473.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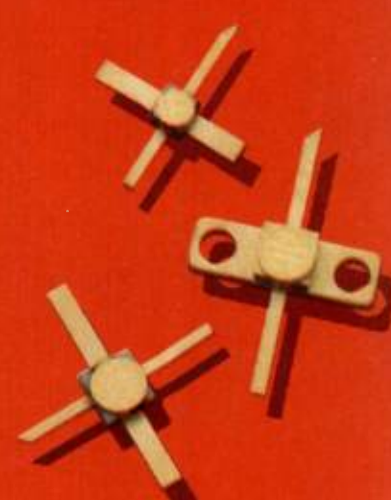

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FREQ. STABILITY (ppm) (ppm over temp., humidity, and voltage)	±2.0 −35°C to +85°C	±5.0 −30°C to +70°C
SUPPLY VOLTAGE (Vdc)	5.0 to 16.0	5.0 ± 0.1
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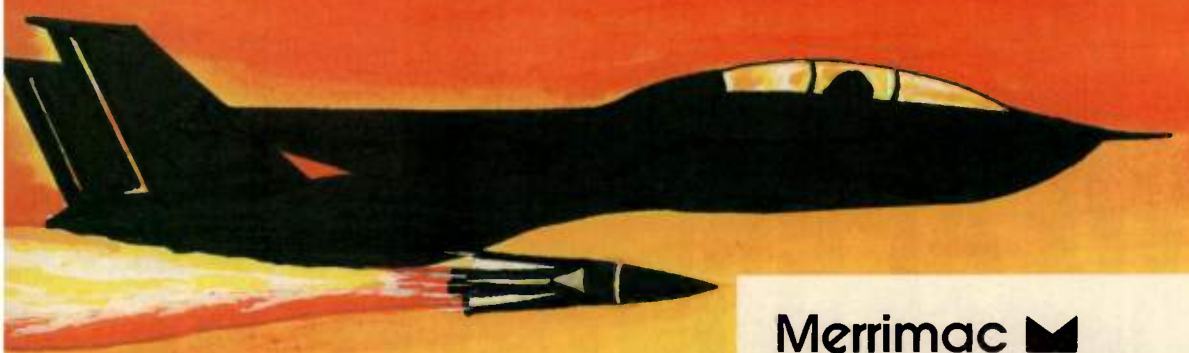
INFO/CARD 31

SIGNAL PROCESSING?



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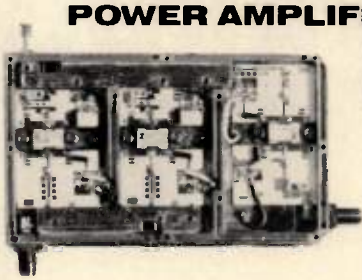
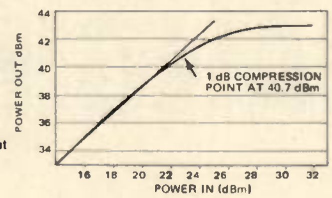


Power Transfer Characteristics at 2235 MHz



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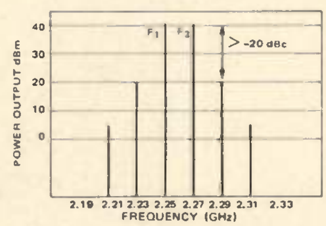
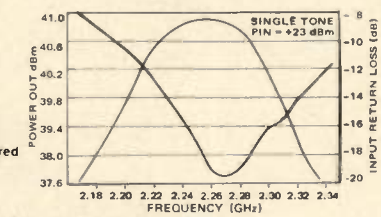


Input Return Loss and Bandwidth Measured at Nominal Power Output



Model No. AMP-10-2.25 G Minimum Performance Specification

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GAIN	16dB
GAIN FLATNESS (MAX.)	0.3dB
POWER OUTPUT AT 1 dB COMPRESSION (MIN.)	+40.7 dBm
VSWR (MIN) INPUT/OUTPUT	1.5:1/1.25:1
DC CURRENT (MAX.) AT +10 VOLTS	5.3 AMP.
THIRD ORDER TWO TONE INTERCEPT POINT	+50.7 dB

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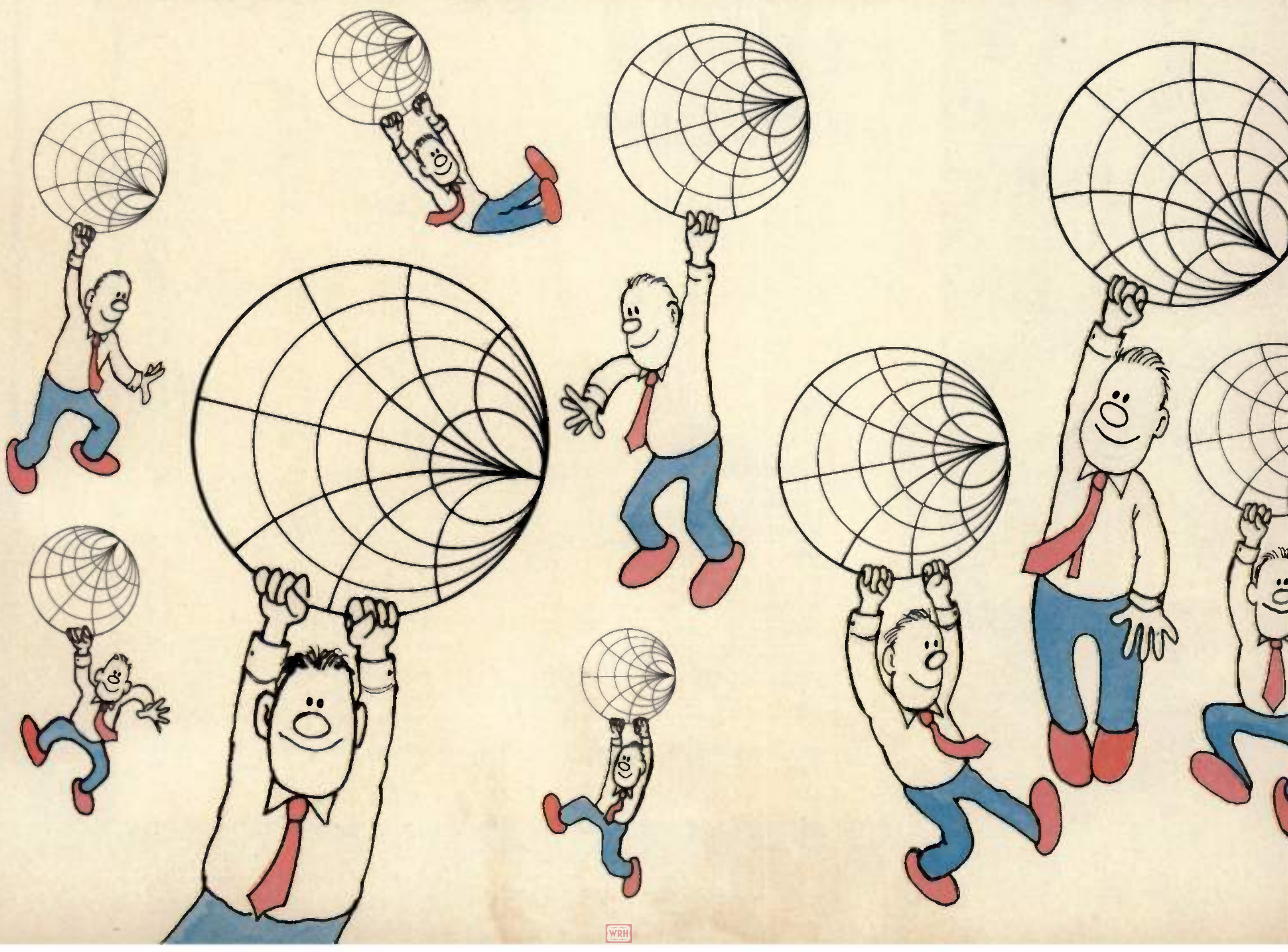

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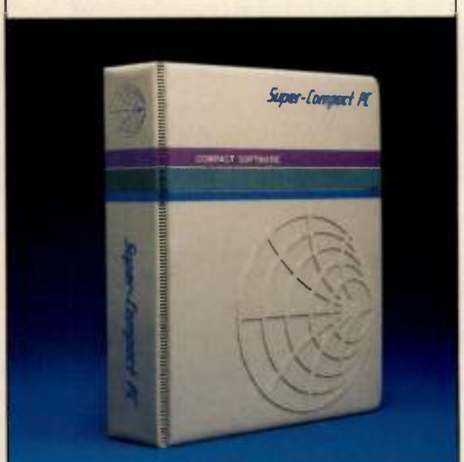

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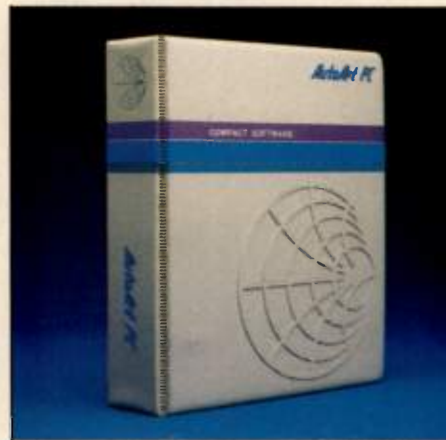

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Commutation Mixer Achieves High Dynamic Range

Introducing the Siliconix Si8901 Quad FET

By Edwin S. Oxner
Siliconix Incorporated

This article is an abridged version of a paper presented by the author at RF Technology Expo '86 *in Anaheim, Calif., and describes the performance achieved using the new Si8901 in a commutation (switching-type) double-balanced mixer. A rigorous analysis of double-balanced mixers and the method of commutation is contained in the complete paper, which has been published in the* Proceedings of RF Technology Expo '86.

Dynamic range remains the principle goal of HF mixer design. The intermodulation performance and overload characteristics of a mixer are fundamental qualities used in the evaluation of a good design. Heretofore, most mixers sporting a high dynamic range have been either the passive diode-ring variety, or the active FET mixer (1, 2).

Common to both the diode and FET is their square-law characteristic so important in maintaining low distortion during mixing. However, equally important for high dynamic range is the ability to withstand overload that has been identified as a principle cause of distortion in mixing (3). Some passive diode-ring mixer designs have resorted to paralleling of diodes to effect greater current handling, yet the penalty for this apparent improvement is the need for a massive increase in local-oscillator power.

This report examines a new FET mixer where *commutation* achieves high dynamic range without exacting the anticipated penalty of increased local-oscillator drive. Using the Siliconix Si8901, third-order intercept points upwards of +39 dBm (input) have been achieved with only +17 dBm of local-oscillator drive!

Unlike either the conventional diode-ring mixer or the active FET mixer, the commutation mixer relies on the switching action of the quad-FET elements to effect mixing action. Consequently, the commutation mixer is, in effect, no more than a pair of switches reversing the phase of the signal carrier at a rate determined by the local-oscillator frequency, as shown in the equivalent circuit of Fig. 1. Ideally, we would anticipate little noise contribution and since the switching mixer, consisting of four "switches," has finite ON resistance, performance is similar to that of a switching attenuator. As a result, the conversion efficiency of the commutation mixer may be expressed as a loss.

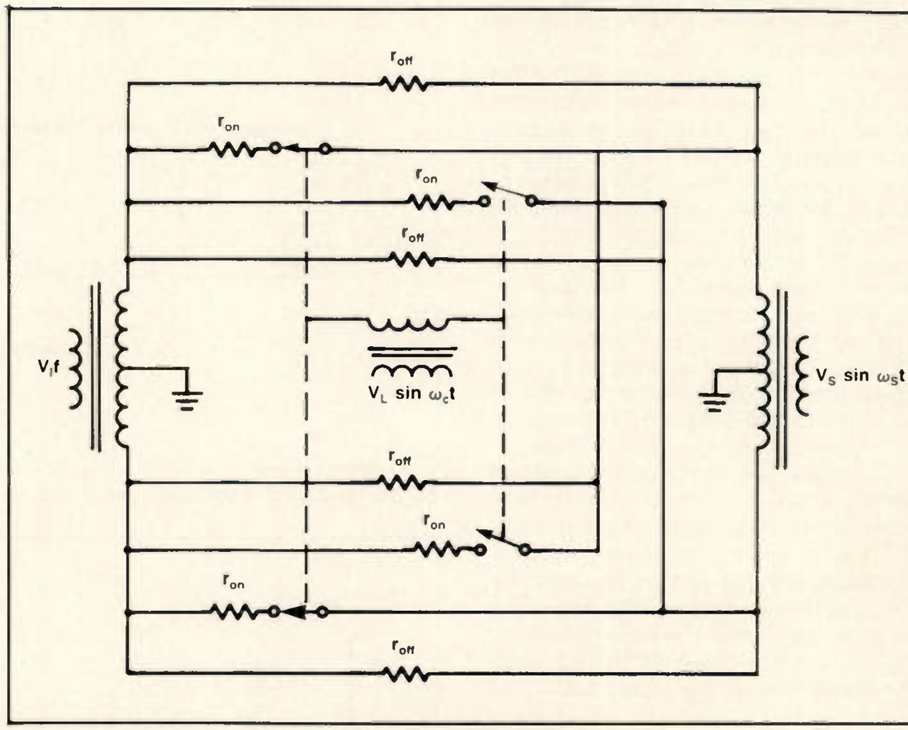

Figure 1. Equivalent circuit of commutation mixer

The Si8901 as a commutation mixer

Because of package and parasitic constraints, the Si8901 appears best suited for performance in the HF to low VHF region. A surface-mounted version may extend performance to higher frequencies. In a review of intermodulation distortion (4) it is recognized that to achieve a high intercept point the local-oscillator drive must:

- approach the ideal square-wave;
- ensure a 50% duty cycle; and,
- offer sufficient amplitude to ensure a full ON and OFF switching condition, as well as to offer reduced r_{DS} when ON.

Furthermore, to maintain superior overall performance in conversion loss, dynamic range (noise figure) and intercept point, some form of image frequency termination would be highly desirable even though the mixer's bandwidth would be restricted. Therefore, the principal effort in the design of a high dynamic range commutation mixer is two-fold. First, and most crucial, is to achieve a gating or control voltage sufficient to ensure a positive and hard turn-ON as well as a complete turn-OFF of the mixing elements (MOSFETs). Second, and of lesser importance, is to properly terminate the parasitic and harmonic frequencies developed by the mixer.

Local-oscillator injection to the conventional diode-ring, FET, or MOSFET double-balanced mixer is by the use of the broadband, transmission-line transformer (5), as shown in Fig. 2. For the diode-ring mixer where switching is a function of loop current, or for active FET mixers that operate on the principle of transconductance and thus need little gate voltage (6), the broadband transformer is adequate. If this approach is used for the commutation mixer, we would need extraordinarily high local-oscillator drive to ensure positive turn-ON. Rafuse (7) and Ward (8) used a minimum of 2 watts to ensure mixing action; Lewis and Palmer (9) achieved high dynamic range using 5 watts! The MOSFETs used in these early designs were p-channel, enhancement (2N4268) with moderately high threshold (6 V max.) and high input capacitance (6 pF max.). All of these early MOSFET double-balanced mixers relied on the conventional 50 to 100-0-100Ω transformer for local-oscillator injection to the gates.

The major goal of the conservation of power cannot be achieved using the conventional design. Increasing the turns ratio of the coupling transformer is counteracted by the reactive load presented by the gates. The obvious solution is to use a *resonant gate drive*. The voltage appearing across the resonant tank (and thus on the gates) may be calculated by:

$$V = (P \cdot Q \cdot X)^{1/2}$$

where P is the power delivered to the resonant tank circuit;
Q is the *loaded* Q of the tank circuit; and,
X is the reactance of the gate capacitance.

Since the gate capacitance of the MOSFET is voltage-dependent, the reactance of the gate becomes dependent upon the impressed excitation voltage. To allow this would severely degrade the IMD performance of the mixer. However, we can minimize the change in gate capacitance and remove its detrimental influence using a combination of substrate and gate bias, as shown in Fig. 3. Not only is it beneficial in this regard, but gate bias is necessary to ensure the required 50%

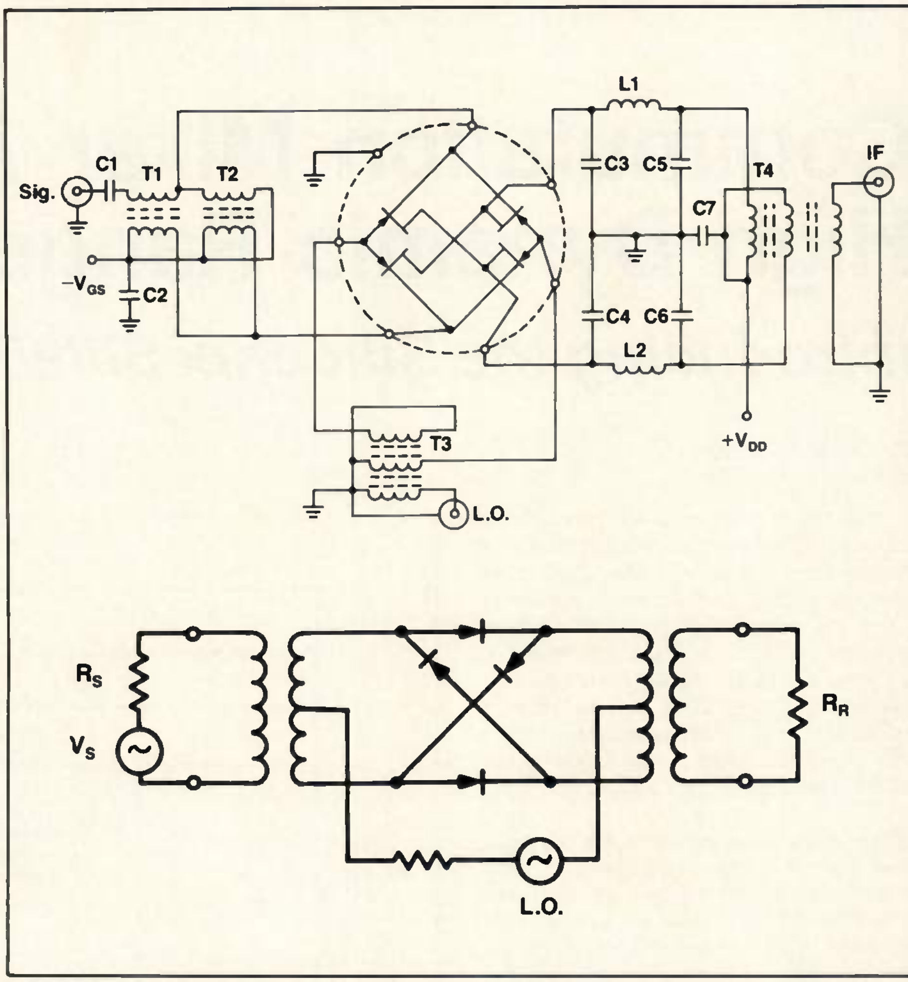

Figure 2. Local oscillator drive using conventional broadband transformers

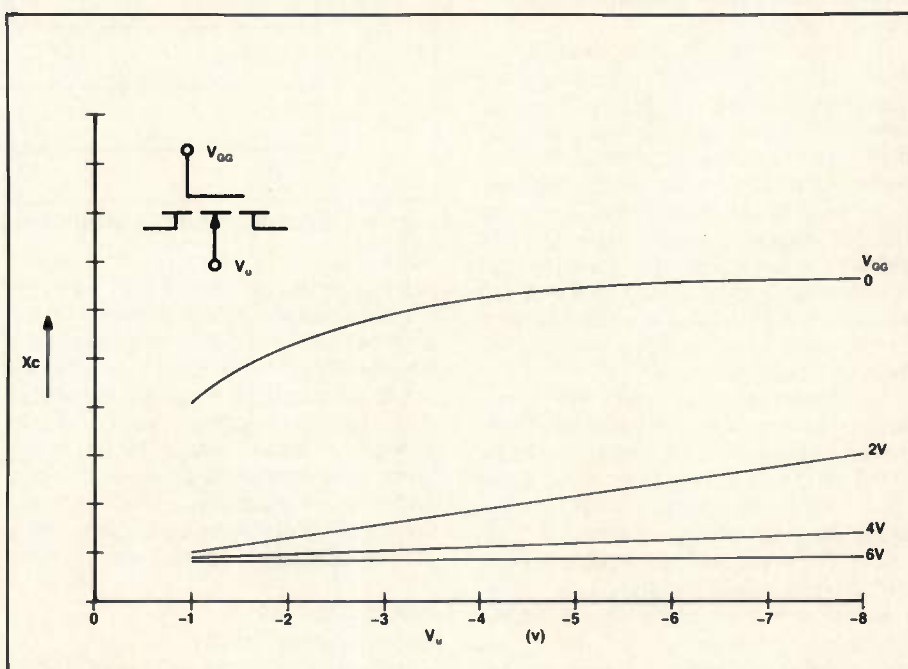

Figure 3. Effect of bias and substrate voltage on gate reactance

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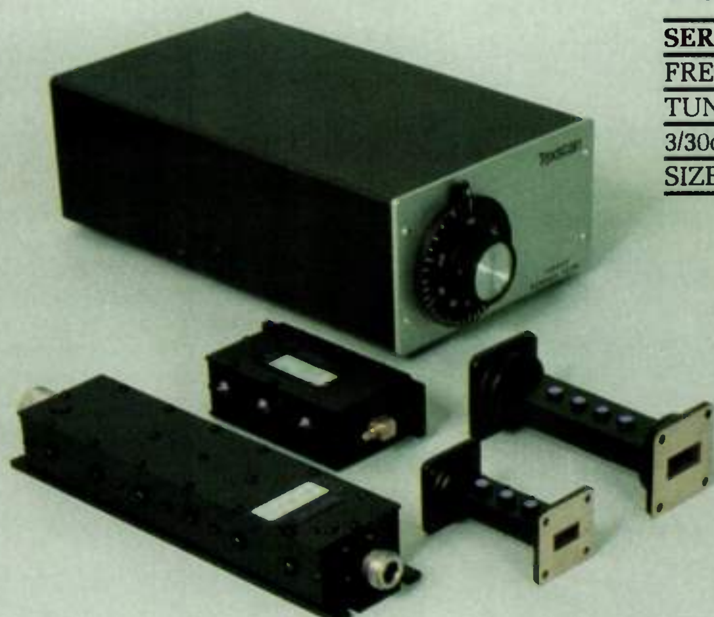


TUNABLE

SERIES	5VF	3VF
FREQ (MHz)	24-4000	24-4000
TUNING RANGE	1 octave	1 octave
3/30dB SHAPE	2.2:1	3.5:1
SIZE	9.6x5.6x3.2″	6.25x5.6x3.2″

CAVITY

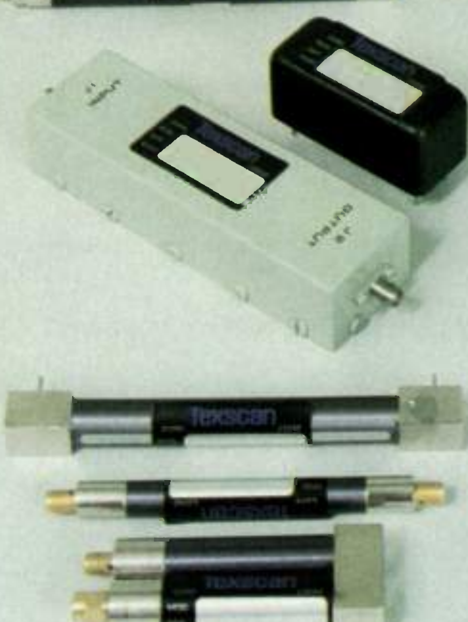
SERIES	CH	CR
FREQ (MHz)	30-400	401-3000
BANDWIDTH	.2-3.5%	.2-3.5%
SECTIONS	2-6	2-6

WAVEGUIDE

SERIES	BW
FREQ (GHz)	5-18
BANDWIDTH	.2-5%
SECTIONS	2-6

TUBULAR LOWPASS

SERIES	LB	LC	LD	LE
SIZE (dia)	3/8″	1/2″	3/4″	1 1/4″
FREQ (MHz)	80-6000	40-4000	25-1500	10-1000
SECTIONS	2-12	2-12	2-12	2-12



BANDPASS LUMPED

SERIES	BM
FREQ (MHz)	5-125
BANDWIDTH	2-60%
SIZE	1x1.1x2.4
SECTIONS	2-8

LOWPASS LUMPED

SERIES	LM
FREQ (MHz)	5-125
SIZE	1x1.1x2.4
SECTIONS	2-8

TUBULAR BANDPASS

SERIES	BB	BC	BD	BE
SIZE (dia)	3/8″	1/2″	3/4″	1 1/4″
FREQ (MHz)	80-6000	60-4000	40-1700	30-1000
BANDWIDTH	2-75%	2-75%	2-75%	2-75%
SECTIONS	2-12	2-12	2-12	2-12

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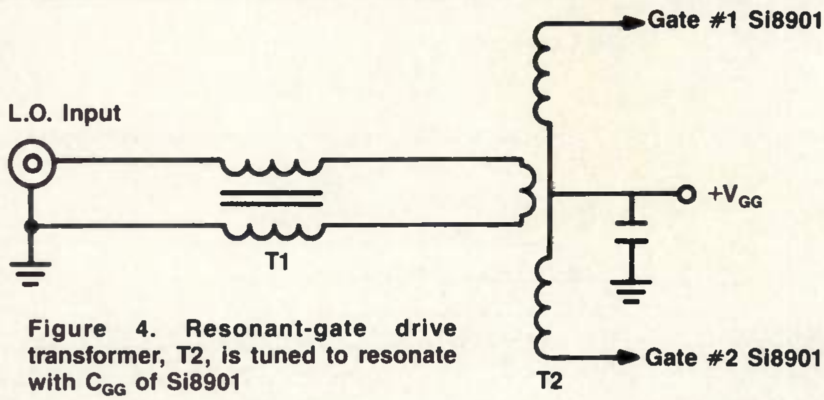

Figure 4. Resonant-gate drive transformer, T2, is tuned to resonate with C_{GG} of Si8901

duty cycle. Also, a negative substrate voltage ensures that each MOSFET on the monolithic substrate is electrically isolated and that each source-/drain-to-body diode is sufficiently reverse biased to prevent half-wave conduction.

Implementing the resonant gate drive may take any of several forms. The resonant tank circuit may be merged with the oscillator, it can be a varactor tuned Class B stage (10), or an independent resonant tank as in the present design (Fig. 4).

To ensure symmetrical gate voltage in 180° anti-phase with asymmetrical local oscillator drive (fed by unbalanced coax), a balun must be used (T1 in Fig. 4), otherwise capacitive unbalance results, with an attendant loss in mixer performance.

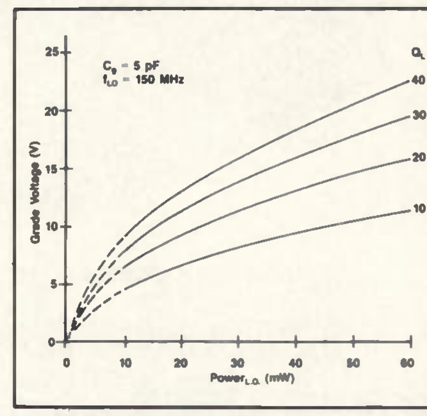

Figure 5. Influence of loaded Q on gate voltage versus L.O. power

Table I offers an interesting comparison between a resonant-gate drive with a loaded tank Q of 14 and conventional gate drive using a 50 to 100-0-100Ω transformer. The importance of a high tank Q is graphically portrayed in Fig. 5. Walker (3) has derived an expression showing the predicted improvement in the relative level of two-tone third-order intermodulation products (IMD_3) as a function of the rise and fall times of the local-oscillator waveforms.

$$20 \text{ Log} \left[\frac{t_r\, \omega_{LO} \dfrac{V_s}{V_c}}{8} \right]^2 \text{ dB} \qquad \text{Eq. 1}$$

where, V_c is the peak-to-peak local-oscillator voltage,
V_s is the peak signal voltage,
t_r is the rise and fall time of V_c,
ω_{LO} is the local-oscillator frequency.

The full impact of a high gate voltage swing can be appreciated by using Equation 1. As V_c (gate voltage) increases, the intermodulation performance (IMD) also improves as we might intuitively expect.

Calculated and measured results shown in Fig. 6 demonstrate reasonable agreement. The difference may reflect problems encountered in measuring V_c as any probe will inadvertently load, or detune, the resonant tank even with the special care that was taken to compensate.

If we have the option to choose "high side" or "low side" injection — having the local-oscillator frequency above (high) or below (low) the signal frequency — a closer inspection of Equation 1 should convince us to choose low-side injection.

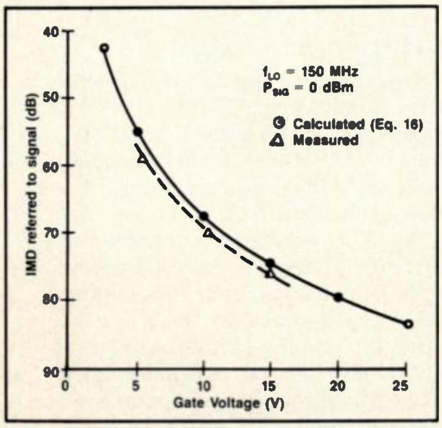

Figure 6. Effects of gate voltage on intermodulation distortion

Terminating Unwanted Frequencies

If our mixer is to be operated over a restricted frequency range where the local oscillator and signal frequencies can be manipulated, image-frequency filtering may be possible. Image-frequency filtering *does* affect performance. For high-side local-oscillator injection an elliptical-function low-pass filter, or for low-side injecton a high-pass filter might offer worthwhile improvement. In either case, the filter offers a short-circuit reactance to the image frequency forcing the image to return once again for demodulation.

The resonant-gate drive consisting of a high-Q tank offers adequate by-passing of the intermediate frequency and image frequency. If the IF is narrow band, filtering may be possible by simply using a resonant LC network across the primary of the transformer.

Building the Commutation Mixer

The mixer was fabricated on a high-quality double-copper clad board shown in Fig. 7. An improvised socket held the Si8901. The signal and IF ports used Mini-Circuits, Inc., plastic T-case RF transformers. For the IF, the Mini-Circuits T4-1 (1:4); for the signal, the Mini-Circuits T1-1T (1:1) or T4-1 was used. The resonant tank was wound on a ¼-inch ceramic form with no slug. The unbalanced-to-balanced resonant tank drive used a T4-1. The schematic diagram, Fig. 8, is for a commutation mixer with high-side injection, operating with an IF of 60 MHz.

The principle effort involved the design of the resonant-gate drive. This necessitated an accurate knowledge of the gate's total capacitive loading effect. To accomplish this, a precision fixed capacitor (5

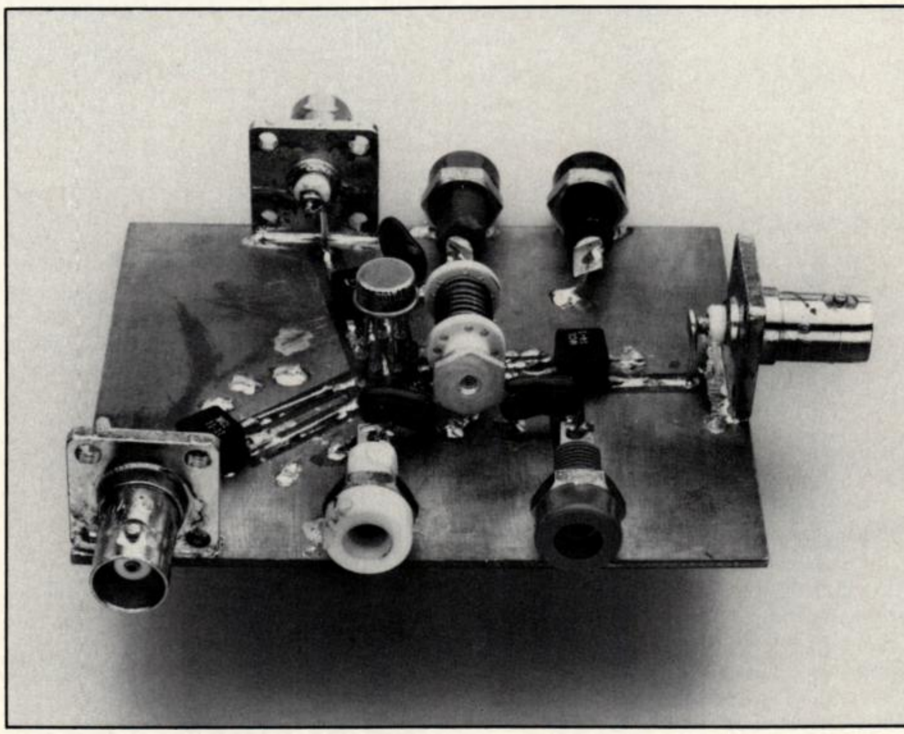

Figure 7. Prototype balanced mixer

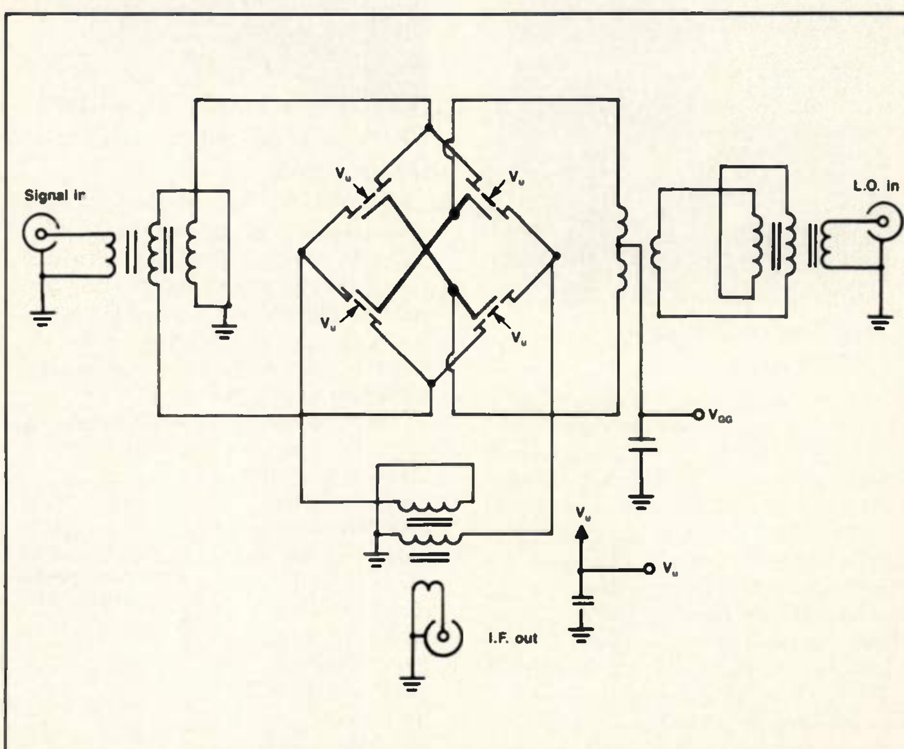

Figure 8. Schematic — commutation double-balanced mixer

pF) was substituted for the Si8901 and at resonance it was a simple task to calculate the inductance of the resonant tank. Substituting the Si8901 made it again a simple task to determine the capacitive effect of the Si8901. Once known, a high-Q resonant tank can be quickly designed and implemented. To ensure good interport isolation, care is necessary in assembly to maintain mechanical symmetry, especially with the primary winding.

Performance

The primary goal in developing the Si8901 commutation double-balanced mixer is to achieve a high dynamic range. If this task can be accomplished with an attendant savings in power consumption, then the resulting mixer design should find wide application in HF receiver design. The following tests were performed:

- Conversion efficiency (loss)
- Two-tone, 3rd-order intercept point
- Compression level
- Desensitization level
- Noise figure

Conversion loss and intercept point are directly dependent upon the magnitude of the local-oscillator power. The mixer's performance is offered in Fig. 9, where the *input* intercept is plotted with conversion loss.

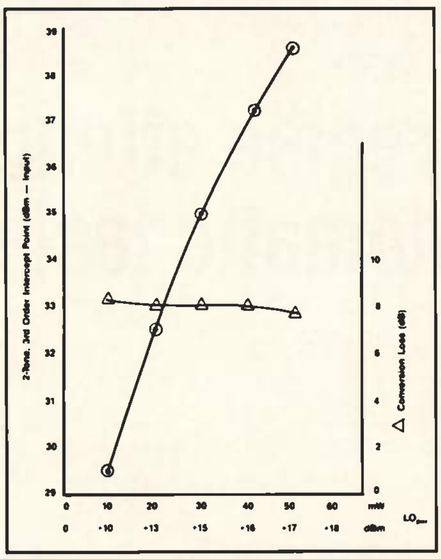

Figure 9. Input intercept point and conversion loss

Both the compression and desensitization levels may appear to contradict reason. Conventional diode-ring demodulators exhibit compression and desensitization levels an order of magnitude *below* the local-oscillator power level. However, with a commutation MOSFET mixer, switching is *not* accomplished by the injection of loop current but by the application of gate voltage. At a local-oscillator power level of +17 dBm (50 mW), the 2 dB compression level and desensitization level was +30 dBm! The single-sideband HF noise figure of 7.95 dB was measured also at a local-oscillator power level of +17 dBm.

Conclusions

Achieving a high gate voltage to effect high-level switching by means of a resonant tank is not a handicap. Although one might at first label the mixer as narrowband, in truth the mixer is wideband. For the majority of applications, the intermediate frequency is fixed, that is, narrowband. Consequently, to receive a wide spectrum of signal frequencies the local-oscillator is tuned across a similar band. In modern technology this tuning can be accomplished by numerous methods. Likewise the resonant tank may take several forms. It can be part of the oscillator, or, as in Ref. 10, it can be a varactor-tuned driver electronically tracking the local oscillator.

If the local-oscillator drive was processed to offer a more rectangular waveform, approaching the idealized squarewave, we might then anticipate even greater dynamic range as predicted by Equation 1.

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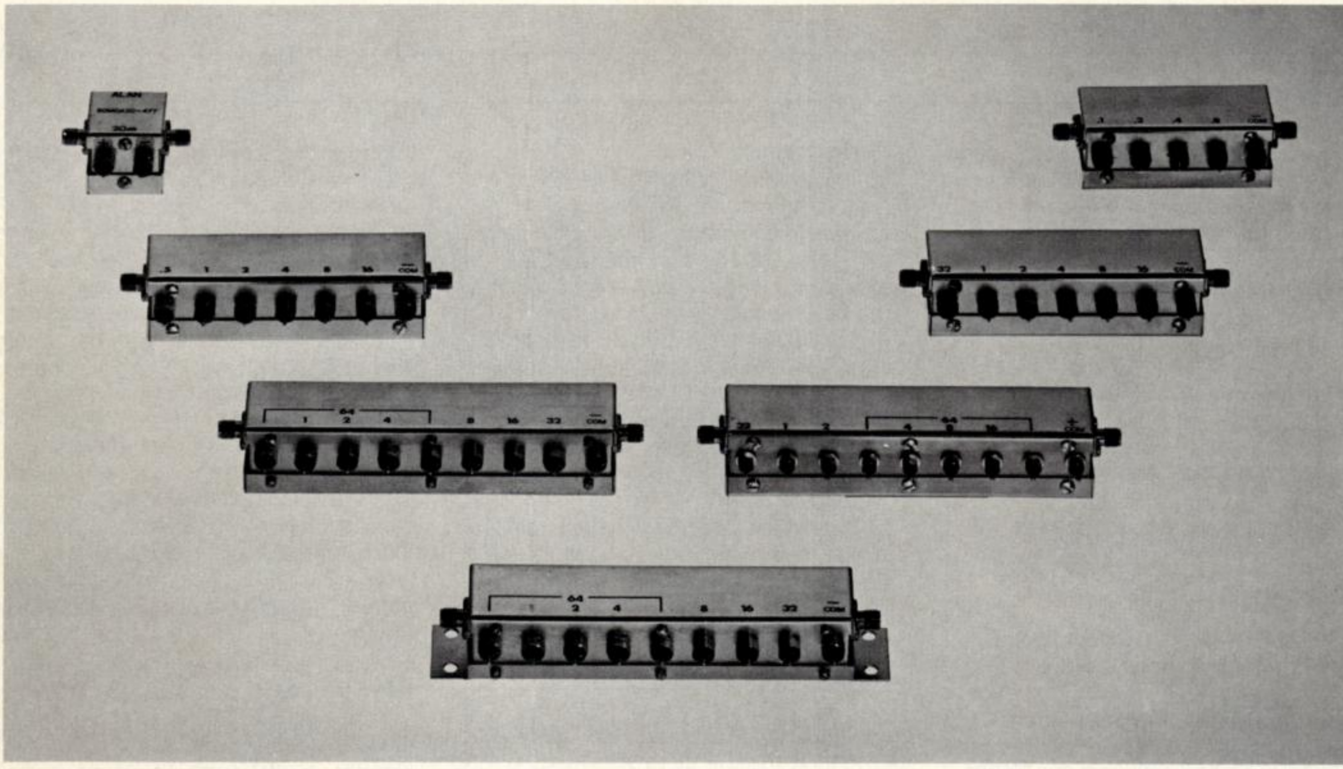
About the Author

Ed Oxner is Staff Engineer with Siliconix Incorporated, 2201 Laurelwood Road, Santa Clara, CA 95054. He can be reached at (408) 988-8000. Ed has many years experience in mixer design.



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BASIC Programs for Symmetrical Attenuators and Active Filters

By Carl Lodström
Dow Key Microwave Corp.

Engineers often require quick solutions to simple problems, and a library of computer programs can take the tedium out of repeated calculations, however simple. The author presents two programs written for the Commodore VIC-20 or C64 computers. Written in BASIC, they may be easily translated for use on many other personal computers.

The first program computes symmetrical attenuators (same input and output impedance), in either Tee or Pi configuration. This program is written for the C64, and requires a small change to run on a VIC-20. Line 3 should be: POKE 36879,8 (to make the screen black), then CTRL 2 should be keyed in to make white characters. Other notes on this program include the references in Lines 901-903. NE is Neper, which is dB with "e" for a base, since the computers use natural logarithms. SH and TH represent SINH and TANH, respectively.

The second program computes 2-pole active lowpass, highpass, notch and bandpass filters. Please note that the scale of units (kHz, kohm, pF) are noted in REM lines. Persons copying the program might wish to make them PRINT statements, as a reminder of the proper units. This program was written on a VIC-20 and will run as-is on a C64.

These programs are simple enough to require no detailed operating instructions. The programs prompt the user as to the required data entry, and inspection of the programs should answer any other questions about the formulas or the display and graphics techniques used. rf

About the Author

Carl Lodström is an Applications Engineer with Dow Key Microwave Corporation, 1110 Mark Avenue, Carpinteria, CA 93013-2918. He can be reached by mail at this address, or by telephone at (805) 684-0427.

```
3 POKE 53281,0:POKE 53280,0
5 PRINT"■"
10 INPUT"SYSTEM IMPEDANCE";Z0
100 PRINT"■■T OR P ATTENUATOR?"
110 GET X$
120 IF X$="T"THEN 200
130 IF X$="P"THEN 400
140 GOTO 110
200 PRINT"■■T ATTENUATOR";Z0"OHM■■"
201 PRINT"       ___      ___"
202 PRINT" ●──┤   ├─┬─┤   ├──●"
203 PRINT"       ___  |   ___"
204 PRINT"       R1   |   R2"
205 PRINT"           ┴"
206 PRINT"          ||"
207 PRINT"       R3 ||"
208 PRINT"          ||"
209 PRINT"           ┬"
210 PRINT"           |"
211 PRINT"           |"
212 PRINT" ●─────────┴─────────●"
220 PRINT"■■GIVEN DB OR R1 (D/R)"
221 GETY$
222 IFY$="R"THEN GOTO 300
223 IFY$="D"THEN GOTO 900
224 GOTO 221
250 R3=Z0/SH
260 R1=Z0*TH
270 PRINT"R1=R2=";R1
280 PRINT"    R3=";R3
299 GOTO 100
300 INPUT"R1 (<Z0)";R1
301 R5=Z0+R1
302 R4=Z0-R1
303 R3=1/(1/R4-1/R5)
304 PRINT"R3=";R3
305 U4=R4/(R1+R4)
306 U5=U4*(Z0/(R1+Z0))
307 DB=LOG((U5)↑2)
308 DB=DB*4.34294482
309 PRINT"|G|=";DB"DB"
310 GOTO 100
400 PRINT"■■P ATTENUATOR";Z0"OHM■■"
401 PRINT"              ___"
402 PRINT" ●────┬─────┤   ├────┬────●"
403 PRINT"      |       ___    |"
404 PRINT"      |       R3     |"
405 PRINT"      ┴              ┴"
```

Program 1. Symmetrical Attenuator Program
This program will repeat itself after each calculation. To exit the program, RUN/STOP should be pressed.

Program 1. Symmetrical attenuator program
Continued

```
406 PRINT"      ||              ||"
407 PRINT"      ||R1        R2 ||"
408 PRINT"      ||              ||"
409 PRINT"      ┬               ┬"
410 PRINT"      |               |"
411 PRINT"      |               |"
412 PRINT" ●────┴───────────────┴────●"
420 PRINT"■■GIVEN DB OR R1 (D/R)"
421 GETZ$
422 IFZ$="R"THEN GOTO 500
423 IFZ$="D"THEN GOTO 900
424 GOTO 421
450 R3=Z0*SH
460 R1=Z0/TH
470 PRINT"R1=R2=";R1
480 PRINT"    R3=";R3
499 GOTO 100
500 INPUT"R1= ( >Z0)";R1
501 R5=R1*Z0/(R1+Z0)
502 S4=1/Z0-1/R1
503 R4=1/S4
504 R3=R4-R5
505 PRINT"R3=";R3
506 U5=R5/(R5+R3)
507 P5=U5↑2
508 DB=LOG(P5)*4.34294482
509 PRINT" |G|=";DB"DB"
599 GOTO 100
800 INPUT"R1 (OHM)";R1
898 IF X$="T"THEN 250
899 IF X$="P"THEN 450
900 INPUT"DB";DB
901 NE=DB/8.68588964
902 SH=(EXP(NE)-EXP(-NE))/2
903 TH=(EXP(NE/2)-EXP(-NE/2))
    /(EXP(NE/2)+EXP(-NE/2))
904 IF X$="T"THEN 250
905 IF X$="P"THEN 450
```

Program 2. Active Filters — highpass, bandpass, notch and lowpass
As written, this program needs to be "RUN" for each computation.

```
2 REM FREQUENCIES IN KHZ EXEPT FOR
3 REM BANDWITH IN BP FILTER
4 REM RESISTANCES IN KOHM
5 REM CAPACITANC ES IN PF
11 PRINT"■ * *                  * *"
12 PRINT"  *  SELECT ONE!   *"
13 PRINT" * *                 * *"
14 PRINT"■■■■"
15 PRINT"     HIGHPASS - F1 ■"
16 PRINT"     BANDPASS - F3 ■"
17 PRINT"     NOTCH    - F5 ■"
18 PRINT"     LOWPASS  - F7"
20 P=0
30 H$=CHR$(133)
40 B$=CHR$(134)
50 N$=CHR$(135)
60 L$=CHR$(136)
70 GET X$:IF X$=""THEN80
80 IF X$=H$ THEN GOTO 100
82 IF X$=B$ THEN GOTO 300
84 IF X$=N$ THEN GOTO 500
86 IF X$=L$ THEN GOTO 700
88 GOTO 30
100 PRINT"■"
101 PRINT"   HIGHPASSFILTER"
102 PRINT"■"
103 PRINT"          C2 R2"
104 PRINT"        ┌┤ ├┬──────┐"
105 PRINT"        |   ┴      |"
106 PRINT"        |   ||  |\ |"
107 PRINT"IN   C1 |C3 ┬   | \ |"
108 PRINT" ●───┤ ├┤├ ├┴───-  \ |OUT"
109 PRINT"       ┴        |   \| ▬"
110 PRINT"       ||R1     |   /───▬"
111 PRINT"       ┬        |  /"
112 PRINT"    /──┴────────+ /"
113 PRINT"                |/"
114 PRINT"■"
115 IF P=1 THEN GO TO 140
116 P=1
113 INPUT "FREQUENCY (KHZ)";F
120 INPUT "Q-VALUE";Q
125 INPUT "GAIN";G
130 INPUT "C1 (=C3)PF";C
135 IF P=1 THEN PRINT"■"
136 GOTO 103
140 W=F*2*π*10↑3
145 R1=1/(Q*W*C*10↑-12*(G*2+1))
150 R2=Q/(W*C*10↑-12)*(2*G+1)
155 C2=C/G
160 PRINT"C1=C3=";C
165 PRINT"C2=    ";C2
170 PRINT"R1=    ";R1/10↑3
```

```
175 PRINT"R2=    ";R2/10↑3
180 END
300 PRINT"▣"
301 PRINT"     BANDPASSFILTER"
302 PRINT"■"
303 PRINT"      C    R2"
305 PRINT"      ┌──────┬──────────┐"
307 PRINT"      ┴      ┴          |"
309 PRINT"      ┬     ||\         |"
311 PRINT"   R1| C    ┬|  \       |"
313 PRINT" ●─[ ]┼─┤├─┴─-  \      |"
315 PRINT" IN   ┴       |   \___|▬"
317 PRINT"     || R3    |   /     ▬"
319 PRINT"      ┬   /────+ /   OUT"
321 PRINT"      |        | /"
323 PRINT"      /        V"
324 PRINT"■"
325 IF P=1 THEN GOTO 340
326 P=1
327 INPUT "FREQUENCY (KHZ)";F
328 INPUT "C1 (=C2)PF";C
329 INPUT "BANDWITH (HZ)";B
330 INPUT "GAIN";G
335 IF P=1 THEN PRINT"▣"
336 GOTO 303
340 F=F*10↑3
345 C=C*10↑-12
350 R1=1/(G*B*C*2*π)
355 R2=G*R1
357 X=F↑2
358 X=X/B
359 Y=-G*B
360 X=X+Y
361 X=X*2*π*C
362 R3=1/X
365 C=C*10↑12
370 PRINT"C1=C2=";C
375 PRINT"   R1=";R1/10↑3
380 PRINT"   R2=";R2/10↑3
385 PRINT"   R3=";R3/10↑3
390 END
500 PRINT"▣"
501 PRINT"     NOTCHFILTER"
502 PRINT"■"
503 PRINT"              |\"
504 PRINT"     R1 R3    | \"
506 PRINT"    ┌[ ]┬[ ]┬────+ \ OUT"
507 PRINT"    |  ┴  |   |   \___▬"
508 PRINT" IN |C2┬  |   |   / |▬"
509 PRINT" ●──┤   ├─|─┬─- /  |"
510 PRINT"    |R2┴  | | | /   |"
511 PRINT"    |  ||  | | V    |"
512 PRINT"    |  ┬   | └──────┘"
513 PRINT"    |  |   |"
514 PRINT"    └┤├─┤├─┘"
516 PRINT"     C1 C3"
518 PRINT"■"
520 IF P=1 THEN GOTO 545
525 P=1
530 INPUT "FREQUENCY (KHZ)";F
540 INPUT "C1 (=C3) PF";C
545 W=2*π*F*10↑3
550 R1=1/(W*C*10↑-12)
555 PRINT"R1=R3=";R1/10↑3
560 PRINT"R2=    ";R1/2000
565 PRINT"C1=C3=";C
570 PRINT"C2=    "C*2
575 END
700 PRINT"▣"
701 PRINT"     LOWPASSFILTER"
703 PRINT"■"
705 PRINT"       ┌─────┬──────┐"
707 PRINT"       ┴     |      |"
708 PRINT"   R2|| C2= |\      |"
709 PRINT" IN  ┬     || \     |"
710 PRINT" ●─[ ]┼[ ]─┴─-  \   |"
711 PRINT"   R1 |R3   |    \_|▬"
712 PRINT"   C1=      |    /  ▬"
713 PRINT"       ├────+ /   OUT"
714 PRINT"       |    | /"
715 PRINT"       /    V"
718 PRINT"■"
719 IF P=1 THEN GOTO 732
720 P=1
725 INPUT "FREQUENCY (KHZ)";F
726 INPUT "Q-VALUE";Q
727 INPUT "GAIN";G
728 INPUT "C1 (PF)";C1
729 C1=C1*1E-12
730 IF P=1 THEN PRINT"▣"
731 GOTO 703
732 W=2*10↑3*π*F
733 K=1/(4*Q↑2*(G+1))
735 C2=K*C1
738 R2=1/(2*Q*K*W*C1)
740 R1=R2/G
742 R3=1/(W↑2*C1↑2*R2*K)
755 PRINT"C1=";C1*1E12
756 PRINT"C2=";C2*1E12
757 PRINT"R1=";R1/1E3
758 PRINT"R2=";R2/1E3
759 PRINT"R3=";R3/1E3
760 END
```

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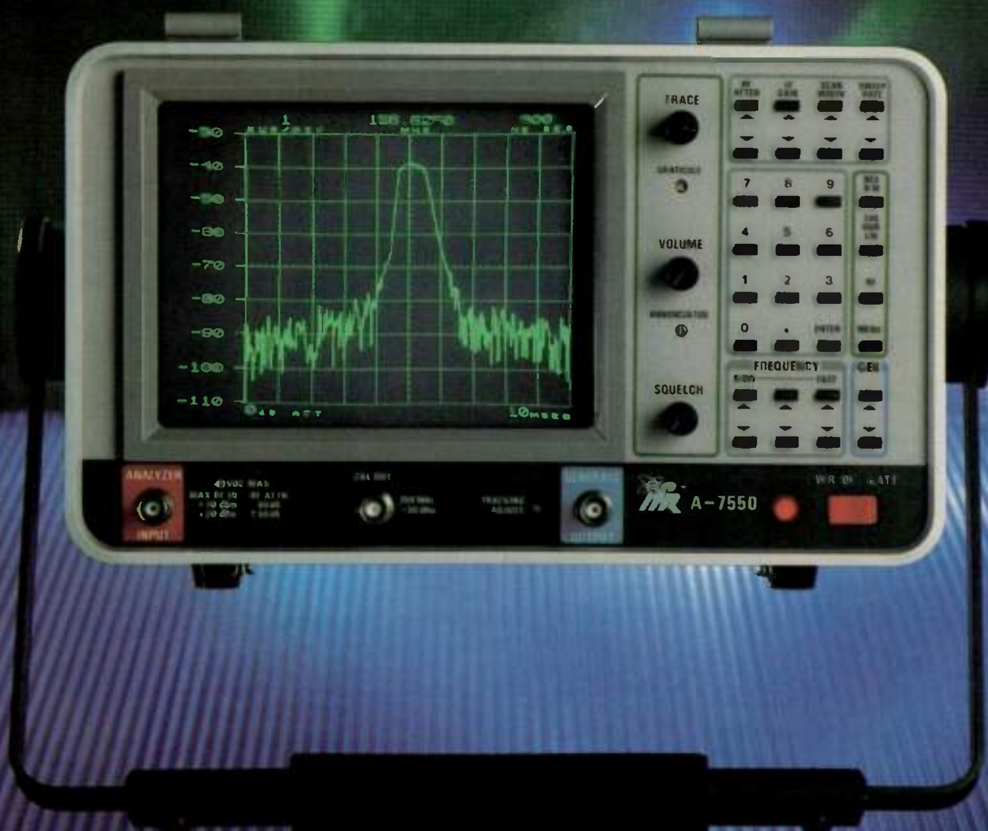

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Model Number	Test Freq. (MHz)	P_{OUT} Min. (W)	P_{IN} (W)	Eff Min. (%)	V_{CC} (V)	Pulse Width (usec)	Duty Cycle (%)
AM 1214-100	1235-1365	125	28	50	32	1000	10
AM 1214-300	1235-1365	270	63	40	50	50	4
AM 1416-100	1400-1600	90	15	40	45	10	10
AM 1416-200	1400-1600	180	40	40	50	10	10
AM 0610-200	650-1000	180	35	40	45	10	10
AM 0710-300	750-950	270	30	40	50	10	10

S-BAND RADAR PULSED POWER TRANSISTORS

Model Number	Test Freq. (MHz)	P_{OUT} Min. (W)	P_{IN} (W)	Eff Min. (%)	V_{CC} (V)	Pulse Width (usec)	Duty Cycle (%)
AM 82731-12	2700-3100	12.5	3.0	32	40	100	10
AM 82731-45	2700-3100	45.0	12.0	30	40	100	10
AM 82931-55	2900-3100	55.0	14.0	30	42	50	10
AM 83135-15	3100-3500	15.0	4.0	30	40	100	10
AM 83135-30	3100-3500	30.0	8.5	30	40	100	10
AM 83135-40	3100-3500	40.0	12.5	30	40	100	10

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Directional Coupler Design Graphs

For Parallel Coupled Lines and Interdigitated 3 dB Couplers

By Alejandro Dueñas J.
Universidad de Colima, Mexico and
Arturo Serrano S., CICESE Research Center, Ensenada, Mexico

3 dB directional couplers (power dividers/combiners) are an integral part of many VHF, UHF and microwave designs. The authors have prepared a series of curves to facilitate design of parallel coupled line and 2, 4 or 6 line interdigitated couplers. The curves were generated by a computer program written by one of the authors (1). Although these couplers could be readily designed using the computer program alone, a visual representation of the design parameters allows the designer to establish basic design criteria without the need for repeated computations and to examine design alternatives literally "at a glance."

In 1969, when Lange (2) introduced the four-line interdigitated 3 dB directional coupler the design approach of divider/combiner coupling devices was radically changed. At that time, branch line (3) (Figure 1) or single parallel coupled line directional couplers (4) (Figure 2) were conventionally used. Today, however, the most often used directional couplers are the interdigitated ones (Figure 3). This structure provides wide bandwidth for better coupling resolution occupying less space. Furthermore, it can be easily constructed with conventional microstrip technology.

A coupler is a four-port device without coupling between diagonally opposite ports (Figure 4) in which an incident wave at port 1 couples power to port 2 and transfers power into port 4 but does not couple power to port 3. Similarly, an incident wave at port 3 couples power to port 4 and transfers power into port 2 but does not couple power to port 1. Therefore, ports 1 and 3 are uncoupled.

With an incident signal at port 1, the parameters which determine the coupler performance are:

The coupling: The ratio of the incident power at port 1 (P_i) to inversely coupled power at port 2 (P_{ic}), is given by:

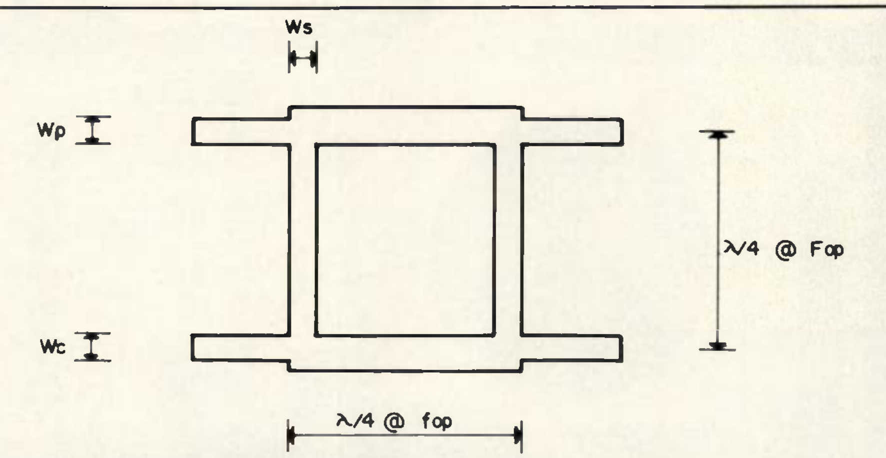

Figure 1. Branch lines directional coupler.

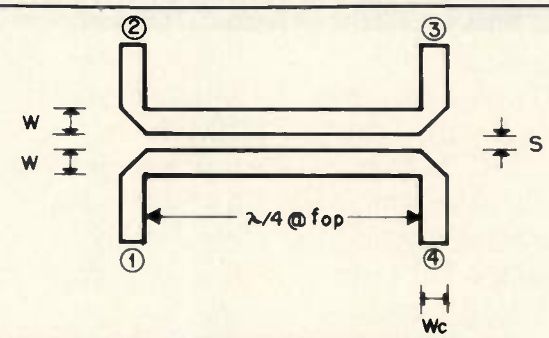

Figure 2. Parallel coupled lines directional coupler.

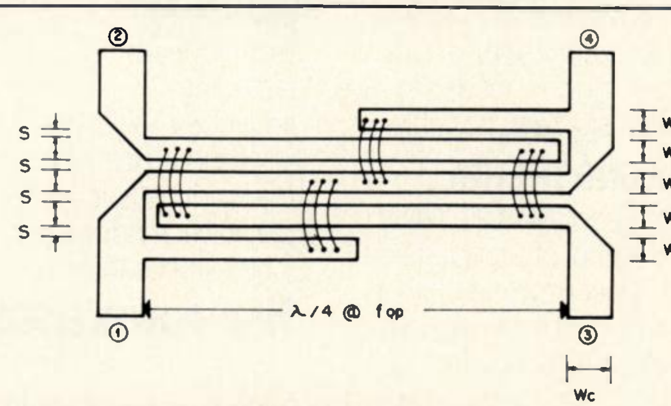

Figure 3. Interdigitated directional coupler.

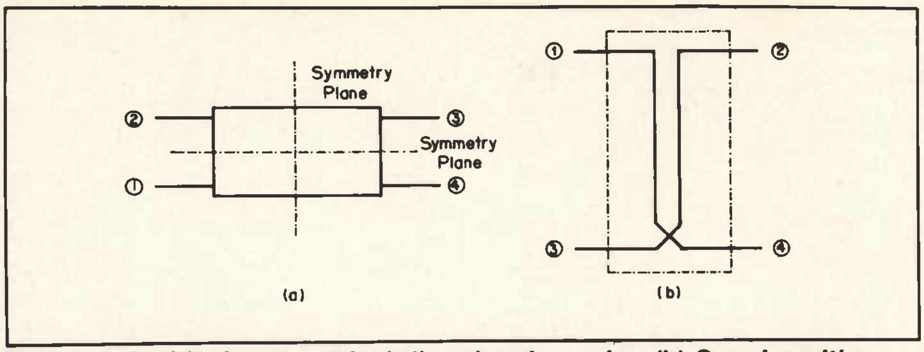

Figure 4. (a) Ideal symmetrical directional coupler; (b) Coupler with ports 3 and 4 crossover.

$$C_{dB} = 10 \log_{10} (P_i/P_{ic}) \quad (1)$$

where P_i/P_{ic} is the power coupling coefficient.

The isolation: The ratio of the incident power at port 1 to straightforward coupled power at port 3 (P_{sc}), is given by:

$$I_{dB} = 10 \log_{10} (P_i/P_{sc}) \quad (2)$$

The directivity: The ratio of the inversely coupled power at port 2 to straightforward coupled power at port 3, is given by:

$$D_{dB} = 10 \log_{10} (P_{ic}/P_{sc}) \text{ or,} \quad (3)$$

$$D_{dB} = I - C \quad (4)$$

An important paper which studies the parallel coupled line directional coupler theory thoroughly was developed by Jones (4). He obtained the coupled and transferred voltages in ports 2 and 4 respectively (Fig. 4) as a function of the voltage coupling coefficient (k_v) and the electrical length (θ) of the coupled lines. The associated voltages, coupling coefficient and electrical length are:

$$V_2 = V \frac{jk_v \sin \theta}{(1 - k_v^2)^{1/2} \cos \theta + j\sin \theta} \quad (5)$$

$$V_4 = V \frac{(1 - k_v^2)^{1/2}}{(1 - k_v^2)^{1/2} \cos \theta + j\sin \theta} \quad (6)$$

$$k_v = \frac{\frac{Z_{oe}}{Z_{oo}} - 1}{\frac{Z_{oe}}{Z_{oo}} + 1} \quad (7)$$

where, V = driving source voltage
Z_{oe} = even mode characteristic impedance
Z_{oo} = odd mode characteristic impedance.

$$\theta = \frac{2\pi f_{op} L}{v} \quad (8)$$

where, f_{op} = operation frequency
L = physical length of the coupled lines
v = propagation velocity.

The Synthesis

The synthesis theory of microstrip circuits has been extensively treated in several works (Wheeler (5), Bryant (6), Schneider (7), Crampagne (8)). The best paper to date is Wheeler's 1965 work, an extension of which was presented in 1977 (9). Based on Wheeler's paper and that presented by Akhtarzad (10), Reisch (11) presented a calculator program which generates good design results.

A Fortran IV computer program with an algorithm similar to Reisch's program was used in this article to obtain synthesis curves. Figs. 5, 6 and 7 show the W/H (width/height) and S/H (spacing/height) ratios vs. dielectric constant for couplers of 2, 4 and 6 lines, respectively. Figs. 8, 9 and 10 show the relative phase velocity for each case.

A general procedure for using the information presented in Figs. 5 to 10 is the following. Knowing the height (H) and the substrate dielectric constant (ϵ_r), the W/H and S/H ratios and the relative phase velocity can be found by drawing a line from the desired dielectric constant point toward its respective curve (dotted lines in Figs. 6 and 9).

A design example shows the advantage of using these graphs. For instance, suppose it is necessary to get 3 dB power division/combination with 90° of relative phase for the input/output of a given balanced amplifier at 3.95 GHz. A 4 lines interdigitated coupler must be used which will be realized using DUROID 5880 (ϵ_r = 2.2). From the graphs of Figs. 6 and 9 the desired parameters are: W/H = 0.55, S/H = 0.052 and RPV = 0.76. The dimensions of the final 3 dB coupler for H = 0.07874 cm are shown in Fig. 11.

With the use of these graphs the design engineer is now able to find rapidly the physical dimensions of three kinds of 3 dB microstrip directional couplers without making tedious calculations or using long calculator or computer programs. rf

About the Authors

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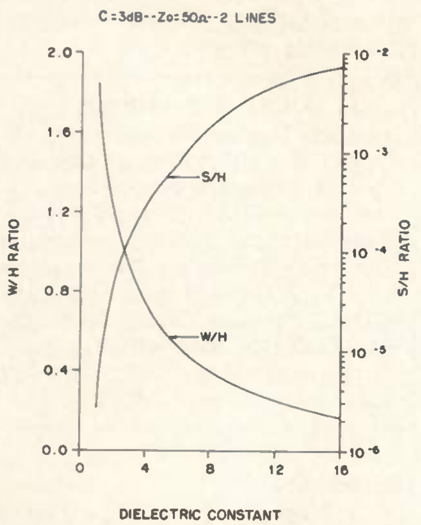

Figure 5. W/H and S/H ratios vs. dielectric constant for 2 lines 3 dB couplers.

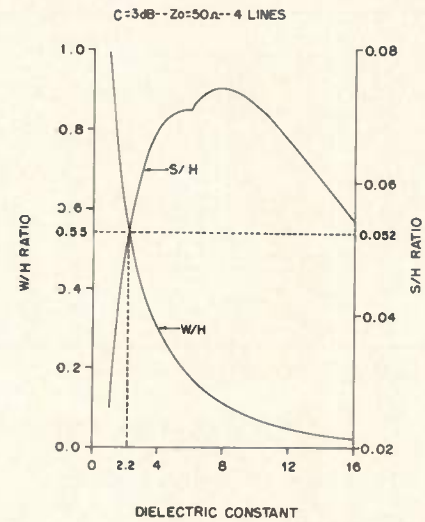

Figure 6. W/H and S/H ratios vs. dielectric constant for 4 lines 3 dB couplers.

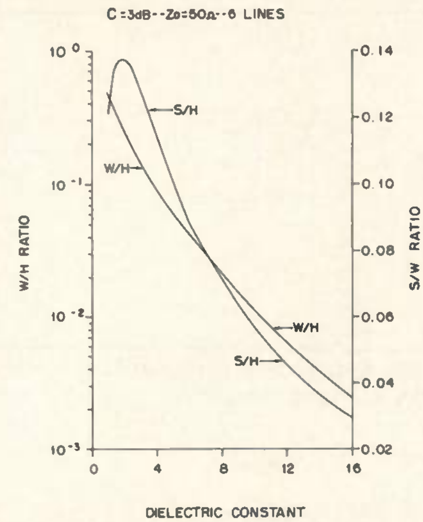

Figure 7. W/H and S/H ratios vs. dielectric constant for 6 lines 3 dB couplers.

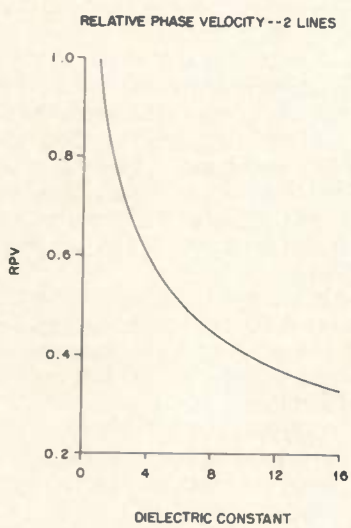

Figure 8. Relative phase velocity for 2 lines 3 dB couplers.

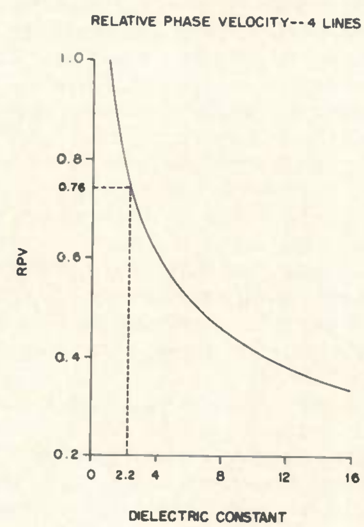

Figure 9. Relative phase velocity for 4 lines 3 dB couplers.

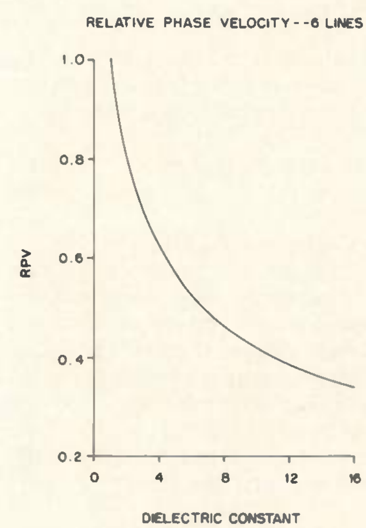

Figure 10. Relative phase velocity for 6 lines 3 dB couplers.

W = 0.043

S = 0.004

H = 0.07874

$$L = \frac{\theta\, v\, RPV}{2\pi f_{op}} = 1.443 \text{ cm}$$

Wc = 0.236 cm for a line of 50 Ω in DUROID 5880

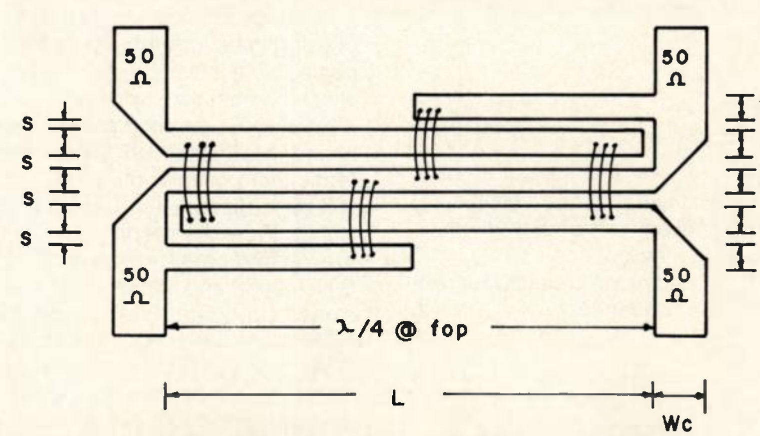

Figure 11. Dimensions for a 4 lines 3 dB interdigitated directional coupler (design example).

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RF/Digital Applications: A Review

By Gary A. Breed
Technical Editor

Rather than explore one topic on the subject of digital applications for RF, this month's Digital Connection *will try to review many of the possibilities for direct applications of digital devices and techniques in RF circuits.*

Some applications are familiar, such as phase-locked loops (PLLs) and microprocessor controllers, but there are many more ways to utilize digital techniques, as we shall see.

GaAs logic works from DC to GHz — Virtually everyone in the electronics industry is predicting a bright future for gallium arsenide (GaAs) components, both digital and analog. Compared to silicon, GaAs has both speed and power consumption advantages. Digital logic that operates at 2 or 3 GHz offers fascinating possibilities to designers of frequency synthesizers, digital signal processing circuits, mixers, modulators, dividers, and analog-to-digital (A/D) or digital-to-analog (D/A) converters.

Direct digital synthesis (DDS) — Current techniques and high-speed digital components now make it possible to digitally synthesize *any waveform* to frequencies beyond 30 MHz. Using digital reconstructions of the waveform and high-speed D/A converters, precise control over all aspects of the waveform's shape, phase and frequency is possible. Without a feedback loop like PLLs, DDS can switch frequencies almost instantaneously with phase coherence and low switching transients. The use of DDS for frequency-hopping communications is obvious, with other applications including test instrumentation, digital modulation and demodulation circuits, plus many of the uses now performed by PLLs.

Digital signal processing (DSP) — The same fast A/D and D/A converters mentioned earlier, along with other high-speed logic, makes DSP an area of much current development. All communications transmitted via RF equipment can be digitized and processed digitally, providing improvement over analog processing in many areas. Filtering, modulation and demodulation can all be done digitally, as well as noise reduction, signal analysis, and data or voice encryption and decryption. The fast Fourier transform used in RF test equipment to provide time domain information is one type of DSP, where the signal is digitized and mathematically manipulated. Other current applications include military communications, secure voice and data communications, and radio astronomy signal analysis.

Class D/E (and higher) RF amplifiers — With potential efficiencies of 90+%, the various switch-mode amplifier designs are exciting projects for RF engineers. To achieve highest possible efficiency, these amplifiers need control over driving pulse characteristics and circuits to monitor operating parameters. Digital circuitry is the obvious method to maintain precise pulse control for these amplifiers, since pulses are the nature of digital signals. Related functions often used in switch-mode amplifier system, such as envelope stripping and restoration and multi-phase driving circuits, may have digital solutions as well.

Analog switches and commutating circuits — Analog switches have already had a major impact on the design of video and RF switching matrices and have wide-ranging applications in digitally-controlled switching of all types. With their space and power consumption savings, analog switches can replace electromechanical relays in many circuits with analog signal levels below ±10 V AC or DC. DMOS and other new fabrication techniques have given the most recently developed switches increased speed, lower ON resistance, higher frequency signal capabilities and greater power handling over earlier components.

Using switches as commutating circuits makes switching mixers, modulators, demodulators, and multiplexing circuits relatively easy to implement. In these applications, the transfer function of a near-ideal switch has significant performance advantages over the transconductance of transistors or the high-current drive requirements of diodes.

Microprocessor controls — Although routine "housekeeping" functions for microprocessors are easy to imagine, some other uses of machine intelligence can be rather novel. AGC, AFC, and ALC circuits can benefit from decision-making algorithms. Built-in test (BITE) procedures need programmable controls. Spread-spectrum communications requires complex controls for frequency control and


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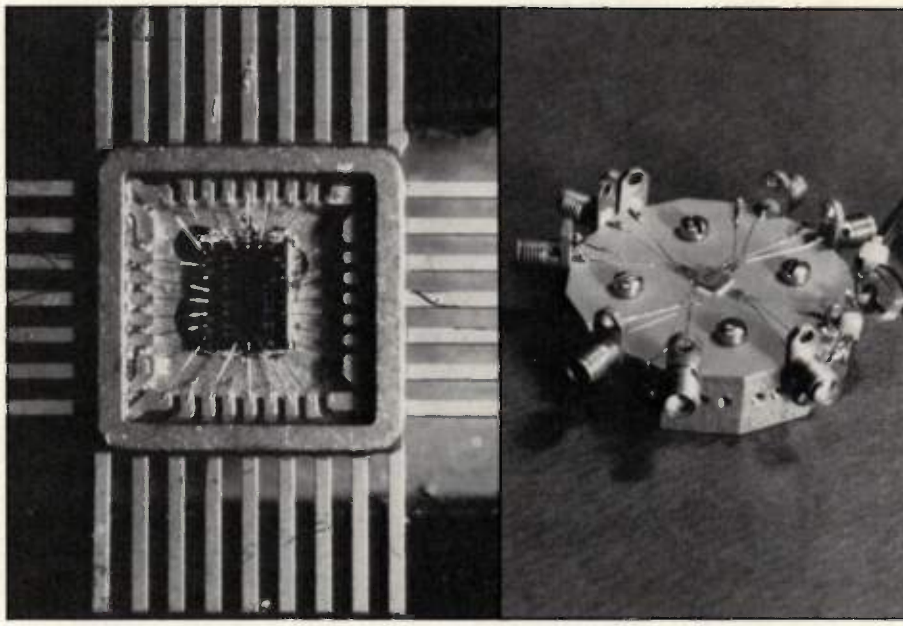
signal processing. The variations in propagation, noise, interference, and transmission delays over the frequency range utilized by spread-spectrum requires an intelligent operational system.

Components — It would take volumes to describe all of the digital components useful for RF design, but there are a few that stand out. The logic families include GaAs at 3 GHz speed, ECL up to about 1 GHz, FAST TTL at 100+ MHz, and the various CMOS types up to about 25 MHz. The really interesting components are large-scale integrated circuits (LSI). There are A/D converters which operate into the tens of MHz, D/A converters up to 200 MHz, multiplier/accumulators up to 100 MHz, PLLs on one chip, even low frequency DDS devices requiring only a D/A converter for a 5 MHz synthesizer. Various circuits of these types are available in each of the logic families.

On the leading edge of technology are some new products, including digital and analog circuits combined on the same IC chip. Speed, accuracy and size all benefit from such technology, which has great

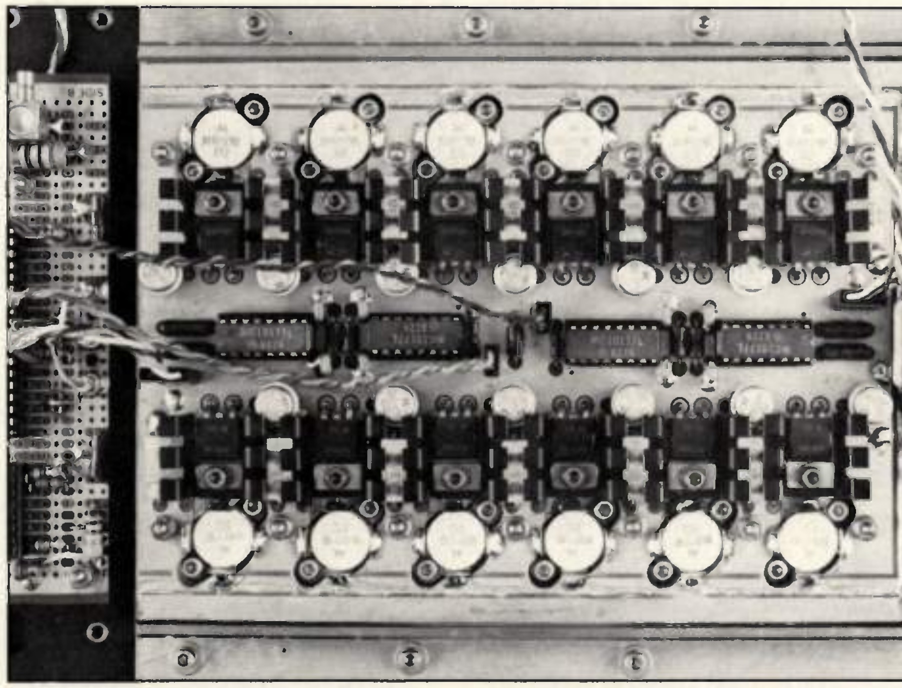


GaAs digital ICs operate to 3 GHz and higher, with many RF-related applications. They also require RF microstrip design techniques for interconnection, as seen in the evaluation kit on the right.

potential for RF-related applications. Another new development is the military-sponsored very high speed integrated circuit (VHSIC) program, which has begun to develop products for digital signal processing applications.

Finally, digitally-controlled analog switches, which can pass VHF signals and switch at similar rates, are being constantly improved. Switched-capacitor filters using the same technology are moving from the audio range to HF, where laboratory models have operated up to 10 MHz, promising performance and precision at lower cost than LC filters.

RF design using digital circuitry and techniques has only begun to discover its potential! With all these possible ways to use digital devices, the RF engineer has a great deal of information to keep on top of. With many engineers moving into RF-related jobs as the direction of the electronics industry changes, those with a digital background will have expertise to share with their analog design colleagues while they develop their own analog skills. rf



This prototype Class D amplifier operates up to 15 MHz with an efficiency of 65%, using ECL ICs to control the input drive pulses.

Simple Approaches to Limiting Radiation from Foil-Shielded Computer Cables

By Howard C. Rivenburg, and
John Juba, Jr.
Atlantic Research Corp.

Electromagnetic (EM) susceptibility has typically been a difficult problem in the development of high-reliability communication, navigation, and electronic warfare equipment. Military EMI requirements can be ten times more stringent than commercial standards. These military requirements result from two prime factors. The first is that, in a typical military communications center, the equipment is installed close together creating a worse-than-normal EM environment. The second is to assure reasonable equipment immunity to a potential hostile environment due to electronic countermeasures.

The military susceptibility standard, MIL-STD-461B, outlines most government electromagnetic interference (EMI) requirements. This document is augmented by MIL-STD-462 which describes acceptable testing procedures. Some equipment must also comply with TEMPEST requirements, part of a classified U.S. government security program dealing with controlling the emission and detection of energy from communication and data processing equipment which could reveal classified information being processed by the equipment. All too often, TEMPEST guidelines for equipment installation and interconnection are considered adverse to typical installation criteria.

MIL-HDBK-419, although not a TEMPEST specification, contains equipment and cable shield grounding recommendations which are highly compatible with the TEMPEST guidelines and represents a more modern approach to facility design. This document clearly states that the only differences in grounding techniques between those employed at facilities processing national security related information and any other facility are the grounding configurations used to terminate cable shields. These configurations are applicable when the equipment involved is referenced to an equipotential ground plane.

Although the majority of MIL-HDBK-419 deal with design considerations for new facilities, implementation of recommended installation techniques in existing facilities is also described. Concerning the ground systems installed in most existing facilities, this standard states, "...While these systems generally do not meet today's standards and requirements, they will continue to be in use for many years at existing facilities. Information on and description of these systems is therefore included for maintenance purposes only...Any major building or facility rehabilitation should include upgrade of the grounding system to include use of the equipotential plane..."

Relating cable shield grounding configurations to the use of a facility equipotential ground plane is fundamental to reducing EM radiation from interface cabling. With this concept in mind, a test setup was designed to study what standard approaches to EM radiation reduction could easily be implemented at older communication facilities.

Test Setup

The test configuration was developed with the intent of establishing a controlled, easily varied test setup. The approach chosen was to enclose a line driver unit, a line receiver unit, and system power supply in a shielded enclosure along with a cable under study. Manual scanning with a receiver system was chosen over a spectrum analyzer because a greater resolution of the E-field radiation profile was desired. The line driver and line receiver units were secured to a copper-clad test bench bonded to the walls of the shielded enclosure. This test bench acted as the equipotential plane of the test setup. The parameters to be varied during the course of testing were 1) the presence or absence of a line-terminating resistor, 2) the cable shield terminations, and 3) the use of filterpin connectors versus non-filterpin connectors.

Two computer I/O cables were chosen for the study as cables typically used in a communications center. The first cable tested contained 13 pairs of stranded wire (not twisted pairs). The cable had only a single foil shield with a stranded drain wire surrounding the wire conductors. The second cable had 27 twisted wire pairs which were each shielded with foil and had individual stranded drain wires. In addition, the 27 pairs and their shields were collectively shielded by an overall cable shield of foil with a drain wire.

In order to test the effectiveness of different configurations of shield terminations, the I/O cable needed to carry digital data of a standard format. For this purpose, a line driver unit and a line receiver unit were constructed in small RF-tight boxes. The line drivers and line receivers used meet the requirements of EIA Standard RS-422. (Balanced transmission of data was chosen because of the greater noise immunity.)

System Grounding

Inside the line driver unit, three pieces of stranded wire connected the filtered Common of the power supply to the inside of the box, to circuit ground on the board, and to the conductors designated as Common from the multi-pin connectors. Inside the line receiver unit, a piece of stranded wire connected the Common cable conductor (at the card-edge connector) to the box. The line driver unit and the line receiver unit were each placed on insulating material on top of the copper test bench, and grounded to the bench by 0.5-inch ground straps.

The cable shields were to be grounded at the line driver and/or line receiver units' bulkheads. Because of the foil-shielded

construction of the cable, drain-wire connections to ground considered to be the simplest termination mode available. A 3.5 cm drain wire length was used as a minimum pig-tail termination. The wire termination was then passed through the rear of the backshield to act as the shield ground termination. These shields, their drain wires, and the ground-wire connection were insulated with electrical tape so as to be isolated from the overall cable shield. 3.5 cm wires were also used at both ends of the overall cable shield and passed through the rear of the backshield for use as this shield's ground termination.

For the 26-line and the 55-line cable shields, tests were performed using various shield termination configurations with and without a matching resistor present. The tests were run using a 9.6 kbit/s data rate.

Use of Impedance Matching

The 26-line cable, having wire-pairs of unspecified characteristic impedance, presented a potential mismatch at the source end of the cable, as well as at the load end. In every test configuration, inclusion of a 100 ohm matching resistor (Z) provided at least a minor reduction of emanation levels. When filterpin connectors were used, the benefits of Z become less obvious. It is suggested that the characteristic impedance of the filterpins (10-100 ohms) placed at both ends of the cable predominates in the transmission line parameters by reducing the impedance mismatch at both ends of the cable.

The 55-line cable, whose wire-pairs are specified as having a 100 ohm characteristic impedance, presented a potential mismatch at the load end of the cable. Omission of the 100 ohm matching resistor generally resulted in higher level emanations with no noteworthy increase in frequency spread. When filterpin connectors were used, improvements arising from the inclusion of Z were less obvious. Again, it is believed that the characteristic impedance of the filterpins, imposed upon the cable prior to Z, reduces the impedance mismatch.

Shield Termination Results

When using the singly-shielded, 26-line cable, it was always best to ground the cable shield at both ends. A great deal of attenuation was forfeited by grounding only a single end of the shield. Some attenuation was noted at the high frequencies when non-filterpin connectors were used. However, any appreciable attenuation due to shielding effectiveness extended only to 6 or 7 MHz for the non-filterpin test cases. When filterpin connectors were used, attenuation of emanations by the shields extended only up to 0.3 MHz.

The shields of the 55-line cable were most effective when the two shields were grounded at both ends of the cable. When non-filterpin connectors were used, the influence of different shield grounding configurations were discernable up through 100 MHz. The effectiveness of shield grounding was predominant at frequencies below 6 MHz. Grounding a single end of the shields caused a loss of attenuation. Termination of the individual shields was most crucial, probably due to greater

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capacitive coupling between the shields and wire-pairs.

When filterpin connectors were used with the 55-line cable, shield grounding was especially important. The worst configurations were those where a shield was grounded at a single end and neither the overall cable shield, nor the individual shields grounded at both ends. These configurations actually resulted in enhancement of frequencies (from 0.2-2 MHz) over the unshielded profile.

Effect of filterpin connectors

Lowpass filterpin connectors proved to be the single most effective method of reducing unwanted emanations. No configuration of shield terminations was nearly as effective as the filterpins. Even with the shields ungrounded, major reduction of emanation levels and overall frequency spread were achieved through the use of filterpin connectors. From the ER shielding perspective, the advantages of this attenuation far outweigh the few disadvantages that surfaced.

From the systems perspective, the filterpin connectors are potentially undesirable in a balanced data transmission system where they may contaminate the system grounds with common-mode currents. While these currents were not actually measured, they seem to have been responsible for enhancement of emanations in some instances.

Aside from the reduction of emanations by filtering, another advantage of filterpins became apparent when the effects of an impedance matching resistor were studied. Emanations resulting from a potential impedance mismatch were reduced by the presence of filterpin connectors. The filterpins are specified as having a characteristic impedance between 10 and 100 ohms. Placement of this impedance at both ends of the transmission line-pairs tends to reduce the VSWR.

In the final analysis, the advantages of filterpin connectors far outweigh the disadvantages. With the proper shield configuration, the inclusion of filterpin connectors results in outstanding attenuation of unwanted emanations. The shielding effectiveness of any of these termination configurations is, however, based on the use of an equipotential ground plane as suggested in MIL-HDBK-419.

This article has been condensed from a paper presented at RF Technology Expo '86. The complete paper contains a detailed description of the test setup and methodology, as well as quantitative results of the various tests. The unabridged text may be found in the Proceedings of RF Technology Expo '86, *available from* RF Design.

About the Authors

Howard Rivenburg is a senior engineer in the Tempest/EMI Department of Atlantic Research Corp., and has been with that company for over seven years. John Juba, Jr., is a junior engineer in the same department, responsible for laboratory testing. They can be contacted at Atlantic Research Corp., 5390 Cherokee Ave., Alexandria, VA 22314.

A Passive Remote Control

By Harvey L. Morgan
TDC, Inc.

This month's column features the solution to a unique engineering problem: implementing controls without physical contact and without power to the controlling switches. Although the application described is for automotive use, the principle could be applied to many types of rotating devices, sealed rooms or containers, or for high voltage isolation.

On-off or digital commands can be implemented with passive (unpowered) remote controls by use of the technique described in this article. *Remote control* means no physical connection between control switch circuitry and output circuitry. The application for which this circuit was developed was control switches mounted on an automobile steering wheel, operating a cruise control. No power was available for controls, nor were sliding contacts or flexible connections between steering wheel controls and the cruise control unit permitted.

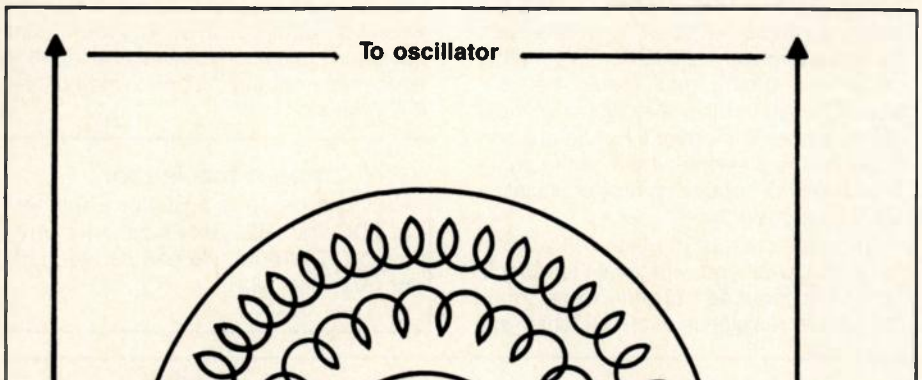


Figure 1. Cross-section of steering column, showing coupled inductors

The method developed and road tested uses the loading on an LC (inductance-capacitance) oscillator by another tuned circuit magnetically coupled to the LC circuit to indicate a "closed" switch condition. The LC oscillator normally operates at high amplitude. When a control switch on the steering wheel is closed, it connects a capacitor across a coil, forming a tuned circuit on a frequency at or near that of the LC oscillator. The steering-wheel coil (formed in an arc) is positioned close to the coil of the LC oscillator (Fig. 1). With the switch closed, energy is coupled to the steering wheel LC circuit loading the oscillator. The drop in oscillation amplitude indicates to the following circuitry that a control switch has been actuated. The logic circuitry determines which switch has been closed and provides an output to controlled circuitry.

At the junction of the inductance and capacitance in the oscillator, a high amplitude clean sinewave is produced. The coupling capacitor to the emitter follower is very small to minimize loading on the oscillator. The rectifier circuit is followed by a Schmitt trigger to convert the amplitude change due to oscillator loading to a logic-level swing (0 VDC to VCC).

The application requires more than one control switch, and associated with each control switch is a unique capacitor size. The LC oscillator is sequenced through alternate frequencies at a rate such that the probability of the closing of control switches going undetected is small. The drop in oscillation amplitude at a particular frequency is detected coincident with the driver state, to generate the particular control output.

One of the control switches tunes the passive coil to the oscillator normal frequency (transistor frequency switch turned off). The other control switch tunes the passive coil to the alternate frequency which occurs with the transistor frequency-control switch biased on (for a two-switch controller). The passive circuit loads the oscillator over about 5% frequency range with the loading (amplitude reduction) a function of the tuned frequency difference. The shifted LC oscillator frequency has to be outside that range to have a clear distinction between switch closures.

The number of control switches can be increased as long as corresponding frequencies can be accommodated. A number of transistor frequency-control switches can be sequenced by shift registers or counters. Decoding logic will also have to be correspondingly expanded and sequenced.

The frequency used in such a control system requires a careful choice. It should not be in the AM broadcast band, or any other frequency used for communication. The frequency used in the demonstration unit was about 20 kHz. Other design considerations include such things as the proximity of conductors to the locations of the coils, and the distance the LC oscillator coil can be separated from the oscillator circuitry. Low frequency operation will allow greater separation distance than higher frequencies, with distributed capacitance and line inductance the factors of importance.

The automotive application is a "natural" for this method. Not only can cruise controls be operated from the steering wheel, but other functions such as lights, turn signals, interior lights, radio on-off and tuning, etc., could be controlled by electronic rather than mechanical switches. The driver's hands are normally on the steering wheel, while dashboard controls require shifting of visual attention and reaching.

Switches used in the test unit were of the membrane type with tactile feedback. Since the induced currents were small, the contact resistance of the switches was no problem. The bulk added by these small controls was minimal.

For greater expansion of the system, two or more oscillators could be used with associated passive control circuits, with each oscillator having several frequencies. Combinations of two oscillators would provide six controls for three frequencies each, etc.

Figure 2 is a schematic of the control system used for the road tests. Latches were not required since they were internal to the cruise control, but other applications might require latches to maintain an ON condition. rf

About the Author

Harvey Morgan is a Senior Engineer at TDC, Inc., 621 Six Flags Drive, Arlington, TX 76011. He can be reached at (817) 649-4631.

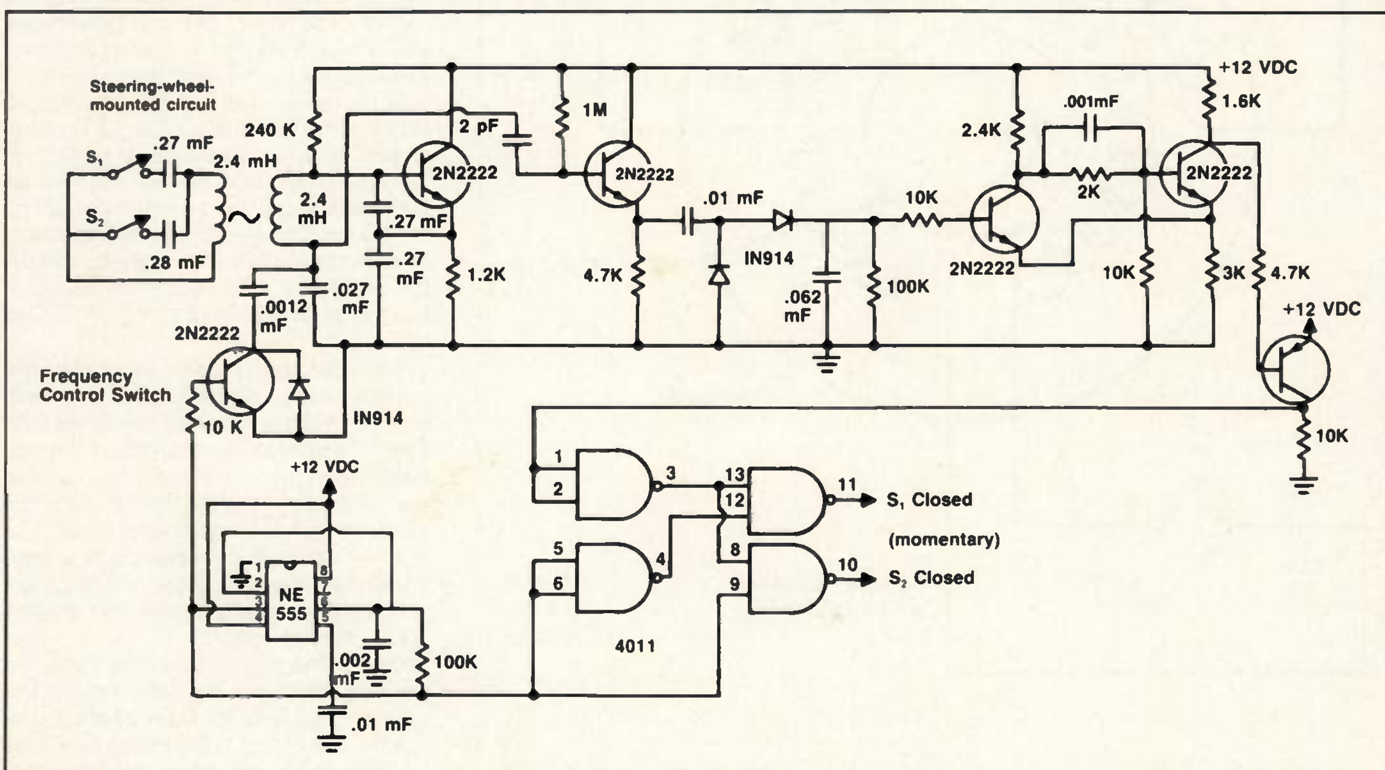


Figure 2. Circuit diagram: Passive remote control

New Products Featured at RF Technology Expo '86

Hewlett-Packard Introduces Network Analyzer at RF Expo '86

Hewlett-Packard — Booth 1001.

The new HP 8753A RF vector network analyzer covers 300 kHz to 3 GHz, measures magnitude and phase of transmission and reflection, and group delay. Resolutions are 0.001 dB, 0.01 degree, 1 ps. A built-in synthesized signal source has 1 Hz frequency resolution and +20 dBm output. Additional features include error-corrected measurements in real time, built-in limit testing and optional time-domain capability. Additional new products from Hewlett-Packard include the HP 8770S Arbitrary Waveform Synthesizer, the HP 3577A 5 Hz-200 MHz Network Analyzer, and the HP 5386A 3 GHz prescaled Frequency Counter.

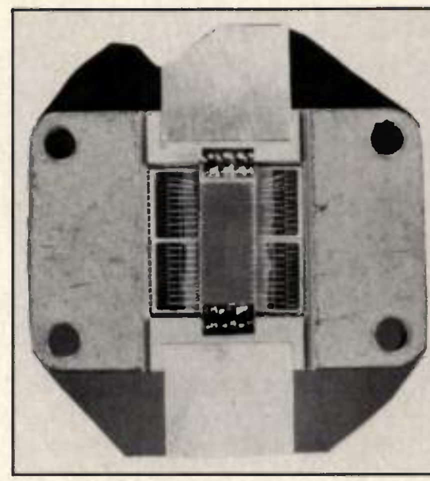
Two new EMI-related products from HP are the HP 11940A Close-Field Probe and the HP 8573A Automatic EMI Receiver/Spectrum Analyzer. **Hewlett-Packard, Palo Alto, Calif. INFO/CARD #176.**

600 W HF Transistor

Motorola — booth 403

Motorola Semiconductor Products announces the MRF430, a 600 watt bipolar RF power transistor for operation from 2-30 MHz. With 10 dB minimum gain (15 dB typical PEP gain), the MRF430 is designed for high power base station linear amplifier applications, and requires only conventional cooling.

Other new devices include the MWA0211, a monolithic IC amplifier in a surface-mount package, and its MACRO-X package counterpart, the MWA0204. Another



surface-mount device from Motorola is the MRF8372, an SO-8 packaged version of the MRF837, offering 0.75 watts output and 8 dB gain at 870 MHz. **Motorola Semiconductor Products, Phoenix, Ariz. INFO/CARD #175.**

RF Hazard Monitor

Holaday Industries — booth 419

Holaday Industries model HI-3500 Broadband RF Hazard Monitor can be mounted in critical areas to sense RF exposure. The monitor provides a relay clo-

sure output for operation of an external alarm when a preset trip point has been exceeded. **Holaday Industries, Inc., Eden Prairie, Minn. INFO/CARD #154.**

Power Meter and Counter

Bird — booth 112

The Bird model 3900 is a new product that provides RF power measurement employing the same elements used in the Bird model 43 wattmeter. The model 3900 also includes a frequency counter providing ±1 PPM accuracy from 5 MHz to 1 GHz. It can be powered from 110/220 VAC as well as its own internal rechargeable batteries.

Another new product, the Bird 4380A-488 provides a digital interface between

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the Bird RF Power Analyst and an IEEE 488 bus for remote readings of forward and reflected power in a 50 ohm transmission line as well as VSWR, modulation percentage (AM) and minimum/maximum power excursions. **Bird Electronic Corporation, Cleveland, Ohio. Please circle INFO/CARD #174.**

6060B Signal Generator

Fluke — booth 102

John Fluke Mfg. Co., Inc., introduces the 6060B programmable, general-purpose signal generator, enhancing and replacing the Fluke 6060A. The 6060B has a wider output frequency range, starting at 10 kHz for VLF and LF applications. The output extends up to 1050 MHz.

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Continued

Guaranteed amplitude accuracy is now ±1.0 dB from +13 dBm to –127 dBm. Standard features for the 6060B include non-volatile memory for 50 instrument settings, reverse power protection up to 50 watts, and an external reference imput. Options include ovenized reference oscillator and IEEE-488 interface. **John Fluke Mfg. Co., Inc., Everett, Wash. Please circle INFO/CARD #173.**

Hybrid Oscillator — Sawtek — booth 911

Sawtek Inc. is introducing a hybrid oscillator which operates at the fundamental IFF operating frequency of 1030 and 1090 MHz. The new hybrid oscillator uses advance L-band SAW resonators to obtain the lowest SSB phase-noise, spurious content and power consumption. It is available in 18-pin DIP plug-in package or surface mountable flatpacks. The oscillator is designed to meet all MIL-STD-883, Method 5008 Class B and Class S requirements. **Sawtek, Inc., Orlando, Fla. INFO/CARD #172.**

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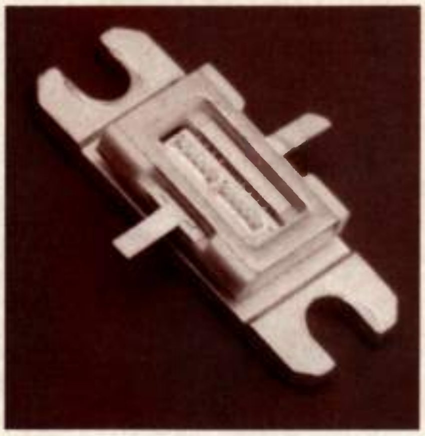
TAKE A REAL CLOSE LOOK AT FUJITSU'S GaAs FET LINE-UP FOR L AND S-BAND



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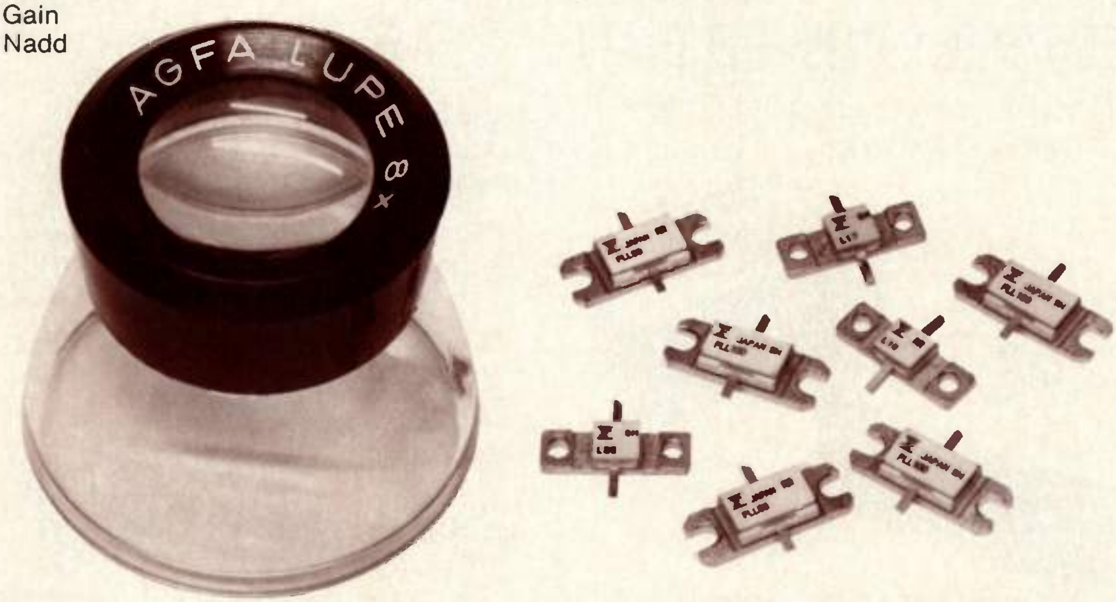
Selection Guide

Part No.	Package	Electrical Characteristics ($T_a = 25°C$)						R_{th} TYP. (°C/W)
		P_{1dB} TYP. (dBm)	G_{1dB} TYP. (dB)	η_{add} TYP. (%)	f (GHz)	V_{DS} (V)	I_{DS} (mA)	
FSC10LF	LF	10.0*	12	—	4.0	3.0	10	—
FSC11LF	LF	16.0	17	—	4.0	4.0	30	—
FSX51WF	WF	18.0	14	—	4.0	8.0	30	120
FSX52WF	WF	23.0	14	—	4.0	8.0	75	70
FLL10ME	ME	28.5	12	45	2.3	8.5	175	35
FLL17ME	ME	31.5	11	43	2.3	8.5	350	20
FLL35ME	ME	34.5	10	42	2.3	8.5	700	11
FLL50MK	MK	36.0	10	40	2.3	10.0	900	7
FLL100MK	MK	39.0	8	37	2.3	10.0	1800	4.5

*Tuned for best noise figure, NF = 0.6dB and Ga = 13dB.



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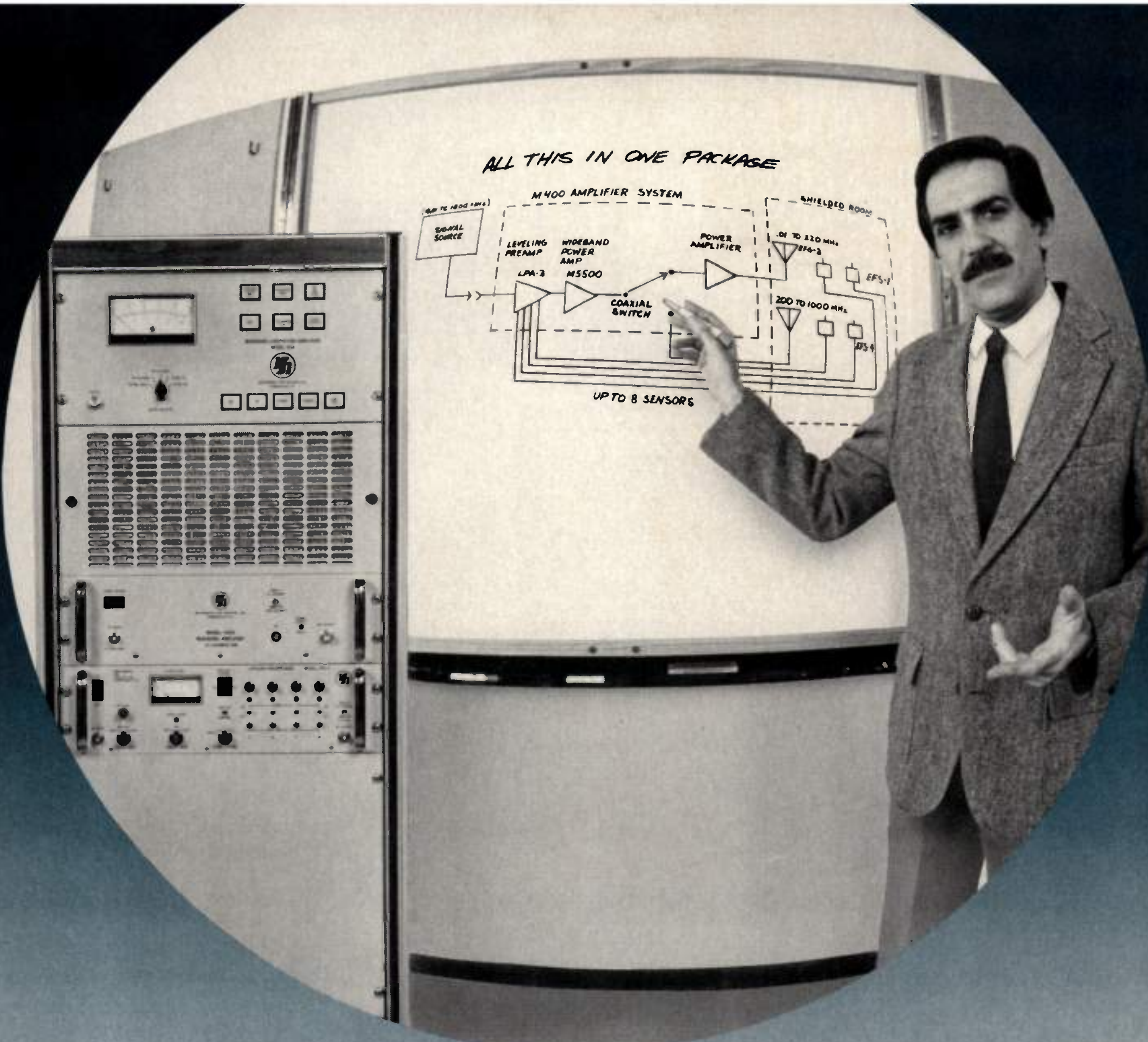

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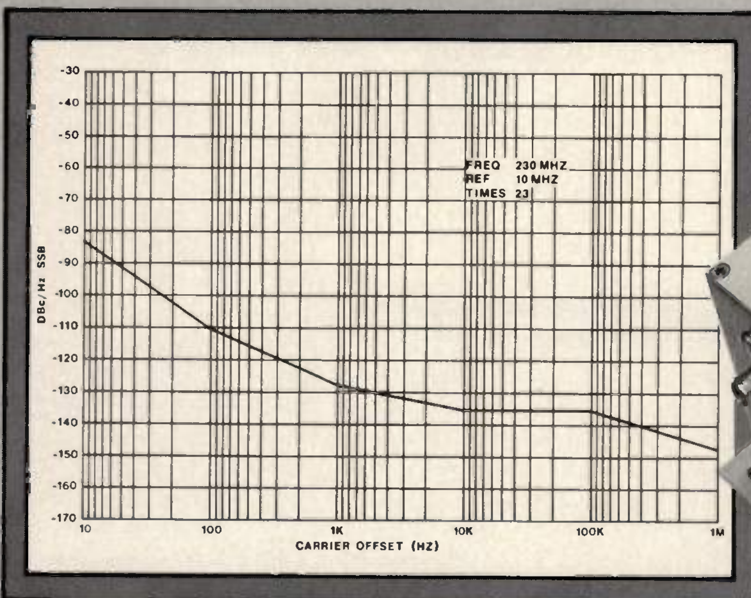

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Techtrol Cyclonetics Inc.

815 Market Street New Cumberland, Pennsylvania 17070

(717) 774-2746

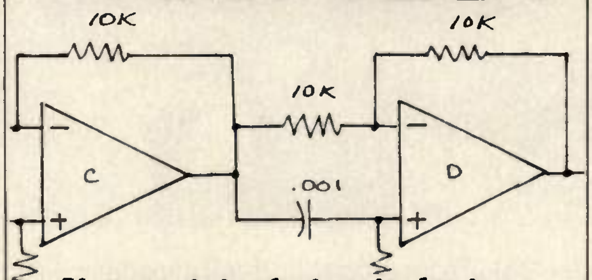
See us at the **RF Technology Expo 86,** Anaheim, California,
January 30-February 1
Booth 209

Design Contest

Sponsored by *RF Design* magazine

Enter your original circuit design in the first Design Contest sponsored by *RF Design*. The winning design will be featured in the July 1986 issue of *RF Design*, and will receive an HP 41CX calculator, courtesy of Hewlett-Packard, plus a recognition plaque. Other top designs will receive recognition plaques and several will be published in the "Designer's Notebook."

WANTED!



Your original circuit design

Judging criteria include originality of concept, imaginative application of design, significant cost or labor savings, elegance, exceptional performance, usefulness, clear description of function and reproducibility. All circuit components must be available for purchase. The designer must be able to document that the circuit operates and performs as decribed.

DEADLINE FOR ENTRIES is April 15, 1986. Send your entries to: *RF Design*, 6530 S. Yosemite St., Englewood, CO 80111.

Contest Rules

1. Design must be an active RF circuit, from VLF to UHF. Active circuit is defined as one that introduces gain or has a directional function, i.e., an amplifier, oscillator, mixer, modulator or demodulator.
2. Design must be original work, not previously published.
3. If the design develops from the entrant's employment, the employer must give permission to enter it.
4. The design must contain a complete description and parts list.
5. Complete schematic diagram and any other necessary photos or drawings must be included.
6. All components must be available for purchase.
7. Patent or copyright infringement will disqualify the design.
8. Entries must be received by April 15, 1986. Mail to: *RF Design*, 6530 S. Yosemite, Englewood, CO 80111.

Contest will be conducted in accordance with all applicable laws and regulations.

G & H Technology

ELECTROMAGNETICS LABORATORY

For over a decade, G&H Technology has been a leader in the development of EMP hardened and/or EMI shielded electromechanical components. The knowledge gained from this experience has been employed in the establishment of our advanced Electromagnetics Testing Laboratory in Camarillo, California.

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- Design Control Plans
- Engineering and Qualification Testing to TEMPEST requirements
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- Testing Per Mil-Std 285 and Mil-Std 461-462
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- Test Reports
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INFO/CARD 65

Fast-Switching Synthesizer

Comstron — booth 312

Comstron's new FS-2000 is the first synthesizer to combine ultra-fast switching and low phase noise over a wide frequency range. Comstron's frequency plan (patent pending) permits direct analysis synthesis over an octave range. The unit covers the frequency range of 10 MHz to 4 GHz in 1 Hz steps (.1 Hz steps optional) and can switch between any two frequencies in less than 1 μs with no exceptions. The FS-2000 is unique in that larger step size has faster switching speed, with 1 GHz steps typically taking 200 ns or less. Phase noise rivals that of the cleanest phase lock loop synthesizers. A parallel BCD interface is provided, with an optional IEEE-488 interface also available. **Comstron Corporation, Freeport, N.Y. INFO/CARD #171.**

RF Switch Control Unit

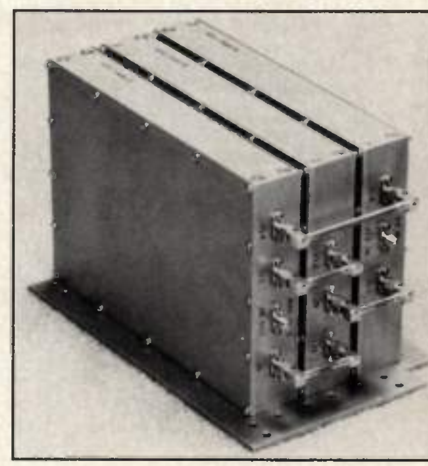
K&L — booth 518

K&L Microwave Inc. announces a new 18 position RF Switch Control Unit. With automated testing in mind, this unit interfaces with a computer to remotely switch up to 18 devices cabled to the unit. This unit is particularly useful when cycling components through environmental tests such as vibration and temperature where the devices are held on or within special chambers or ovens. Switch specifications include 1.5:1 maximum VSWR from DC to 18 GHz, insertion loss of 0.5 dB maximum from DC to 18 GHz, and isolation >60 dB through 18 GHz. Communication with controlling computer is through the standard IEEE-488 interface bus. **K&L Microwave Inc., Salisbury, Md. Please circle INFO/CARD #170.**

New Modem Synthesizer

Sciteq — booth 921

Sciteq announces the VDS-1400-70, a new frequency synthesizer designed specifically for modem applications. It covers 50 to 90 MHz in 1 Hz steps, with



5 msec switching, excellent spectral purity, and the ability to support even those modems that operate at very low bit rates. Depending on required performance, the product can be built as either two or three modules, each only 4" × 6" × 1". Options include resolution to 1 MHz, phase rotation and modulation in .36° increments, broader bandwidth, and miniaturization. In modest quantities, unit price is below $1,500. A complete instrument with IEEE-488 control is under $3,000. **Sciteq Electronics Inc., San Diego, Calif. Please circle INFO/CARD #169.**

SAW Filter Bank

Andersen Labs — booth 317

The filter bank consists of a series of switchable surface acoustic wave (SAW) bandpass filters preceded by a rooting filter and an amplifier and followed by another rooting filter. SAW filters can be arranged either contiguously providing instantaneous broadband coverage combined with narrow based signal sorting, or by centering the filters at various bandwidths. At a single frequency adaptive processing can be done to compensate for changes in the signal environment.

Andersen is also introducing a compressive receiver for real-time signal analysis and identification, using linear dispersive SAW delay lines. **Andersen Laboratories, Inc., Bloomfield, Conn. INFO/CARD #168.**

Optimic™ Program

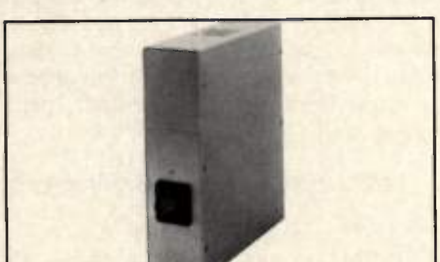
Summit Technology — booth 203

Summit Technology announces Optimic, a low cost, high performance optimization program for Microwave and RF circuits. Optimic is available for the Apple II and IBM PC computers. **Summit Technology, Los Gatos, Calif. Please circle INFO/CARD #167.**

Coaxial Relay Matrix

Matrix Systems — booth 310

A miniaturized, wide bandwidth 8 × 8 matrix switching configuration with a frequency response of DC-500 MHz is introduced by Matrix Systems Corporation. Designated Model 4108, the compact,



lightweight module weighs only 1.5 lbs. and measures 6"L × 7.2"H × 2.2"W. It is completely self-contained, requiring the user to supply only TTL control signals and +5 VDC power through dual-edge connectors. Model 4108 modules are priced at $3,200 in 1-9 quantities and at $3,075 in

10-24 quantities. **Matrix Systems Corporation, Calabasas, Calif. INFO/CARD #165.**

"CADEC-4"

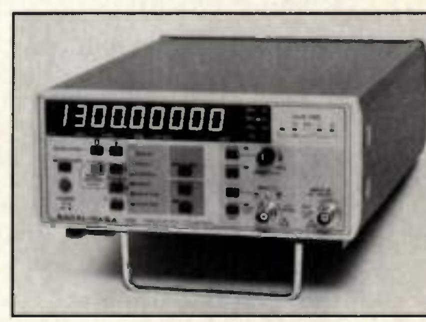
Communications Consulting Corp. — booth 803, 902

A new, expanded version of the popular circuit analysis program, "CADEC-4" offers expanded microwave modules, with complete nodal circuit noise analysis and a two-times speed improvement over previous versions. "CADEC-4" is for the Hewlett-Packard series 9000 computers. **Communications Consulting Corp., Upper Saddle River, N.J. INFO/CARD #166.**

1.3 GHz Frequency Counter

Racal-Dana — booth 709

A high-speed, high-resolution frequency counter has been introduced by Racal-Dana Instruments, Inc. The half-rack-sized Model 1998 features nine-digit resolution in one second over the entire 10 Hz to 1.3 GHz frequency range. Displayed resolu-

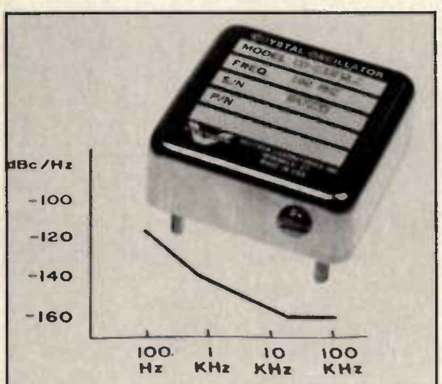


tion may be varied from three to ten digits depending on the degree of resolution and speed of measurement required. Optional GPIB (IEEE-STD-488) capability provides full programmability for front panel function keys and signal conditioning controls. For maximum stability a standby power mode ensures that continuous power is applied to the frequency standard. **Racal-Dana Instruments, Inc., Irvine, Calif. INFO/CARD #164.**

Low Noise Crystal Oscillator

Vectron — booth 811

Vectron has introduced a series of crystal oscillators with noise floor below −160 dBc/Hz. Series CO-233L2 is available at any frequency in the 5-200 MHz range. It provides an aging rate of 2 ppm per year and is available with several stability options ranging from ±3 ppm over 0°C/50°C to ±50 ppm over −55°/+125°C. Its initial accuracy at 25°C is ±10 ppm but



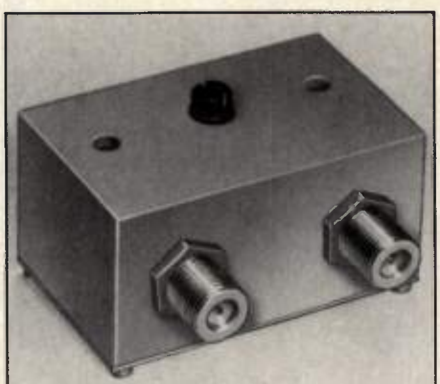
a tuning option permits setting to ±1 ppm. Output level is +7 dBm over 50Ω with +13 dBm optionally available.

Vectron also announces the new CO-404V Hybrid DIP VCXOs specifically designed for phase-locking applications from 25-70 MHz. **Vectron Laboratories, Inc., Norwalk, Conn. INFO/CARD #163.**

Variable Attenuator

Alan Industries — booth 804

Alan Industries announces their model 50CAL20, a 75 ohm continuously variable attenuator for the 50-800 MHz frequency range. Minimum attenuation is 20 dB with



an accuracy of ±3 dB over the frequency range. The unit is available with either BNC or F connectors. **Alan Industries, Inc., Columbus, Ind. INFO/CARD #162.**

Super-Compact PC 3.0

Compact Software — booth 803, 902

Super Compact PC version 3.0, a new version of the popular Compact PC series, is announced by Compact Software. This version offers all of the features of the mainframe-based Super Compact software. **Compact Software, Paterson, N.J. INFO/CARD #161.**

SMD Mixers

Synergy Microwave — booth 803, 902

Synergy Microwave announces new commercial SMD (surface-mounted) mixers, offering all of the features of

Synergy's line of SMD mixers in a low-cost package suitable for high-quality commercial applications. **Synergy Microwave, Paterson, N.J. INFO/CARD #160.**

New Software

EEsof — booth 503, 602

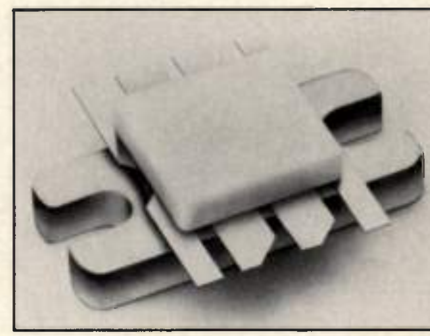
EEsof, Inc., announces several new programs and enhancements to their existing program line. *Synthesis* is a program for lumped matching networks, filters and multiplexers. *Touchstone Sr.* adds user-defined elements and customization flexibility to all of Touchstone's capabilities. The *Touchstone/VAX Connection*™

combines PC workstation operation with simultaneous simulations and optimizations on a VAX mainframe. *Microwave Spice* is a superset of Berkeley Spice 2G, with added interactive user capabilities, and an S-Parameter file which is readable by Touchstone. **EEsof, Inc., Westlake Village, Calif. INFO/CARD #158.**

RF Power Transistors

M/A COM PHI — booth 903

Headlining new RF power transistors from M/A COM PHI, Inc., is the UF28100V DMOS FET offering 100 watt output at fre-

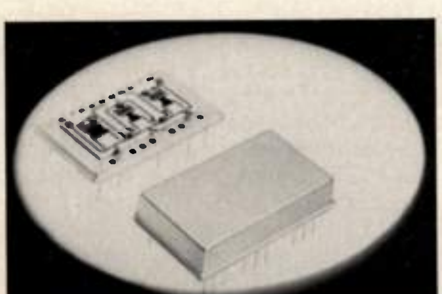


quencies up to 400 MHz with 55 percent efficiency and 12 dB power gain. Other new devices from M/A COM PHI include the PHO105-100 push-pull pair with 100 watt output up to 500 MHz, and the PHO104-125 with 125 watt up to 400 MHz. In the 1200-1400 MHz range, the new PH1214-60 and PH1214-30 offer 60 watt and 30 watt, respectively, with internal matching at both input and output. **M/A COM PHI, Inc., Torrance, Calif. Please circle INFO/CARD #157.**

Thick Film Attenuators

KDI Electronics — booth 1013

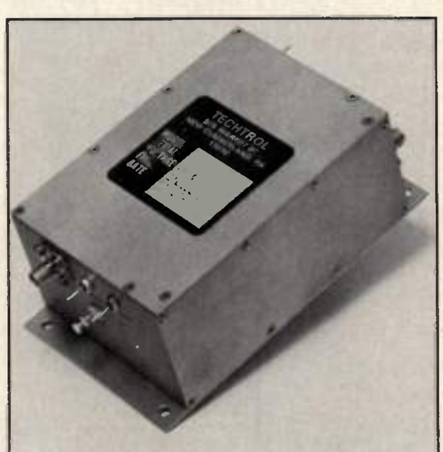
KDI Electronics is expanding its line of thick film products to include new 2 GHz digital attenuators in hermetic plug-in packages, plus surface-mount digital attenuators and other components up to 5 GHz. KDI also features custom thick film subassemblies with switches, dividers, attenuators, logic and control circuitry. **KDI Electronics, Inc., Whippany, N.Y. Please circle INFO/CARD #156.**



Synthesizer/Multiplier

Techtrol — booth 209

Techtrol Cyclonetics Inc. (TCI) announces the PLX6000 low-noise synthesizer/multiplier, using both analog and digital synthesis techniques to achieve the lowest possible noise output signal. The PLX6000 is available with integer or fractional multiplication, and single or multiple frequency operation. **Techtrol Cyclonetics, Inc., New Cumberland, Pa. INFO/CARD #159.**



Low Cost Transistors

California Eastern Labs — booth 124

NEC is now producing two new low cost silicon bipolar transistors in large volume, the NE680 and NE681, designed for both low noise/high gain amplifiers and oscillators. The NE680 is suitable for UHF, VHF, and microwave amplifiers from .5 to 6.0 GHz, while the NE681 is well-suited for the range of .5 to 4 GHz. At 2 GHz, the NE 680 and NE681 have low noise figures of 1.7 and 1.6 dB and associated gain of 12.5 and 12.0 dB, respectively. Both the NE680 and NE681 are also available as surface mount, low cost plastic and hermetic micro-x packages as well as chip form. **California Eastern Labs, Santa Clara, Calif. INFO/CARD #134.**

SMD Soldering Kit

An experimental soldering kit with a variety of tip sizes and shapes to fit most popular SMD packages is available from Hexacom Electric Company. The new kit

permits industrial engineers to experiment with hand soldering, desoldering and rework techniques for SMD printed wiring boards without a large investment. The kit is also valuable for field service repair work. Included in the kit are tip sizes and shapes for use on the popular size 1206 chip components, SOT-23 transistors, and SOIC packages. **Hexacom Electric Co., Roselle Park, N.J. INFO/CARD #153.**

4000 MHz Signal Generator

Colby Instruments, Inc. introduces the SG 4000A, specifically designed as an ideal driving source for their new 4000 MHz pulse generator, Model PG 4000A, because a phase-coherent subharmonic trigger pulse is made available. The SG4000A signal generator can be used quite independently for other applications which call for low-cost microwave signal.

The frequency range is 10 MHz to 4000 MHz in 12 bands. Output amplitude is +13 dBm, internally leveled to 0.5 dBm. Output amplitude is directly displayed to within 0.1 dBm. Harmonic Distortion is −26 dBc or better. Price is $2,990 to 2000 MHz and $4,950 to 4000 MHz (option 1). **Colby Instruments, Inc., Los Angeles, Calif., INFO/CARD #152.**

L-Band Power Divider

Sage Laboratories, Inc. has developed a new low loss, L-Band 3-way power divider for a specialized application. The Model FP3777 was designed to operate at 1090 MHz, and features a VSWR of 1.3:1 maximum with peak to peak amplitude unbalance of 0.3 dB maximum. Phase unbalance is 1° maximum, and

isolation between outputs is 20 dB minimum. **Sage Laboratories, Inc., Natick, Mass., INFO/CARD #151.**

Coaxial Power Terminations

As an extension to the existing product line of coaxial terminations, Suhner now

offers power terminations with 6, 15, 25, 50 and 60 watt continuous power rating. Depending on power rating and connector, these terminations are specified and tested up to 2, 5, 10 or 12.4 GHz. Six different connectors are available. **Huber & Suhner Ltd., Herisau, Switzerland, please circle INFO/CARD #150.**

Silicone Rubber RFI/EMI Shielding

Silicone rubber molded and extruded products with a volume resistivity as low as .002 ohm-cm can be provided by Moxness Products, Inc. For use in RFI/EMI shielding applications silicone rubber can be formulated as carbon filled, silver-plated filled and pure silver filled to achieve specified resistivity and conductivity levels. Tubing can take almost any form required — round or oval, large or small, heavy or thin walls. **Moxness Products, Inc., Racine, Wis., please circle INFO/CARD #149.**

Diamond MICutter

A.P. Microwave announces a new high performance direct circuit cutter on rubylith for HP Plotters HP7580/85, HP7470/75 and HP9872. It is ideal for use with MICAD, AUTO-ART, EMG and other MIC CAD software programs. Price: $149.50 (1-9). **A.P. Microwave, Sunnyvale, Calif., INFO/CARD #148.**

High Reliability RF Switches

Internal termination of each unused or open port is now available on nearly all models of the ultra-high-reliability RF switches recently introduced by the Wavecom Division of the Loral Corporation. With this option, each such port of these multi-position electromechanical switches is internally and independently terminated in a 50-ohm (5w CW) resistive load, ensuring the isolation and power matching needed for critical low-noise and stable signal applications. The SP2T switch covers the frequency range from DC to 26.5 GHz, the SP3T to SP8T models operate up to 23 GHz, and the 2P2T models up to 24 GHz. **Wavecom, Northridge, Calif., INFO/CARD #147.**

Telemetry System

The General Instrument NSL-1017 Telemetry System is a battery powered, 40-channel, portable telemetry system designed for short range analog and digital data transfer and recording, particularly in the presence of high level RF interference. Although the NSL-1017 was developed to support the U.S. Navy's HERO (Hazards of Electromagnetic Radiation to Ordnance) program, it is useful in any application where remote sensing of analog or digital data is required. The system is provided with both RF and fiber optic link capability. **General Instrument, Northern Scientific Laboratory, Fairchild, N.J., INFO/CARD #143.**

Laser Machining Service

Coors/Ceramics, a subsidiary of the Adolph Coors Company, now provides full laser machining services to hybrid substrate users. The new Coors' laser services include scribing, cutting, contouring, and hole drilling for simple to complex shapes in numerous ceramic substrate materials. Coors' inventory of ADS-86R, ADS-995 and ADOS-90R (opaque) substrates allow the ceramic substrate manufacturer to provide 2 to 4 weeks delivery. Faster delivery is also available upon request. **Coors/Ceramics,**

Ga As FET Amplifiers For Communications, Radar and EW

*Many Models Available For Off-The-Shelf Delivery!**

MAJOR FEATURES:

- 100 MHz - 18 GHz
- Noise Figure as Low as 0.9 dB
- Medium Power Available
- MIL-STD 883
- Hermetically sealed packages
- Phase and Gain Matching Optional

MODEL NUMBER	FREQUENCY	GAIN (MIN.) (dB)	GAIN VARIATION (MAX.) (± dB)	NOISE FIGURE (MAX.) (dB)	VSWR (MAX.) IN/OUT	1dB COMP PT. (MIN.) (dBm)	SIZE (INCHES) L x W x H
To 4 GHz							
CP12932	.5 - 2.0	18	1.0	3.5	2.0:1	+20	3.25 x 1.5 x .85
*CP12933	.5 - 2.0	27	1.0	3.5	2.0:1	+20	3.25 x 1.5 x .85
CP12934	.5 - 2.0	36	1.0	3.5	2.0:1	+20	3.25 x 1.5 x .85
C15603-9	1.0 - 2.0	30	1.0	1.3	2.0:1	+10	1.64 x .76 x .26
C15613-8	1.0 - 2.0	30	1.0	1.8	2.0:1	+10	4.75 x 1.75 x 1.0
*C30634	2.0 - 4.0	30	1.0	2.5	1.5:1	+10	4.75 x 1.75 x 1.0
C32524	2.4 - 4.0	40	1.0	2.6	2.0:1	+15	4.75 x 1.75 x 1.0
*C25923-1	1.0 - 4.0	17	1.0	5.0	2.0:1	+15	4.75 x 1.75 x 1.0
To 8 GHz							
C40943	2.0 - 6.0	25	1.0	4.5	2.0:1	+10	1.64 x .76 x .26
C50423	4.0 - 6.0	30	0.5	2.5	2.0:1	+10	3.0 x 1.2 x .46
C60632	4.0 - 8.0	18	1.0	3.5	2.0:1	+10	1.23 x 1.2 x .67
C60633	4.0 - 8.0	28	1.0	3.5	2.0:1	+10	2.05 x 1.2 x .67
C60634	4.0 - 8.0	38	1.0	3.5	2.0:1	+10	2.05 x 1.2 x .67
To 12 GHz							
C100452	8.0 - 12.0	20	1.0	5.5	2.0:1	+10	2.05 x 1.2 x .67
C100453	8.0 - 12.0	30	1.0	5.5	2.0:1	+10	2.05 x 1.2 x .67
C100454	8.0 - 12.0	40	1.0	5.5	2.0:1	+10	2.87 x 1.2 x .67
To 18 GHz							
C150462	12.0 - 18.0	20	1.0	6.0	2.0:1	+10	2.05 x 1.2 x .67
C150463	12.0 - 18.0	30	1.0	6.0	2.0:1	+10	2.87 x 1.2 x .67
C150464	12.0 - 18.0	40	1.0	6.0	2.0:1	+10	2.87 x 1.2 x .67
NARROW BAND — VERY LOW RANGE							
*C19513	1.4 - 2.4	30	±1.0	1.6	1.5:1	+10	4.75 x 1.75 x 1.0
*C14013	1.43 - 1.54	30	±0.5	1.1	1.5:1	+10	4.75 x 1.75 x 1.0
*C22103-9	2.2 - 2.3	30	±0.5	0.9	1.5:1	+10	4.75 x 1.75 x 1.0
*C22113	2.2 - 2.3	30	±0.5	1.1	1.5:1	+10	4.75 x 1.75 x 1.0

Call factory for your special requirements.
Variations on noise figure and power output available.
Narrow band ultra low noise amplifiers available to 4.0 GHz.

California Amplifier Inc.

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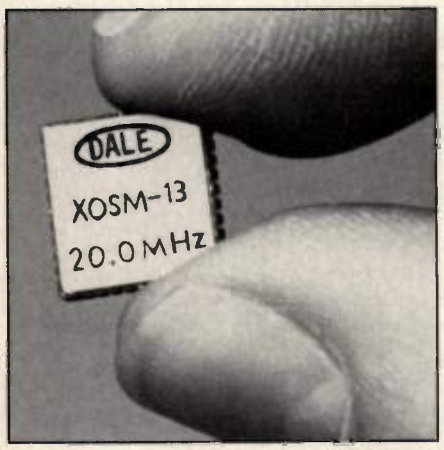
INFO/CARD 80

See us at the RF Technology Expo, booths #211 and 213.

Grand Junction, Colo., please circle INFO/CARD #142.

Surface Mounted Oscillator

A chip carrier style clock oscillator has been added to the line of surface mounted components available from Dale Electronics, Inc. Designated as the XOSM-13, the TTL compatible clock oscillator has a hermetically-sealed package and is available in a frequency range from 16 to 24 MHz. Information on other logics and frequencies available in this style can be obtained from the factory. Supplied in a 40 pin leadless chip carrier, the XOSM-13 occupies board space .480"W x .480"L x .085"H. It is hermetically sealed to meet MIL-Std-833, Method 1014 and is designed for reflow soldering. **Dale Electronics, Inc., Tempe, Ariz., please circle INFO/CARD #141.**



Coaxial Detectors

MIDISCO has introduced a Zero Bias Schottky Detector with precision 7mm (APC-7) input connector for use from 0.01 to 18 GHz. Model MDC1087-7 has a maximum VSWR of 1.2:1 up to 4.0 GHz and 1.4:1 up to 18 GHz. The broadband frequency response is ±0.3 dB to 8 GHz and ±0.5 dB to 18 Ghz. Low level sensitivity is >0.42mV/uW. The MDC1087 series also contains detectors in other connector configurations. **MIDISCO, Commack, N.Y., INFO/CARD #140.**

Axial Lead Inductors

The Robert G. Allen Co., Inc., introduces its new series of axial lead inductors. Available in a range of 0.1 to 4700 micro henry (uH), inductive tolerances are ±2.5, 5, 10, and 20 percent. These inductors are color coded, with packaging available in bulk, taped in boxes or reels. The new RGA inductors are direct replacements for the Taiyo Yuden "03", "04" series and TDK "SP0305/SP0406" series. Future production will include replacements for the Taiyo Yuden "02" series coil. **Robert G. Allen Co., Inc., N. Hollywood Calif., INFO/CARD #139.**

Microwave MIS Capacitors

This family of high quality metal-nitride-oxide-silicon capacitor chips can be used in circuits to greater than 18 GHz. Capacitance values of 1.5 to 50 pF are available and working voltages range from 50 to 200 volts. Die sizes are available in .015" square and .020" square with maximum possible pad sizes of .011" and .016" square respectively. A thick gold metal system is provided which is suitable for ribbon or wire bonding and eutectic or epoxy die attach. **Virtech, Los Gatos, Calif., INFO/CARD #145.**

Now that we have your attention, why don't you get our attenuators?

A recent production breakthrough allows us to offer attenuators at prices that are one third to one half less, for any quantity—even one at a time!

These price reductions apply throughout our lines of programmable attenuators, 50Ω and 75Ω turret attenuators and fixed attenuators. Frequency capabilities are DC to 1 or 2 GHz, depending on model.

So whether you're building OEM test instrumentation, military or commerical RF systems, or just putting together a benchtop setup, you'll find our new attenuator prices are impossible to turn down.

Programmable
Model 5P130
0 to 130 dB/10 dB steps
dc to 2 GHz, 50 ohms
$320 ea.

Rotary
Model 5070A
0 to 70 dB/10 dB steps
dc to 2 GHz, 50 ohms
$87 ea.

SMA Fixed Pad
Model A151
1 to 20 dB
dc to 2 GHz, 50 ohms
$9.85 ea.

TO-5 Micropads
1 to 20 dB
dc to 3 GHz, 50 ohms
$8.50 ea./$3.75 ea./1000 qty.

Especially when you consider that quantity discounts are available on top of the basic price reduction.

For detailed specifications and prices, phone Toll Free 800-851-1202. In Indiana, call 317/788-5975, or write Wavetek Indiana, Inc., 5808 Churchman, P.O. Box 190, Beech Grove, Indiana 46107 TWX: 310-687-6033. Telex: 6876033.

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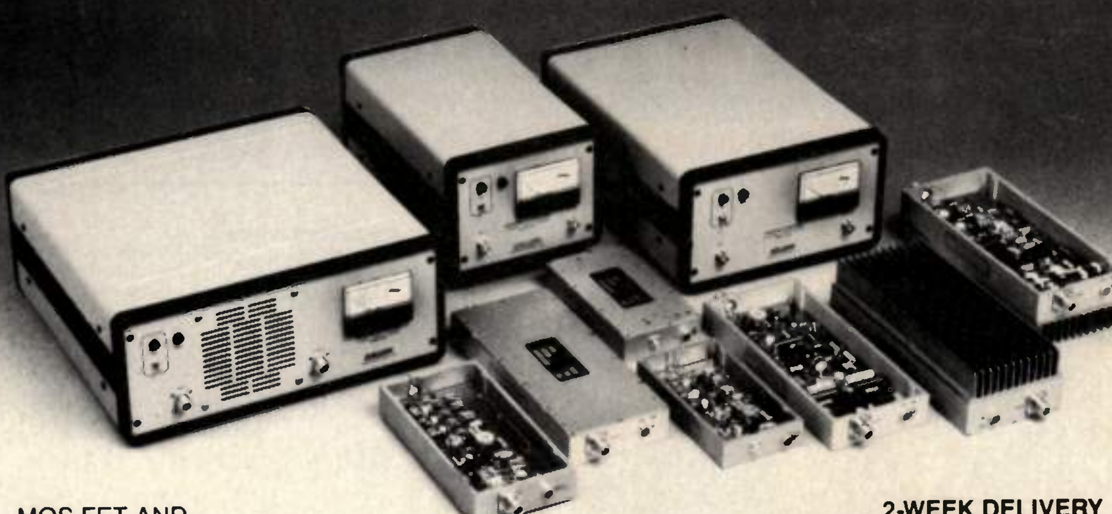
- Innovators in Solid State Design
- Superior Quality Construction



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**2-WEEK DELIVERY
MOST ITEMS IN STOCK**

A complete line of high quality RF Power Amplifiers designed for versatility and reliability. Choose from over 30 laboratory type AC instruments, or from more than 40 state-of-the-art DC modules for OEM or special project use. All modules are housed in "one-piece" solid aluminum machined RFI-proof enclosures for reliability and low leakage performance. Over 16 years of RF POWER design and manufacturing experience enable us to supply you with a combination of the very best amplifier system for your money and provide the know-how to quote you on your special requirements. If we don't have what you need, we'll design it! Send for your free amplifier catalog.

APPLICATIONS: NMR/ENDOR/ESR, Communications, Lab Test Equipment, Ultra Sonics/Sonar, RFI/EMI Testing, Accelerators, Medical Research.

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INFO/CARD 81

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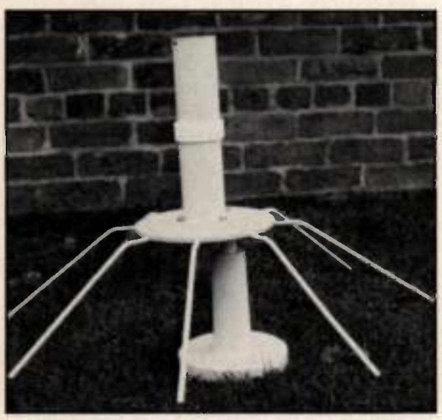
HP41 Emulator Software

Straightforward introduces the FortyOne. The Hewlett Packard HP41, HP41CV and HP41CX are the world's most popular handheld computers, with over 1.4 million in use. The FortyOne is an HP41CV Emulator for the IBM PC and can immediately run most of the 5000 programs in the HP41 users Library without alteration. The FortyOne-ES (software version) is $115. The FortyOne-EF (8087 version) is $100. **Straightforward, Gardena, Calif., INFO/CARD #155.**

Broadband Antenna

The OD310 Omni-Directional Antenna manufactured by Credowan Limited provides full band coverage from 210-240 MHz in fixed, mobile or shipborne applications. Designed to handle an input



power of 250W via the type "N" connector, novel design prevents wasteful high angle radiation and provides a DC path to static as well as providing lightning protection. Input VSWR is 2.0:1 max and the antenna is designed to operate over a temperature range of −55° to +75°C. **Credowan Limited, West Sussex, U.K., INFO/CARD #136.**

PCB Connector System

McMurdo Connectors has introduced the 801/801CX Series two-part PCB connector system utilizing a 0.05 in staggered pitch with 0.10 in between rows, offering a combination of LF and RF contacts as well as polarizing and locking guide formats. All are designed to meet the latest requirements of the MIL-C-55302/140 through 155 specification as and when allocated. All contacts are removable and as an alternative to RF, high power variants are available as a substitute for RF contacts. Other main features include ¼ turn locks, hoods and pin shrouds. **McMurdo Connectors, Lexington, Mass., INFO/CARD #146.**

rf literature

FCC/VDE Testing Brochure

Schaffner EMC, Inc., announces the availability of their new EMI Test System brochure. This literature contains useful information on the Schaffner EMI Test System which provides users with cost-effective, uncomplicated FCC or VDE Testing. Included are technical specifications of the system as well as an in-depth look at Radiated Emissions and Conducted Emissions. **Schaffner EMC, Inc., Union, N.J. INFO/CARD #153.**

Honeywell Microwave Catalog

Honeywell Inc., Santa Barbara Microwave Center, has released an extended Short Form Catalog. This revised catalog features SBMC's standard product line, which covers the frequency ranges from 2 to 110 GHz. Included in SMBC's new short form catalog are MIC and Waveguide mixers, mechanically and varactor tuned Gunn oscillators, IF amplifiers, MIC and Waveguide multipliers, network analyzer frequency extenders, and line extenders. **Honeywell Inc., Santa Barbara Microwave Center, Santa Barbara, Calif. INFO/CARD #152.**

QPL Cross Reference Guide

Abbott Transformer Division now offers over 750 models QPL certified to MIL-T-27. Included in this offering are six complete product lines — 60 Hz and 400 Hz models; Grades 4 and 5/Class S; ranging from 5 V to 220 V and 2 VA to 375 VA. To aid the design engineer and purchasing agent, a free Abbott/QPL Cross Reference Guide is available upon request. **Abbott Transistor Laboratories, Inc., Burbank, Calif. INFO/CARD #151.**

Porcelain Capacitors

An 8-page brochure describes ultra high Q porcelain capacitors according to MIL-C-55681/4 and 5. CDR12 and CDR14 styles are QPL approved. The brochure provides specification of dimensions, performance characteristics and terminations. Also included are Q vs. frequency, ESR vs. frequency curves and comparison ESR vs. frequency of the three dielectric materials. **Dielectric Laboratories, Inc., Cazenovia, N.Y. INFO/CARD #150.**

Allen Avionics Catalog

Allen Avionics video and pulse delay lines and video filters are presented in Catalog 19V. The product line includes the VES series of fixed delay lines and the HEC1000 Hum Eliminator which provides hum reduction to 50 dB depending on system. A group of low cost, high quality fixed attenuators for the video industry is also illustrated. **Allen Avionics, Inc., Mineola, N.Y. INFO/CARD #149.**

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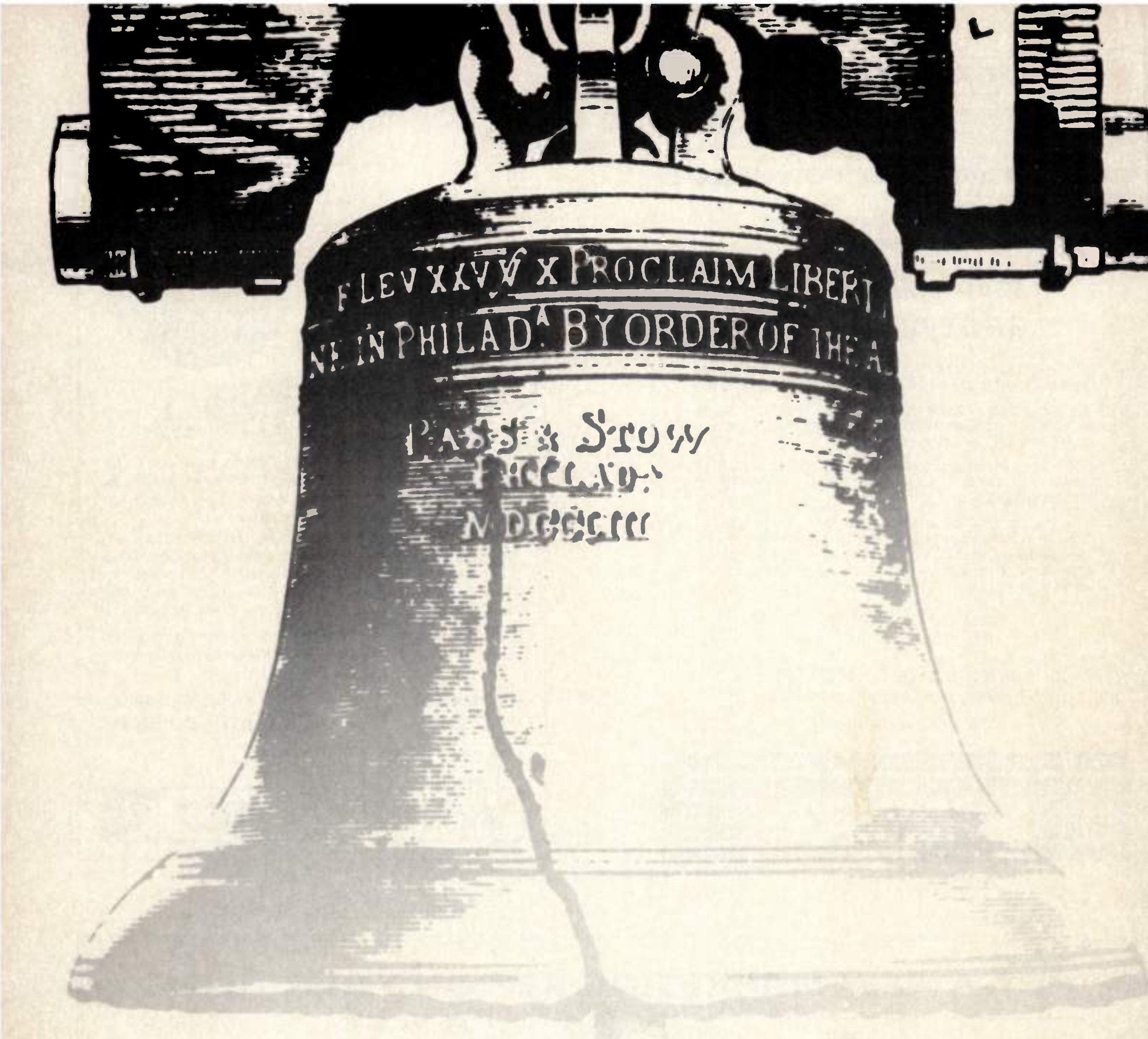

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Advertiser's Index

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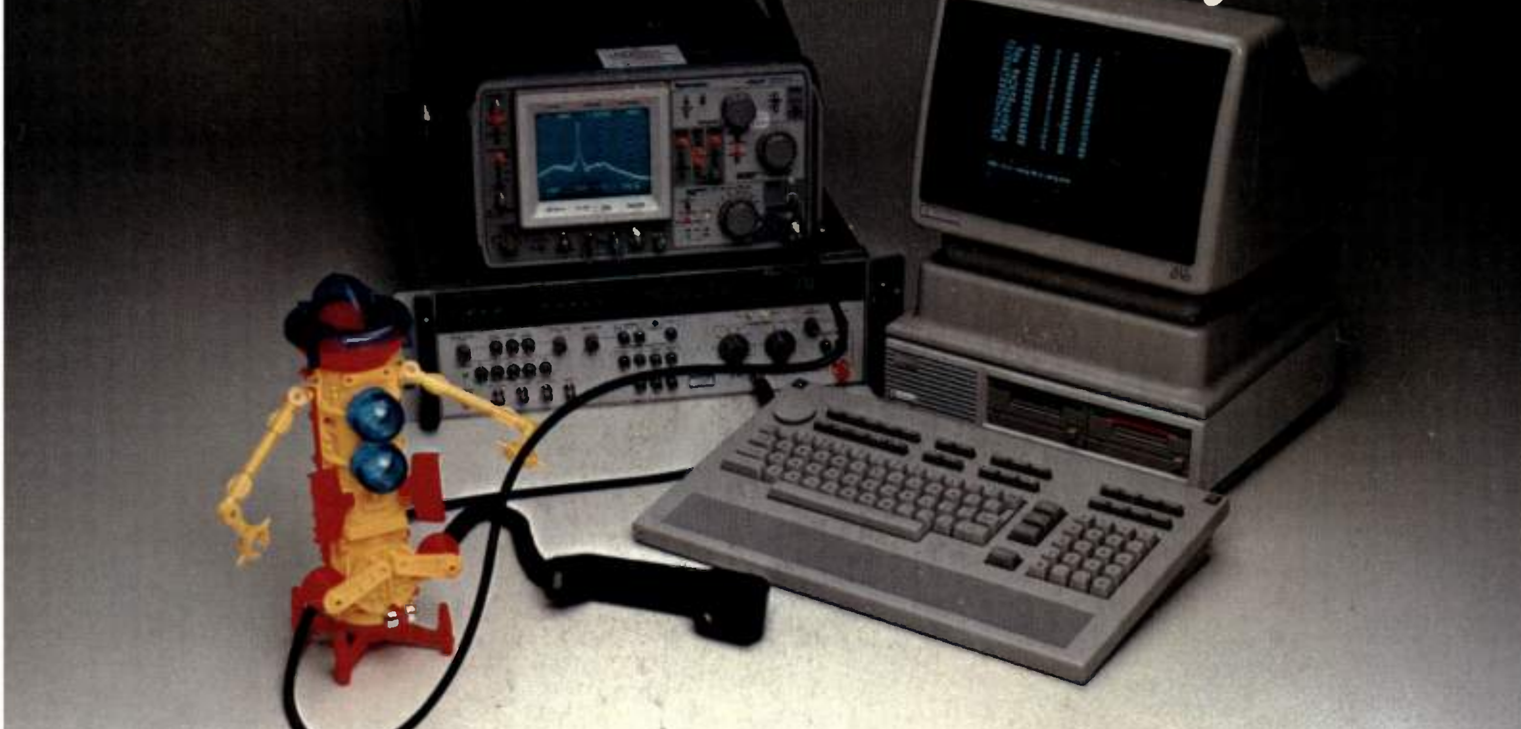
INFO/CARD 93

From Test to Toys



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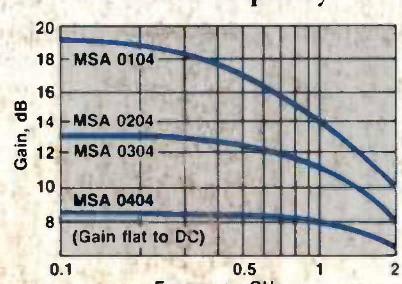
Gain vs. Frequency



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