rf design

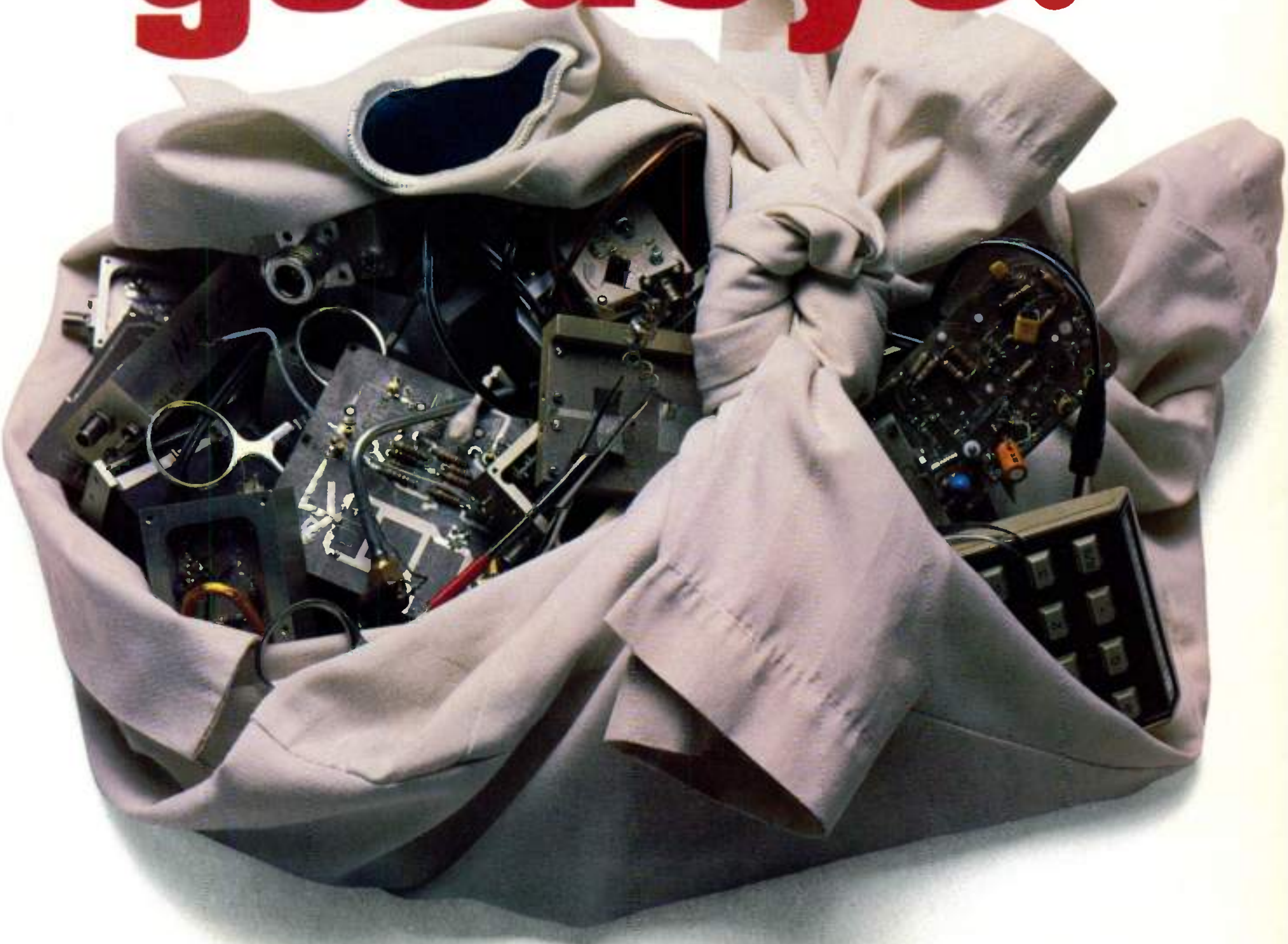
ideas for engineers

April 1986

Special Report

Diodes: An Old Standard Keeps Getting Better

Kiss 'em goodbye!



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Touchstone/RF is the most advanced program there is for computer-aided RF design. You use it in your own office, on your own PC.

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First, we've eliminated expensive microwave models that are unnecessary for even complex RF circuit designs. So Touchstone/RF is less than half the price of Touchstone.

Just as important, we've added some things specifically for the RF engineer. With Touchstone/RF you have everything you need for circuit design, simulation and analysis:

- **toroidal transformers**
- **lumped elements**
- **transformers**
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- **ideal transmission lines**
- **device models**
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...and much more.

You build your circuit with Touchstone/RF, predict performance, tune, change elements and retune, optimize. All, with just a few keystrokes.

In short, you perfect your circuit – right at your own desk. Quickly, easily, accurately.

Touchstone frees you from the lab, from the breadboard-bashing and component-crunching that can sap so much of your time and talent. With Touchstone/RF, you'll work on elegant, completed, well-running circuits. You won't spend your time tweaking trash.

Think what this new freedom will do for your output, for your engineering creativity!

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

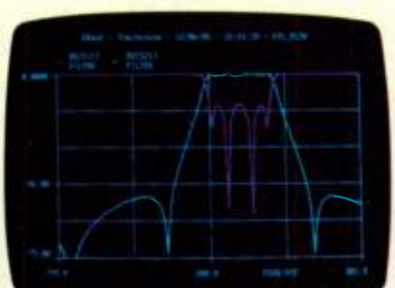
A. Touchstone analysis of an active triplexer circuit with sampled output.

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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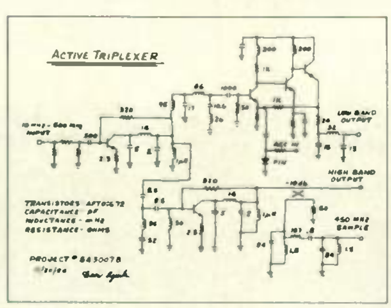

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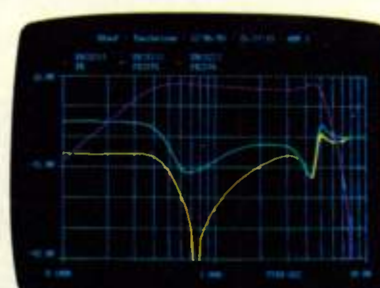

D

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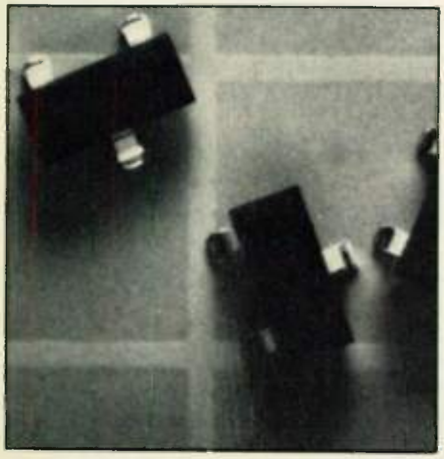
rf design

April 1986



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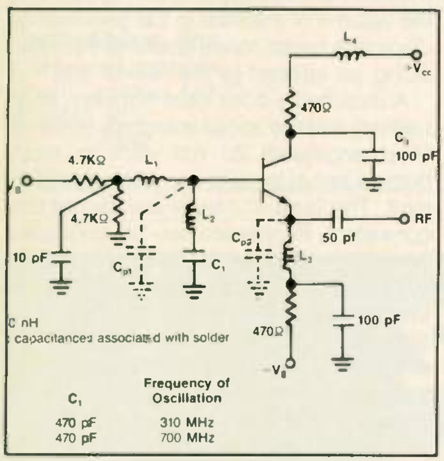
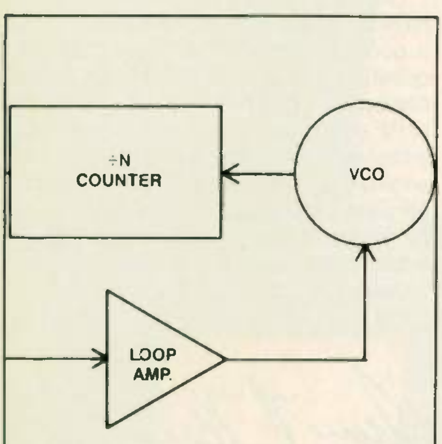


Page 41 — A Varactorless VCO



Page 50 — Digital Connection

Cover

This month's cover shows a sampling of the semiconductor diodes manufactured by Alpha Industries. Diodes are Alpha's largest business, with over 65 percent of the devices sold to manufacturers of consumer and commercial products.

Features

Departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in August. April 1986, Volume 9, No. 4. 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 viewpoint

Our Engineers: We Ignore Them At Our Peril

By Keith Aldrich
Publisher

It is too soon, of course, to ascribe a definite cause to the tragic explosion of the Challenger space shuttle on January 28, which cost the lives of seven brave astronauts and put the entire space exploration program of this country on hold. The final verdict awaits the results of a formal investigation which may drag on for some time.

One thing is already certain, however: Had the objections of the booster engineers been heeded, the launch would not have taken place. Whether or not the now-famous O-ring was the culprit, it is certain that the engineers responsible for its performance disavowed its functioning in such cold as prevailed on that unusually wintry Florida morning. On that basis they advised against and objected to the launch.

What is uncertain is on what basis those responsible for the launch decision overruled the engineers' objections. Whatever is discovered in that regard, it should serve to remind everyone in the sector of our society now called High Technology that we overrule our engineers' judgments only at great risk.

It is ironic that engineers are overruled routinely in matters about which they are depended on to be expert. Why do we train them at such great expense and pay them so well if we are going to ignore what we pay them to tell us?

Perhaps we have all been listening too attentively to the current saw which says that engineers have poor judgment in such matters as product development. Engineers will develop a product which performs marvels that the market doesn't care about, goes the saw.

What this saw ignores is that market research is not the normal, natural province of engineers. Such truisms ought not to affect the value we place on engineers' judgments in areas which *are* their province.

In the RF industry, for instance, management would be foolish to turn a deaf ear to engineers' opinions about: personnel safety associated with radiation in the workplace; consumer safety; and RF interference caused by a company's products.

I assume hopefully that we have no foolish managers in the RF field.

Keith Aldrich

You'll Find Our New ECM-85 Can Beat FR-4 In Processibility, Performance, and Price.

At last there's a viable alternative to FR-4—a laminate that's strong yet easy on drilling tools, stands up to the most demanding electrical requirements, and offers you a price advantage.

It's an all-glass laminate from Cincinnati Milacron called ECM-85 (IPC-designated CRM-5).

In processing, ECM-85 virtually eliminates PTH barrel cracks, consistently provides smooth & smear-free holes, and features the best solderability in the industry.

In electrical performance, it provides more stable long-term insulation resistance; lower and more stable dielectric constant and dissipation factor; and wider safety margins in arc resistance, tracking resistance, and high current ignition resistance.

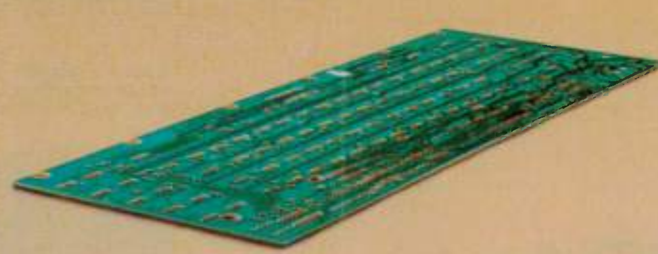
And in price, ECM-85 is more cost-effective than FR-4 in most applications.

If our new laminate looks attractive to you, tell your OEM to call Milacron. Getting a second opinion could really pay off.

Direct inquiries to Steve Hayden or Arlyne Adams, Cincinnati Milacron Marketing Company, P.O. Box 246, Blanchester, Ohio 45107

1-800-221-7084

(in Ohio call 513-783-2464)



CINCINNATI MILACRON

Electronic Circuit Materials Division

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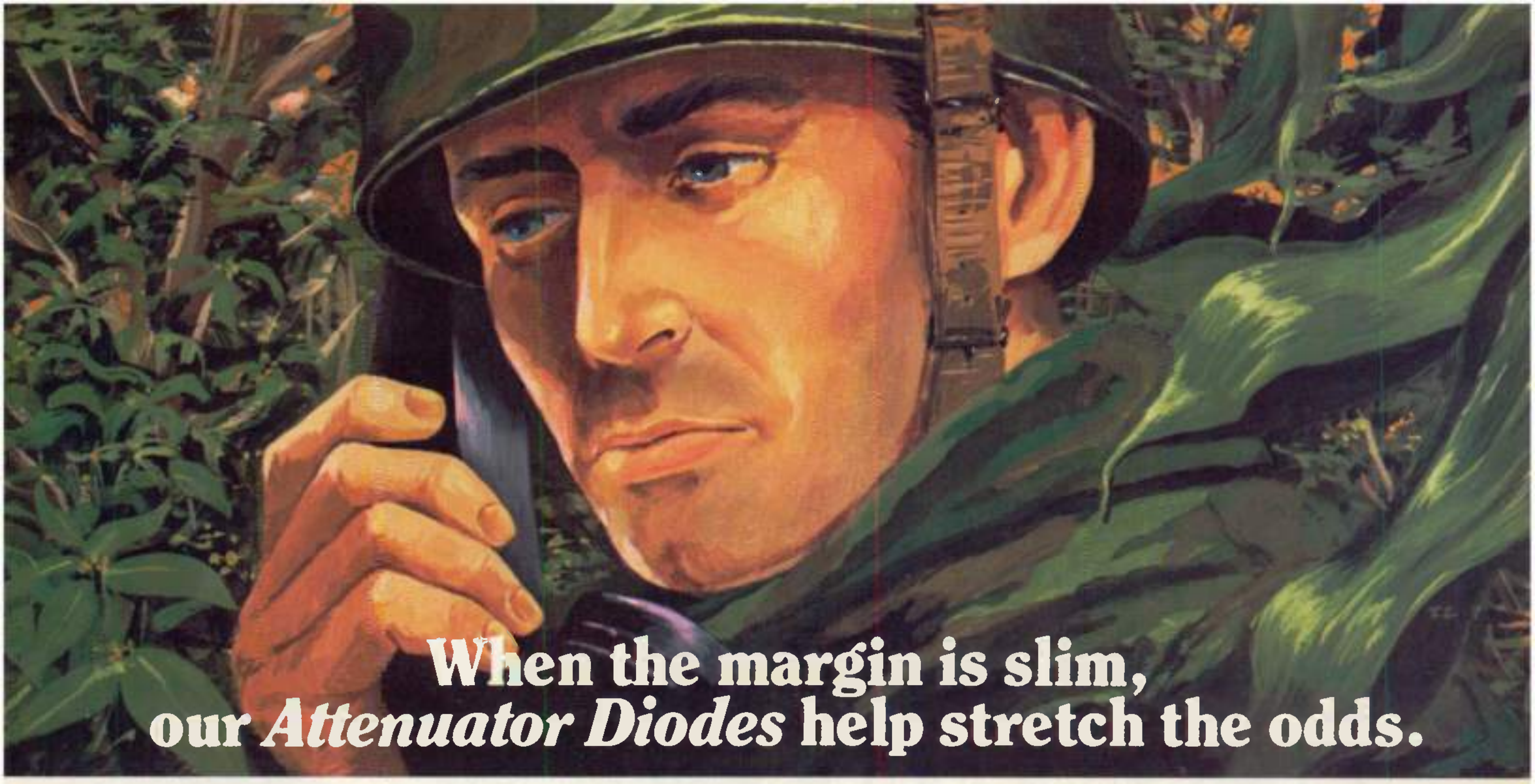


When the margin is slim, our *Attenuator Diodes* help stretch the odds.

Alpha's new attenuator diode series combines flexibility with wide dynamic range and a variety of packaging options to satisfy your most pressing design needs.

When it comes to designing transportable radios, dependable performance *must* be taken for granted. An entire mission may depend on it.

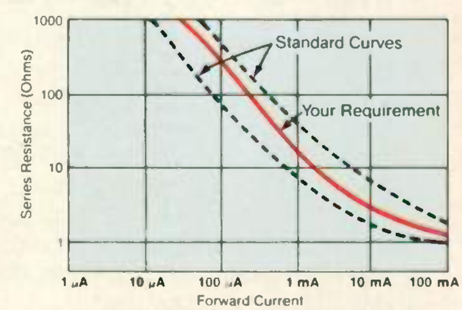
Alpha helps you meet the challenge with a new line of current-controlled attenuator diodes that are ideal for applications involving attenuators, modulators, electronically tuned filters, phase shifters, limiters, switches, and AGC applications.

Offering a broad selection of features, these devices operate over the entire RF range, with their low capacitance permitting attenuation well into the microwave spectrum. Furthermore, their thick intrinsic region permits their use at frequencies as low as 1MHz with low distortion. And they are capable of generating a 50-ohm impedance at many different current loads, ranging from 200 μA to 2 mA.

Other distinguishing characteristics include a low level of harmonic distortion and a wide selection of glass packaging configurations. In addition, when our standard curves don't match your design requirements precisely, we'll go back to the drawing board and come up with a set that will.

Features and Specifications

- Wide Resistance Variation
- Low Harmonic Distortion
- Low Capacitance
- Low Series Resistance
- Long Operating Life and Thick Intrinsic Region



When your design requirements fall in between two of our standard curves, our design engineers will come up with the curve to meet them.

Part Numbers	Typical Resistance 1.0 mA 100 MHz ohms	High Resistance 10.0 μA 100 MHz ohms (min.)	Low Resistance 20.0 mA 100 MHz ohms (max.)	T_L I_f = 10 mA I_R = 6 mA ns (min.)	C_T −50 V 1.0 MHz pf (max.)	V_B I_R = 10 μA — volts (min.)	Series Resistance 100 mA — ohms (max.)
DSB 6419-52	15	800	—	800	0.3	100	1.5
DSB 6419-53	20	1100	—	800	0.3	100	1.5
DSB 6419-55	25	1200	—	800	0.3	100	1.5
DSB 6419-59	40	1500	8.0	1000	0.4	100	2.5
DSB 6419-61	60	1500	—	1300	0.4	100	3.5
IN5767	40	1000	8.0	1000	0.4	100	2.5

Alpha Semiconductors. Our built-in flexibility lets you come as close as possible to meeting your design requirements…so that you don't have to compromise! Send for more information today.

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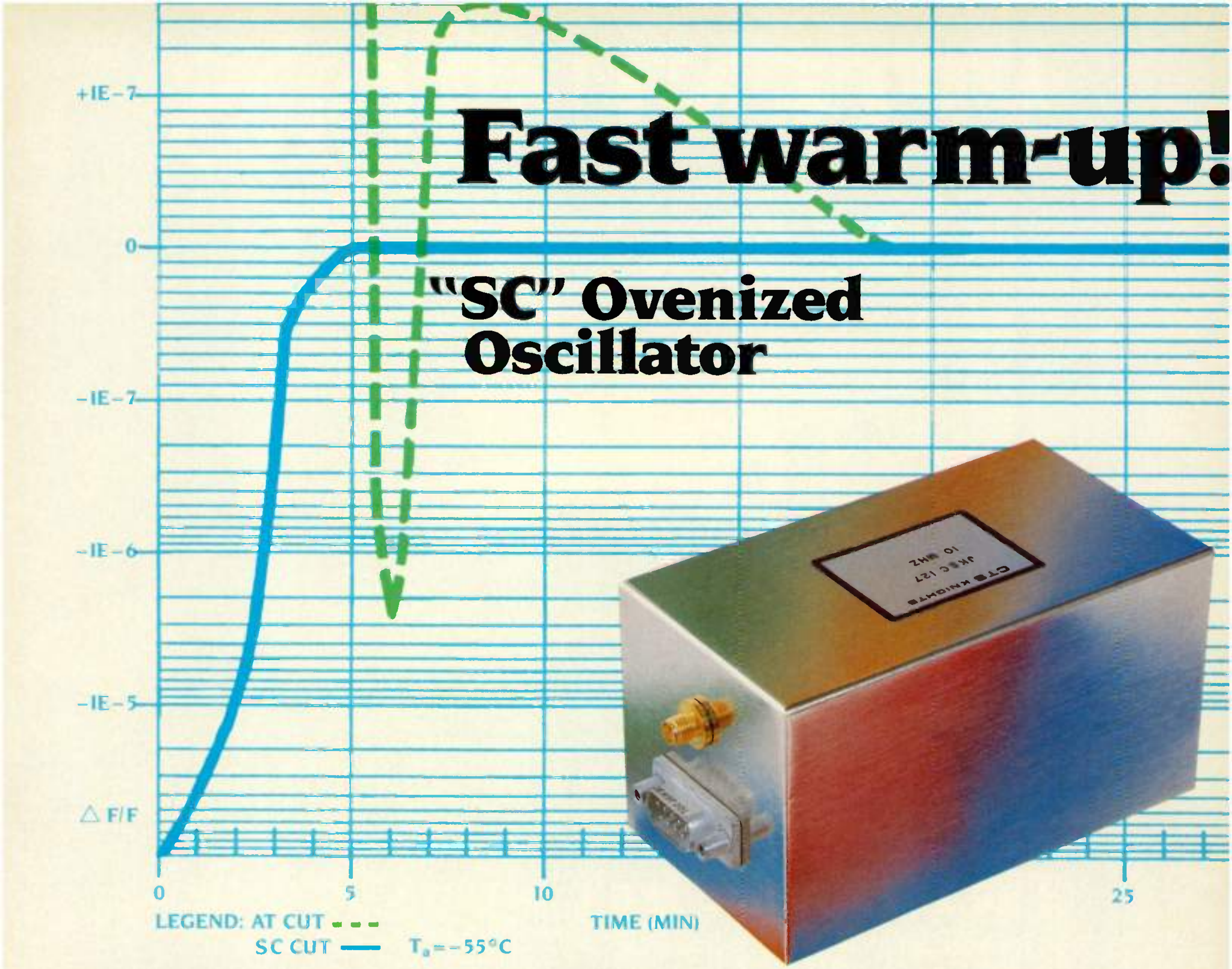
"SC" Ovenized Oscillator



These proven CTS Ovenized Oscillators provide fast warm-up, low power, excellent stability and low phase noise. When you need premium quality, state-of-the-art precision oscillators for industrial and military applications, you can depend upon CTS. With the largest staff of engineers in the industry, we've been building premium crystal products for 40 years. Because *we manufacture our own precision crystals*, you are assured of consistent oscillator performance and quality. With extensive design and manufacturing capabilities, CTS Knights Division crystal products have become the choice when reliability cannot be compromised.

WRITE TODAY for complete specifications on these CTS Ovenized Oscillators. Contact: CTS Corporation, Knights Division, 400 Reimann Ave., Sandwich, IL 60548. Phone: (815) 786-8411.

INFO/CARD 13

General Specifications JKSC-127 Ovenized Oscillator (Stress Compensated)	
Center Frequency	10.0 MHz and 10.230 MHz
Warm-Up	@ −55°C $\pm 5 \times 10^{9}$ in 7 minutes @ −32°C $\pm 5 \times 10^{9}$ in 5 minutes @ +25°C $\pm 5 \times 10$ in 3 minutes
Input Power	Oven @ turn on 1.2 A maximum @ +28 V Oven @ 25°C 125 mA typical @ +28 V Oven @ −55°C 240 mA typical @ +28 V Oscillator 20 mA maximum @ +15 V
Frequency Stability Vs. Temperature	$\pm 5 \times 10^{9}$ from −55°C to +71°C
Phase Noise	(1 Hz BW) @ 10 Hz offset −120 dbc @ 100 Hz offset −140 dbc @ 1 KHz offset −150 dbc @ 100 KHz offset −150 dbc

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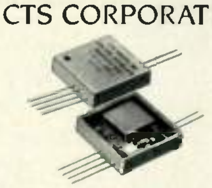

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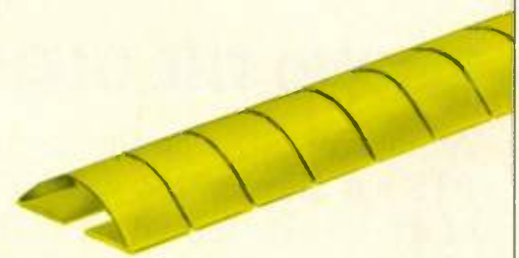
INFO/CARD 12

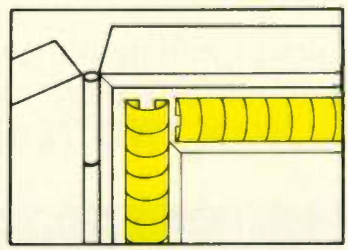
New!

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

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

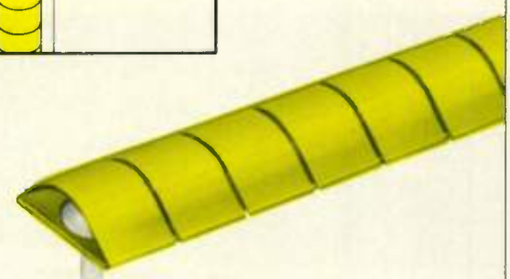


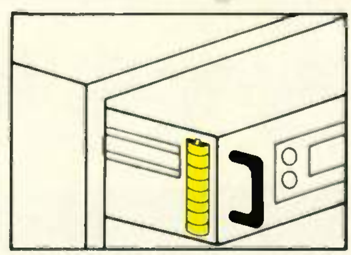
Three models are available: basic, rivet-mount and double-faced adhesive-mount designs. The basic design consists of low-compression, adhesive-mounted strips. A generous radius profile provides for the greatest incident engagement angle with the lowest force. As with all Sticky Fingers® shielding strips,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



Adhesive-mounted strips for typical electronic enclosures.

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

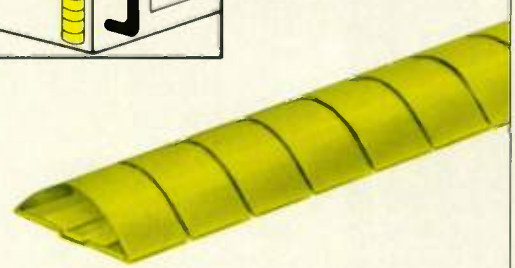


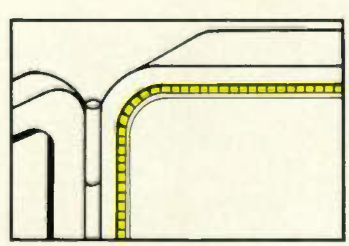


Strips with integral mounting track* and nylon push rivets, for sliding drawer applications.

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

For complete information, including exact specifications, dimensional drawings, etc., on these and other Instrument Specialties shielding strips, use this publication's Reader Service Card. Or write to us directly at Dept. RFD-27.





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

*patent pending

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rf calendar

April 7-10, 1986
International Conference on Frequency Control and Synthesis
University of Surrey, Guilford, England
Information: Institution of Electronic and Radio Engineers, 99 Gower St., London, WC1E 6Az; Tel: 01-388-3071

April 8-10, 1986
Test and Measurement World Expo
San Jose Convention Center, San Jose, California
Information: Meg Bowen, Conference Director, Test and Mesurement World Expo, 199 Wells Avenue, Newton, MA 02159; Tel: (617) 964-8900

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

April 16-17, 1986
RF and Microwave Component & Test Equipment Exhibit
Sheraton Inn, Fort Wayne, Indiana
Information: Jim Leach, RF Management, Inc., P.O. Box 336, Beech Grove, IN 46107; Tel: (317) 887-1349

April 22, 1986
The New York/Long Island Chapter MTT Society 1986 Symposium: "Microwave ICs — Hybrid to Monolithic and Something In Between"
Marriott Hotel, Uniondale, New York
Information: Bob Koelzer, Narda Microwave Corp., Hauppauge, NY 11788; Tel: (516) 231-1700 ext. 309

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, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (213) 772-2965.

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, United Kingdom; Tel: 0892-44027

June 16-19, 1986
EMC Expo 86
Sheraton Washington, Washington, DC
Information: EMC Expo 86 Registration Manager, 117 King St., Suite 200, Alexandria, VA 22314; Tel: (703) 548-2802

June 23-27, 1986
Conference on Precision Electromagnetic Measurements
National Bureau of Standards, Gaithersburg, Maryland
Information: Judy Wilson, Conference Assistant, National Bureau of Standards, Gaithersburg, MD 20899; Tel: (301) 921-2721

rf courses

The George Washington University
Electronic Warfare Systems: Technical and Operational Aspects
June 9-13, 1986, Ottawa, Canada

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

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

Interference Control Technologies
Grounding and Shielding
April 15-18, 1986, Atlanta, Georgia
May 6-9, 1986, San Jose, California
May 20-23, 1986, Minneapolis, Minnesota

Tempest Design, Control, Testing
May 20-23, 1986, Sunnyvale, California

Tempest Facilities Design, Installation and Operation
April 8-10, 1986, Washington, DC

EMC Design and Measurement for Control of EMI
April 21-25, 1986, Philadelphia, Pennsylvania

Mil-Std 461/462 and System Level Testing & Procedures
May 20-23, 1986, Philadelphia, Pennsylvania

Practical EMI Fixes
May 20-23, 1986, Seattle, Washington

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

R & B Enterprises
Electromagnetic Pulse Design and Test
May 14-15, 1986, Washington, DC

Two-Week EMI Training Institute — Commercial (FCC)
May 1-2, 1986, Philadelphia, Pennsylvania

EMI in the Automotive System
May 7-9, 1986, Dearborn, Michigan

Grounding, Bonding, Shielding
April 28-29, 1986, Washington, DC

Information: Greg Gore, Director of Training, R & B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428; Tel: (215) 825-1960

University of Colorado
CAD of Microstrip Circuits and Antennas
May 27-30, 1986, Boulder, Colorado

Information: Office of Conference Services, University of Colorado, Campus Box 454, Boulder, CO 80310; Tel: (303) 492-5151

Editor:

Now that RF Expo 86, Anaheim, is history, believe me it's the best history that I have ever experienced in over 20 years of involvement in electronic conventions! You and your staff who participated in making it perform so superbly need the heartiest congratulations of all the attendees.

But, boy, did you place a burden on your shoulders: to outdo this one with the next!

I'm already eagerly looking forward to next year's at the Disneyland Hotel.

Ed Oxner
Staff Engineer
Siliconix, Inc.
Santa Clara, California

Editor:

After receiving my February issue of *RF Design*, I wanted to write and tell you how much I appreciate the types of articles you seem to choose to publish.

This month, I especially appreciated the "Directional Coupler Design Graphs," and "BASIC Programs for Symmetrical Attenuators and Active Filters," and I always enjoy reading the new product announcements and other small news items.

For many months, I have looked forward to receiving my latest issue of *RF Design*, and hope you can continue with articles that educate and inform.

I am especially interested in I.C.'s, transistors, or other solid-state devices for 1 GHz to 10 GHz, and any training or education articles that involve such frequencies.

I happen to think that many design programs are over-priced, and especially appreciate articles like the ones mentioned above, and advertisements from good software suppliers such as Circuit Busters, Inc. who are willing to supply decent RF design software for very reasonable prices. Please run more!

Alan Rutz, President
Community Systems Co.
La Porte, Indiana

Mr. Breed:

Your article on the importance of antennas and antenna couplers in maximizing portable HF communications system performance was most enlightening. It depicted the many ways that total system performance can be optimized by careful attention to these parameters.

Stephens Engineering has been involved with the design and manufacture of HF transceivers for more than a decade, with primary market emphasis in HF marine communications. We have pioneered the use of tune on voice techniques which, coupled with our exclusive Memory System, allows our automatic antenna coupler to handshake and be used with virtually any HF transceiver without modification. Our experience with automatic coupler design dates from 1982, during which time we have developed a number of innovations which are now widely used in the industry.

Our coupler work has been directed by Bill Forgey, vice president of engineering, who would be happy to act as a technical resource on this subject.

David C. Thompson
Chief Executive Officer
Stephens Engineering Associates, Inc.
Mountlake Terrace, Washington


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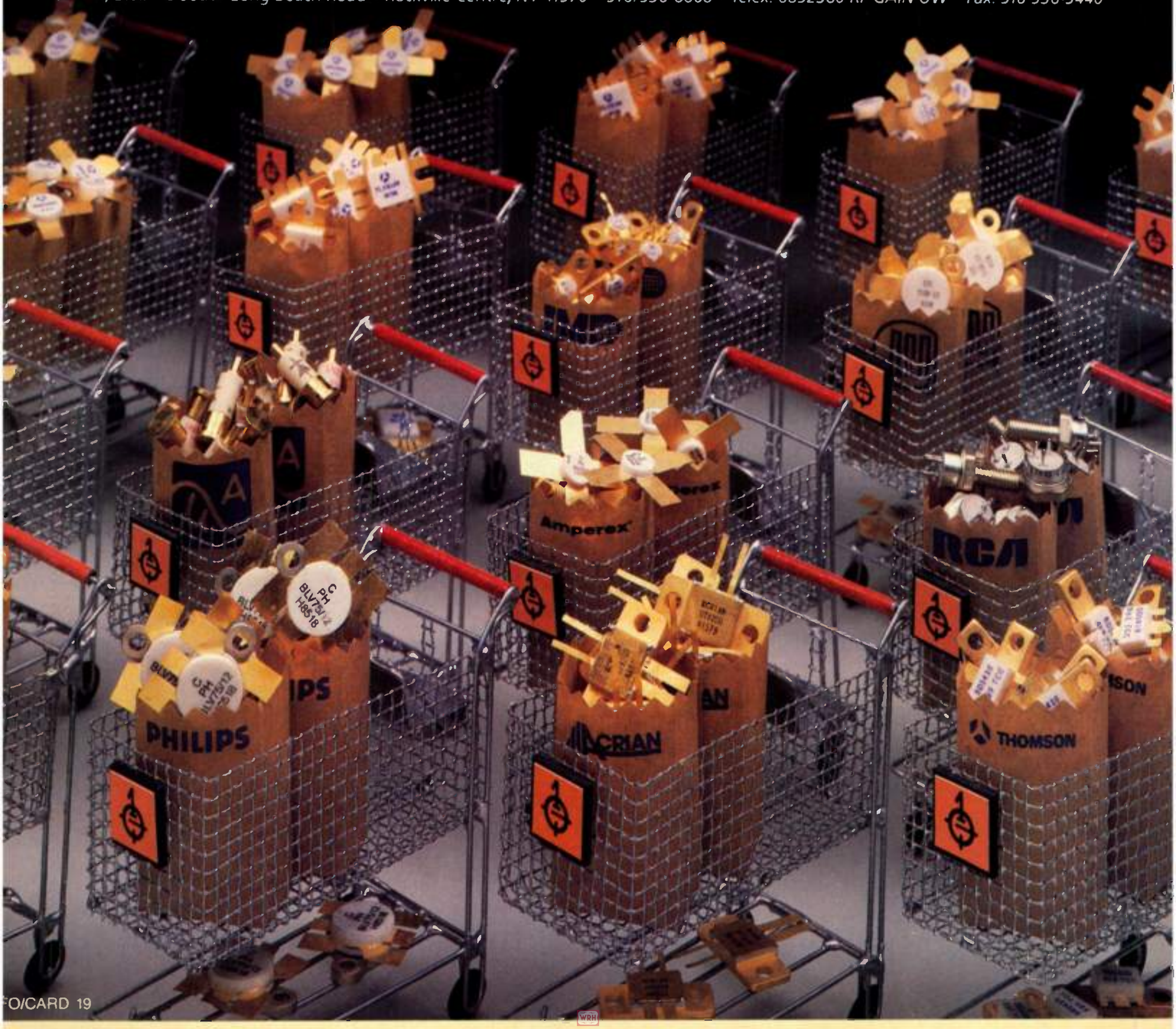

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A Call for Papers

For two years in a row, *RF Design* magazine has sponsored a highly successful conference and show in Southern California tailored to the needs of RF engineers. Now, at the request of many east coast engineers we are going to hold the first such conference in that region.

RF Expo East will be held Nov. 10-12, 1986, at the Boston Marriott Copley Place. We are calling for 45 papers for this show and 75 for RF Technology Expo 87, to be held Feb. 11-13, 1987, in Anaheim.

We are looking for two kinds of papers: those describing design techniques and principles and those describing new product applications. Design techniques can encompass circuit or component testing and performance evaluation. New product applications should emphasize the parameters and characteristics that designers need to know, with practical information about the best use of the product.

All papers will be published in the Proceedings, available at the conference and afterward. The principle author of each paper will receive a free copy of the Proceedings as well as full conference registration.

To propose a paper for either conference, cut out or photocopy the form below and send it to Jim MacDonald, Program Chairman, RF Expo East/RF Technology Expo 87, 6530 South Yosemite St., Englewood, CO 80111. A separate letter can be used instead of the form.

Proposal For Paper At The Following RF Convention:

☐ **RF EXPO EAST**
November 10-12, 1986
Boston Marriott Copley Place

☐ **RF TECHNOLOGY EXPO 87**
February 11-13, 1987
Disneyland Hotel, Anaheim

I propose the following paper of 30-40 minutes in length, to be presented by me (and collaborators, if any) at the RF convention indicated above.

Title: ____________________

Abstract: ____________________

Author(s): ____________________

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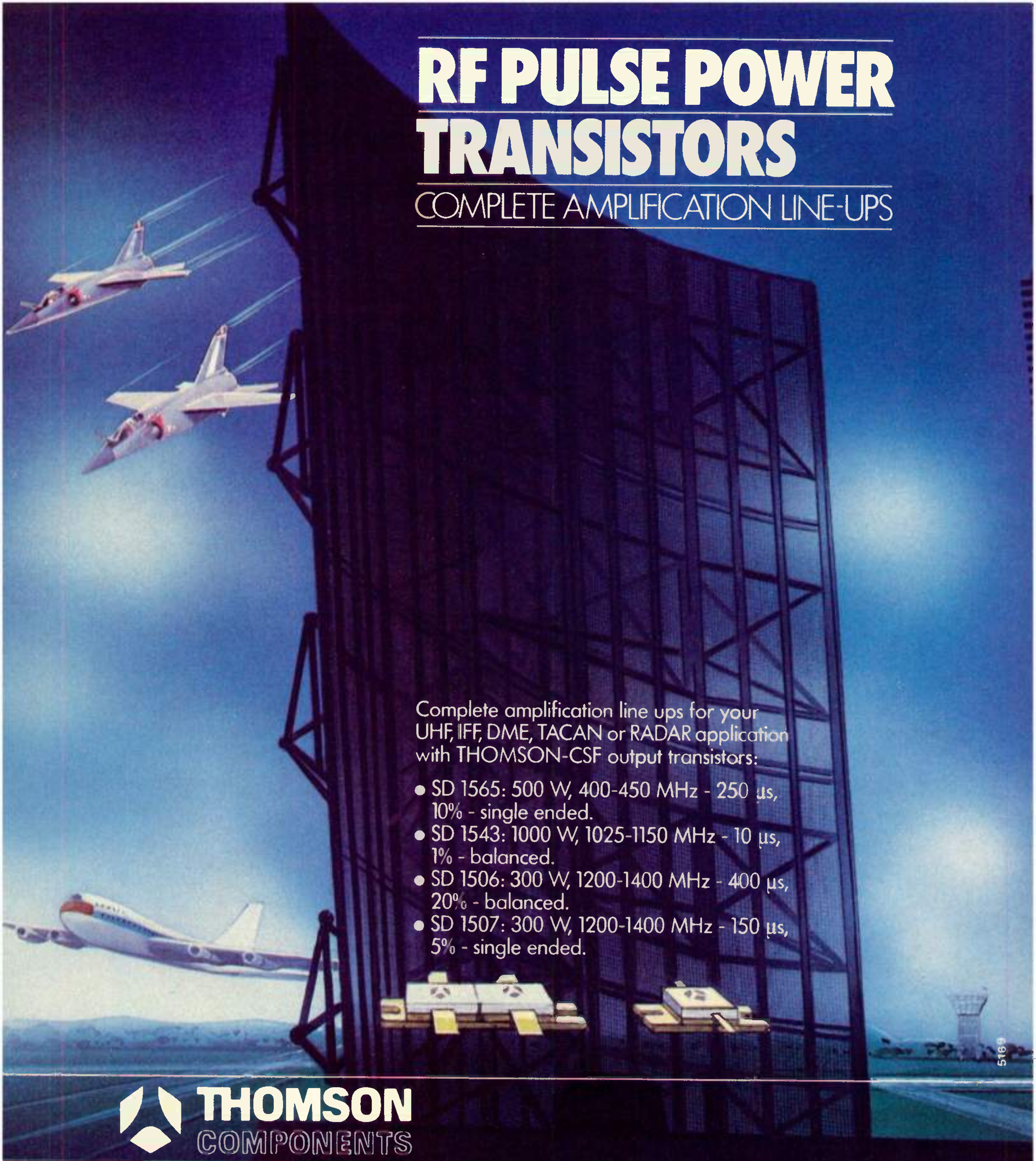
Deadlines:	**RF EXPO EAST**	**RF TECHNOLOGY EXPO 87**
Proposal:	May 26, 1986	August 25, 1986
1st Draft:	July 14, 1986	October 13, 1986
Final Manuscript:	August 25, 1986	November 24, 1986



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SAS-200/511	1000 - 12000 MHz	Log Periodic
SAS-200/512	200 - 1800 MHz	Log Periodic
SAS-200/518	1000 - 18000 MHz	Log Periodic
SAS-200/530	150 - 550 MHz	Broadband Dipole
SAS-200/540	20 - 300 MHz	Biconical
SAS-200/541	20 - 300 MHz	Bicon'l Collapsible

MODEL #	FREQ. RESP.	DESCRIPTION
SAS-200/542	20 - 300 MHz	Biconical, Folding
SAS-200/550	.001 - 60 MHz	Active Monopole
SAS-200/560	per MIL-STD-461	Loop - Emission
SAS-200/561	per MIL-STD-461	Loop - Radiating
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INFO/CARD 26

Composite EMI/RFI Shielding

Selection Guidelines for OEM Applications

By Wayne Morrow
Keene Corporation

It's no secret that OEM electronic products need more and better EMI/RFI shielding. In many cases, the material of choice is composite EMI/RFI shielding. That's the foil-coated sheet-type material which is most often applied like wallpaper or contact paper to create the barrier.

The question then becomes: which composite shielding? The decision can get complicated, since there are hundreds of choices within the generic category of composite shielding. However, the right choice can make a big difference in electronic performance, weight and space, FCC compliance and overall serviceability, not to mention material and manufacturing costs. This article will discuss the options available, and offer some guidelines for narrowing down the selection. It also will discuss some of the myths that have arisen about EMI/RFI shielding.

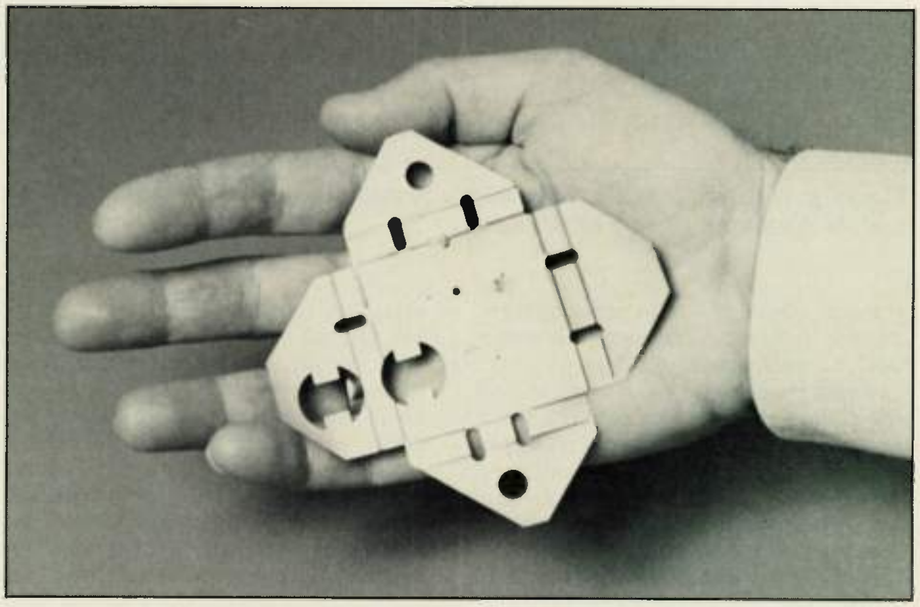


Photo of folded out, formed EMI shielding.

First, why shield in the first place, and why go with composite shielding rather than metal sprays or conductive plastics? The first answer isn't as obvious as it sounds. There is the very obvious FCC part 15 emission regulations to contend with but less obvious is performance reliability of the product. Susceptibility of a device to incoming interference could be a bigger problem than emissions, so the design should be looked at from both the emission and susceptibility standpoints. In fact, for some equipment, regulations for susceptibility as well as emissions are being developed.

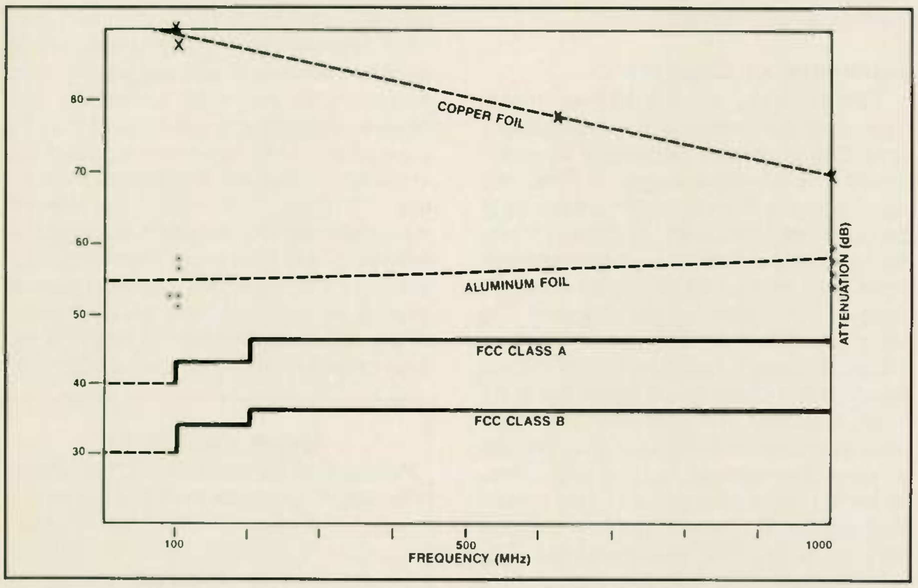


Figure 1. Attenuation vs. frequency for copper and aluminum foils, compared with FCC requirements.

Why composite rather than metal sprays? They are cleaner to apply than metal sprays, and pose no OSHA or EPA issues. They don't impair structural integrity of the enclosure, as do some conductive plastics or additives. Also, there is greater assurance against voids in the barrier due to incomplete spray coverage or resin mixing. However, composites usually require an extra, essentially manual, production step.

Composites Rescue "Bad" VCRs

Recently, a major VCR manufacturer found that composite EMI shielding can also serve a rescue function. Some 8,000 of its ready-to-ship units were emitting out-of-compliance EMI levels. The original zinc spray-on shielding inside the enclosure wasn't containing the emissions well enough, so the company was faced with finding a solution. There wasn't enough internal clearance to accommodate overspraying the original coating with another 5 mil of zinc. Also, masking for an after-the-fact spray operation would have been prohibitively expensive, with no certainty that more of the same would solve the

Material	Electrical Conductivity (Higher is Better)	Magnetic Permeability (Lower is Better)
Silver	11	1
Copper	10	1
Aluminum	6	1
Zinc	3	1
Nickel	2	100
1045 Steel	1	1000

Figure 2. Relative electrical conductivity and magnetic permeability of six metals frequently used in shielding.

problem. Then, the VCR manufacturer came to Keene to explore whether some type of composite shielding might work.

At first, they considered a two-part system. First, apply a polyester film, coated on both sides with adhesive. Next, apply copper foil to the film surface. Finally, they settled on a one-step, 2-mil foil/adhesive construction using much less expensive aluminum foil instead of copper. The VCR manufacturer die-cut the shielding to fit the cabinet walls, including all holes and wiring lead entries. This was done on the same dies that trim the original plastic enclosure and allowed the manufacturer to retrofit the cabinets very inexpensively. About $1,600,000 worth of "bad" product was salvaged.

Composite Shielding Choices

There are four basic types of composite EMI shielding. Each can usually be supplied with or without pressure-sensitive adhesive backings:

- Adhesive coated foils, usually in copper or aluminum.
- Foil/film laminates, with or without adhesive.
- Foil/paper laminates, with or without adhesive.
- Specialty composites.

The specialty composites include:

- Foils with special fire retardant or conductive adhesives.
- Margin laminates, where the foil shield doesn't completely cover the backing areas, available with center laminate, butt laminate and ship-lap laminate for shielding cylindrical shapes.

Silver, copper, aluminum, zinc, nickel and steel are used as the conductive material. Most requirements, however, are filled by either copper or aluminum.

Since EMI shielding is largely a matter of surface reflection from the conductive foil, the foil can be as thin as desired. Theoretically, a consistent, uninterrupted layer one atom thick would fulfill the electronic function. However, mechanical conditions of handling, forming, die-cutting, stress and abrasion resistance usually determine the backing material and total thickness. The backing can be selected to add the necessary thickness, shape retention and other mechanical properties.

Environmental factors also influence the choice of backing. For example, polyethylene film backing has good chemical and humidity resistance while electrical grade kraft paper retains its shape after folding, and has some handling "heft" to it. Where service temperatures exceed 90°C, aramid fiber, which withstands temperatures up to 220°C, might be the better backing choice.

Aluminum or Copper?

EMI shielding already has its myths. The most pernicious one is that copper shielding is always preferable to aluminum. If you believe copper is "the only way," you are likely to pass up savings in product cost and weight. Aluminum is perfectly adequate for the majority of applications and costs about two-thirds less than copper, with less weight. Despite the weight and cost advantages, aluminum-based composite shielding fulfills FCC regulation 15J, Class A and Class B (Fig. 1).

As indicated in the curves, RF attenuating copper foil is superior to aluminum at lower frequencies, but the gap diminishes at higher frequencies. Both metals well exceed FCC code requirements (as well as NEMA 101 requirements). The principal situation favoring copper over aluminum is the requirement for soldering to the conductive surface, such as the attachment of a ground wire.

Copper's superiority may be important in near-field situations. To understand why, it's important to see how shielding works fundamentally. Attenuation of radiated interference waves by a conductive barrier has three components. The first is reflection by the outer surface of the shielding metal — by far the largest. Next is absorption within the metal layer, and the last is re-reflection by the inner surface of the metal. The closer and more powerful the source, the greater the influence of the absorption and re-reflected components. Copper has proportionately better absorption and re-reflection properties than aluminum. So, where the emitter is powerful and near-field, copper foil does have an edge.

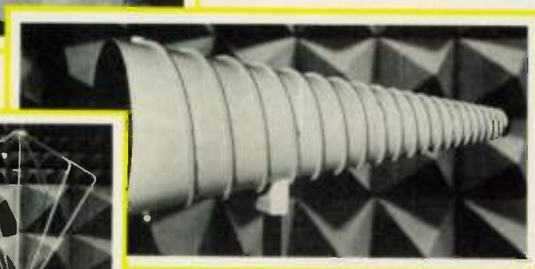
Specifying Composites

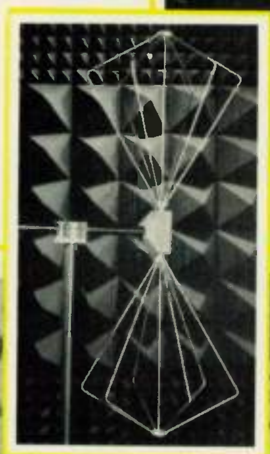
Before specifying EMI shielding, or even making an inquiry of a supplier, be sure you know the nature of the interference — strength, frequency, relative proportions of electric fields and magnetic fields (impedance); and the proximity of the emitter to the shielding (near field vs. far field). If the interference is a combination of electronic and magnetic emissions, both electrical conductivity and magnetic permeability of the shielding must be considered (Fig. 2). Of the six commonly used shielding metals, only nickel and 1045 steel have appreciably poorer magnetic permeability.

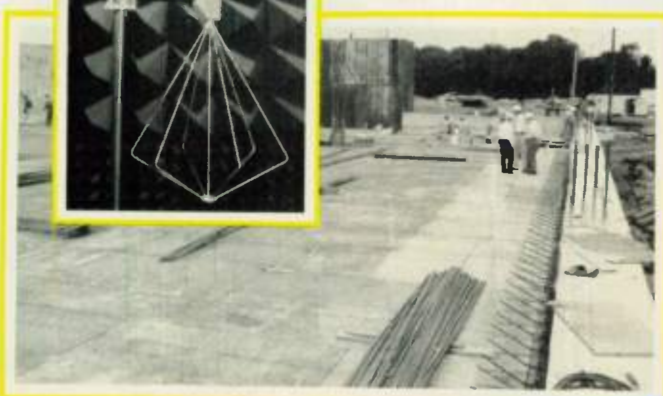
Another factor to consider is the required mechanical strength and rigidity to withstand fabrication and end-use service. If the shielding is to be applied like wallpaper, characteristics of the adhesive rather than the strength or rigidity of the backing material may be the chief concern. However, often the shielding will be constructed into a self-supporting mini enclosure. In that case, formability and ease of assembly or die-cutting may be paramount. If MIL specs are entailed, the application engineer will apply a different set of criteria. Fire resistance requirements also call for a custom approach to selecting adhesives and backing laminates or coatings. The supplier must, of course, be fully informed on all aspects of the shielding problem to help the design engineer find the best solution. rf

About the Author

Wayne Morrow is director of marketing for flexible products at Keene Corporation, Laminates Division, 199 Amaral St., East Providence, RI 02914. He can be reached by telephone at (401) 434-2340.







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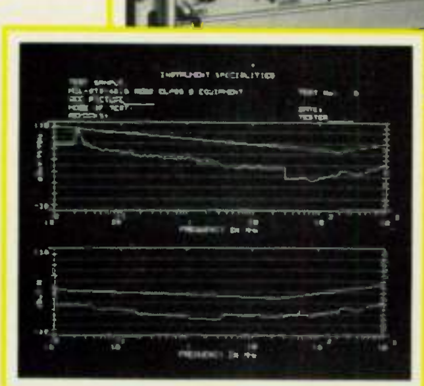
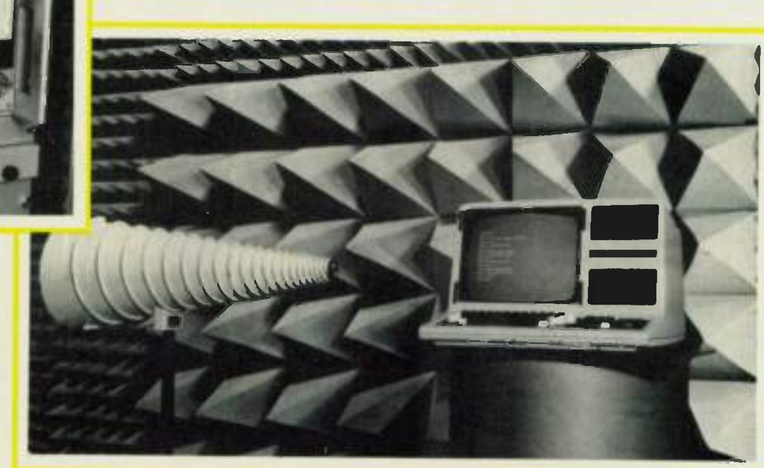




INFO/CARD 27

These Numbers Mean Business

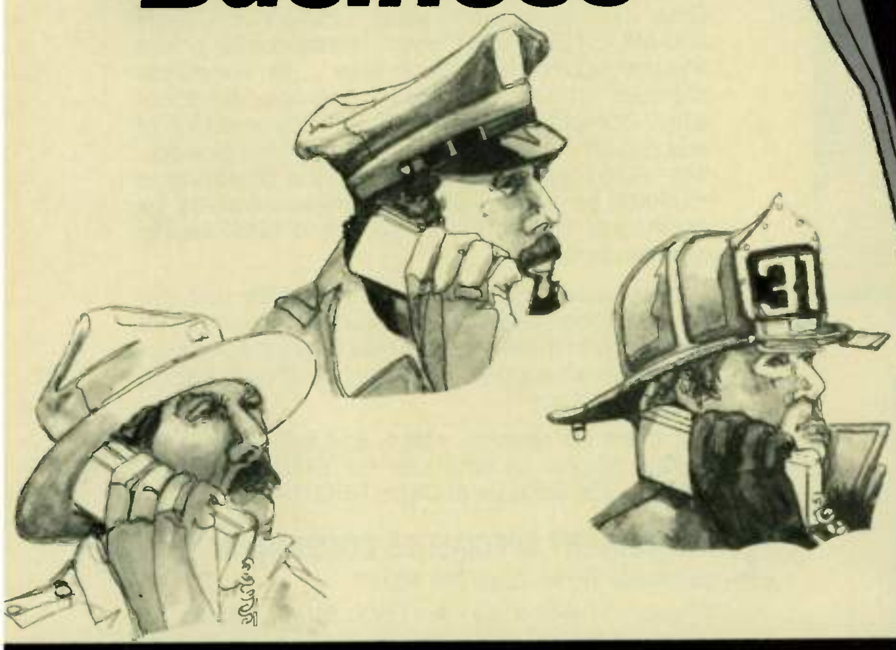
900 MHz	MOBILE APPLICATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLU98	0.5	900	9.0	12.5	SOT-103/E1
BLV90	1	900	7.5	12.5	SOT-172
BLV91	2	900	6.5	12.5	SOT-172
BLU99	4	900	7.3	12.5	SOT-122
BLV92	4	900	8.0	12.5	SOT-171
BLV93	8	900	6.0	12.5	SOT-171
BLV94	15	900	6.0	12.5	SOT-171

400 to 512 MHz	MOBILE APPLICATIONS				
BLU60 12	60	470	4.8	12.5	SOT-119
BLU45 12	45	470	5.1	12.5	SOT-119
BLU30 12	30	470	6.0	12.5	SOT-119
BLU20 12	20	470	6.5	12.5	SOT-119
BLW82	30	470	5.0	12.5	SOT-119
BLW81	10	470	6.0	12.5	SOT-122
BLU99	5	470	10.5	12.5	SOT-122
BLW80	4	470	8.0	12.5	SOT-122
BLW79	2	470	9.0	12.5	SOT-122
BLX65	2	470	6.0	12.5	TO-39

175 MHz	MOBILE APPLICATIONS				
BLV75 12	75	175	7.0	12.5	SOT-119
BLV45 12	45	175	6.5	12.5	SOT-119
BLV30 12	30	175	8.2	12.5	SOT-119
BLW60C	45	175	5.0	12.5	SOT 120
BLW31	28	175	9.5	12.5	SOT-120
BLY89C	25	175	6.0	12.5	SOT-120
BFQ43	4	175	12.0	12.5	TO-39E
BFQ42	2	175	10.5	12.5	TO-39

30 to 900 MHz	BASE STATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLW96	200	30	13.5	50	SOT-121
BLV25	175	108	10.5	28	SOT-119
BLV80 28	80	175	6.5	28	SOT-119
BLV33F	85	225	10.5	28	SOT-119
BLV36	120	225	10.0	28	SOT-161
BLU53	100	400	6.5	28	SOT-161
BLV97	30	860	6.5	24	SOT-171
BLV57	38	860	6.5	25	SOT-161

66 to 870 MHz	AMPLIFIER MODULES FOR LAND MOBILE				
Type	Freq (MHz)	P In (MW)	P Out (W)	VCC	Package
BGY32	68-88	100	20	12.5	SOT-132
BGY33	80-108	100	20	12.5	SOT-132
BGY35	132-156	150	20	12.5	SOT-132
BGY36	148-174	150	20	12.5	SOT-132
BGY43	148-174	150	13	12.5	SOT-132B
BGY40A	400-440	100	7.5	12.5	SOT-132C
BGY41A	400-440	150	13	12.5	SOT-132C
BGY40B	440-470	100	7.5	12.5	SOT-132C
BGY41B	440-470	150	13	12.5	SOT-132C
BGY40A	470-512	100	7.5	12.5	SOT-132C
BGY41C	470-512	150	13	12.5	SOT-132C
BGY45A	68-88	150	30	12.5	SOT-301-A-03
BGY45B	144-175	150	30	12.5	SOT-301-A-03
BGY46A	400-440	30	1.5	9.6	SOT-26NC
BGY47A	400-440	45	2.2	9.6	SOT-26NC
BGY47B	430-470	45	2.2	9.6	SOT-26NC
BGY47C	460-512	45	2.2	9.6	SOT-26NC
BGY22	380-512	50	2.9	12.5	SOT-75A
BGY23	380-480	2.5 WATTS	7	12.5	SOT-75A



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G_{NF} (dB)	8.5	7.5
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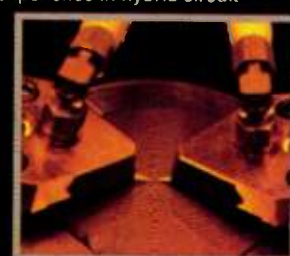

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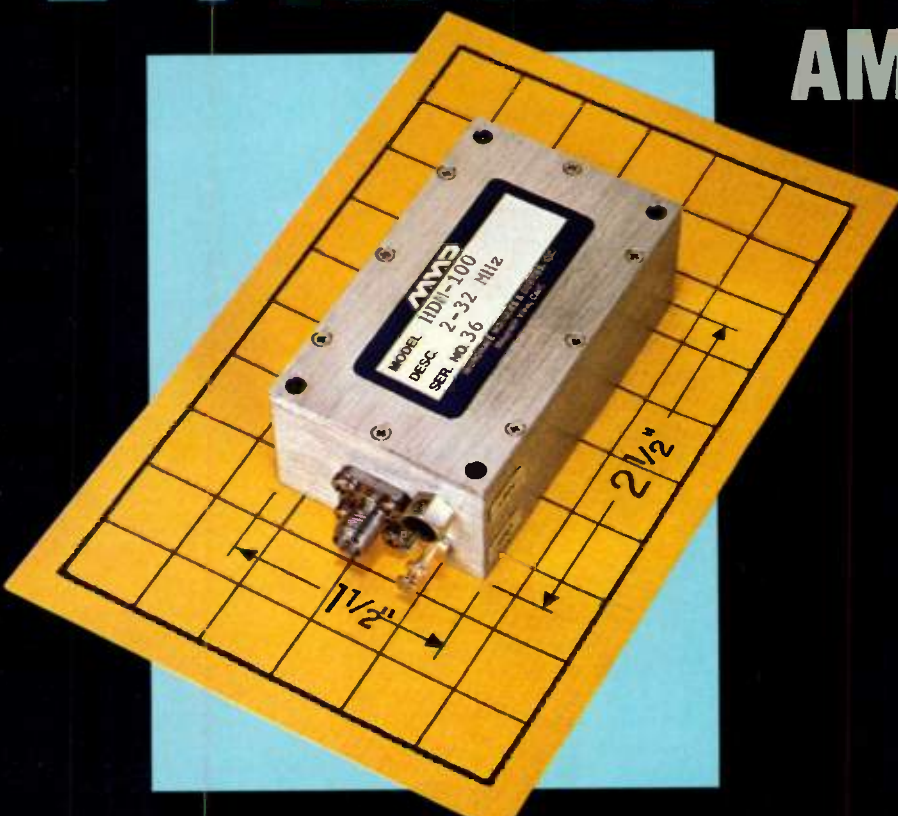

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Gain:	16.5 dB ±0.5 dB.
IP_3:	+50 dBm.
IP_2:	+90 dBm.
VSWR (In/out):	1.75:1 max.
DC input:	+20 VDC @ 1 amp.

Size (case less connectors):
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INFO/CARD 30

Diodes: An Old Standard Keeps Getting Better

Packaging, Performance and Price are Demanded in a Growing RF Marketplace.

By Gary A. Breed
Technical Editor

Diodes, the first semiconductor components, have come a long way since the Galena crystal and cat's whisker! Although the basic technology for RF diodes has not changed much over the past few years, no earthshaking discoveries have been made, manufacturers remain as excited as ever about their RF diode products. Why?

There is nearly unanimous agreement among diode makers that RF frequencies represent a sizeable growth area for diodes. Companies that have traditionally been "microwave" oriented are expanding their product lines to include devices suited for lower frequencies. This Special Report will explore some of the reasons why diode technology continues to be a vital and exciting part of the RF world, refusing to slow down in its "old age."

For applications in the kHz to 2 GHz frequency range, there are five types of diodes which fill virtually all of the needs: varactors, PIN diodes, Schottky barrier types, noise diodes, and point-contact types. The new, highly publicized microwave and mm-wave devices (Gunn, avalanche, step-recovery, and IMPATT diodes, for example) have limited use at lower frequencies, and have little impact on RF designs. Laser diodes and other optical devices have an indirect relationship to RF as high speed data transmission takes place at MHz rates.

With apologies to readers who are quite familiar with RF diodes, here is a brief summary of the five basic types:

Varactor diodes take advantage of junction capacitance which varies with the amount of reverse bias. Charge-storage characteristics of these devices also make them good frequency multipliers.

PIN diodes are three-layer devices (P-doped, lightly doped or intrinsic, and N-doped materials). Basically, they operate as purely resistive switches, or as voltage-variable resistors. Low reactance and low "on" resistance make them good switches and attenuator components.

Schottky barrier diodes ("hot carrier diodes") use a metal-semiconductor barrier instead of P-N junction or point-contact. The result is a non-linear, fast-switching device with picosecond switching times and 1 or 2 pF capacitance. As near-ideal switches, they make good mixers and detectors.

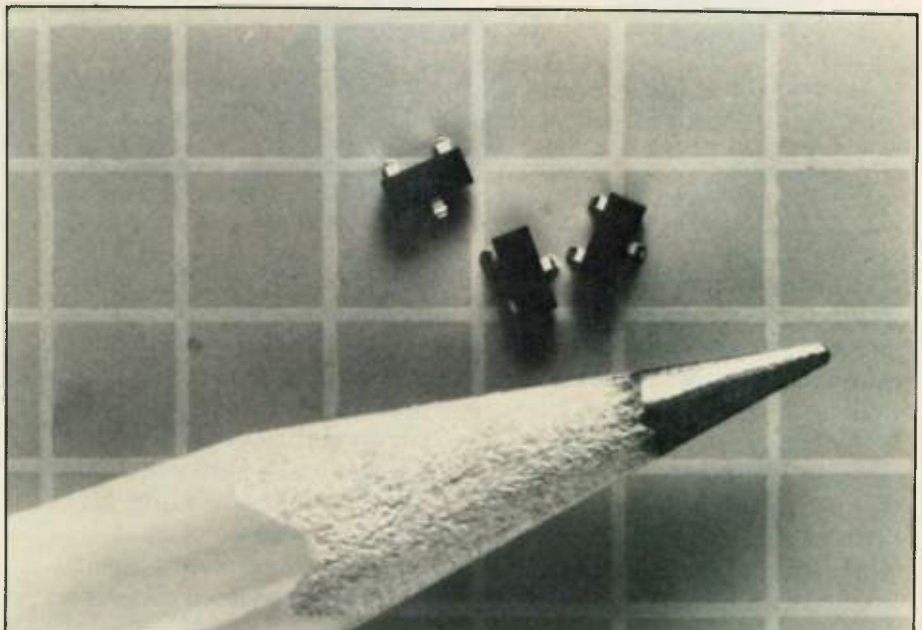
Noise diodes are devices enhanced to maximize the noise that naturally occurs in a conducting diode (particularly a Zener diode biased to its "knee" voltage). Noise diodes are specified by their excess noise ratio (ENR), the amount by which they exceed purely thermal noise output.

Point-contact diodes are truly "old standards", constructed by pushing a fine wire (usually gold) into a N-doped layer and alloying the junction with an electric current. They are low-capacitance devices, still used quite extensively, but usually replaced in new designs by Schottky barrier types.

There are certainly other RF diode types, but they are of limited use. Tunnel diodes, backward diodes and others may still exist in a few specialized designs, but for the most part, their functions have been superseded by the types listed above.

Packaging is Primary

Packaging is at the top of the list in RF diode activity. Designers are using innovative construction techniques to enhance the performance, size and cost of their RF products, which forces component manufacturers to provide their products in the right configurations. The principal techniques which are being seen by the application staffs of diode manufacturers are



Surface-mount packaging is a topic of high interest among diode users. One package style is the SOT-23 package, shown in this photograph from Hewlett-Packard. These devices are Schottky diodes.

available at a given price, the better the product.

With these factors in mind, diode manufacturers are working hard to create products where the improved performance that is being demanded by designers does not come at too high a price.

New Applications are Creating an RF Boom

The optimism expressed among diode makers is based on the growth that they see happening in the RF market. Of the 10 or so diode manufacturers interviewed for this report, *none* of them saw anything but growth in their RF markets. Much of this growth is coming from new applications of RF, rather than growth in any one or two existing areas. Some of the new applications are:

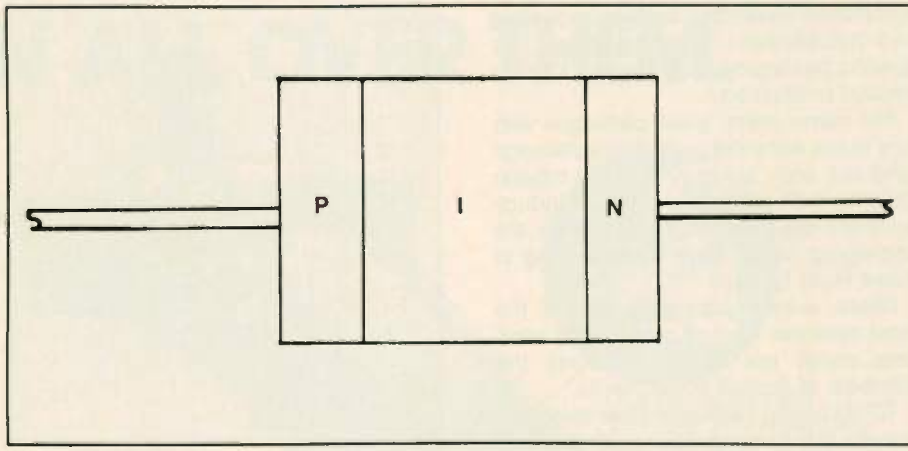
- Frequency-agile radios (spread-spectrum or frequency hopping), which require switched or tunable filters and high performance VCOs.
- Phased-array radar, with transmit/receive switching and phase shifter requirements.
- Built-in test systems (BITE) using noise diodes for test signals.
- Medical imaging and treatment equipment requiring switching for pulse-shaping and cut-off during imaging detection.
- QPSK and other modulation techniques for local area networks operating with RF modems or optical fiber links.
- High power radio equipment with PIN-switched elements.

There is no engineer who cannot say he wished he had a device that did its job better! Wider tuning range varactors, better Schottkys, higher power PINs, noisier noise diodes, and lower voltage drop detectors are all on engineers' wish lists.

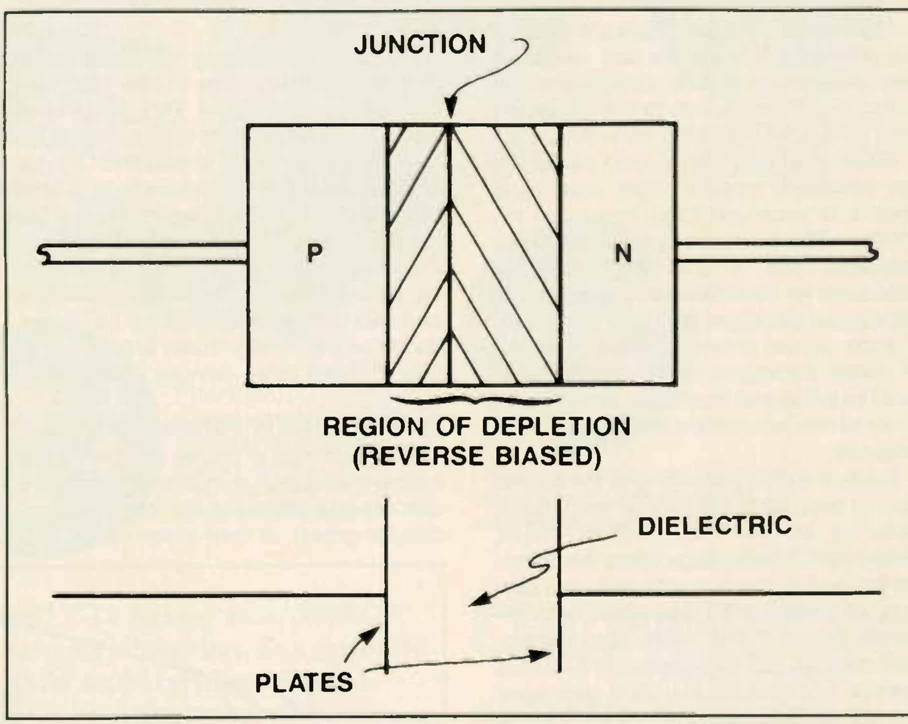
While this wide diversity of applications prevents the manufacturers from picking a certain technology to aim their marketing efforts at, it guarantees that development of diodes will be strongly customer-driven. Perhaps this is the most important information in this Special Report: *Although a mature technology, diode products continue to grow in response to the needs of their customers.*

Future Trends

We are already in the future in many ways. The basic physics of diodes is well understood from DC through RF. No new diodes have recently been discovered for RF, and no fundamentally new principles are being investigated for production. Microwave and mm-wave diodes are still under development and can spin off some precision manufacturing ideas to the lower frequencies.



PIN diode construction: With a P-region diffused onto one side of a silicon wafer and an N-region onto the other, a very lightly doped intrinsic region remains between them. When the diode is forward-biased the I-region is injected with electrons or holes from the doped regions, lowering the resistance of that region.



The varactor diode: The diode (top) in a reverse-biased condition exhibits a capacitance analogous to the parallel-plate capacitor (bottom). Varying bias voltage effectively changes the spacing between the plates by varying the extent of the depletion region.

There is one device yet to be manufactured for RF: the linear voltage vs. frequency varactor, with a capacitance curve of the right shape to obtain this tuning characteristic. Even this represents a refinement of existing technology, and devices have been prototyped and evaluated. Designers will soon have this item to work with.

The future is now, since the processes of economical manufacturing, customer requirements for packaging and price, and the use of diodes in a growing number of applications represent a very visible trend which should continue for a long time. rf

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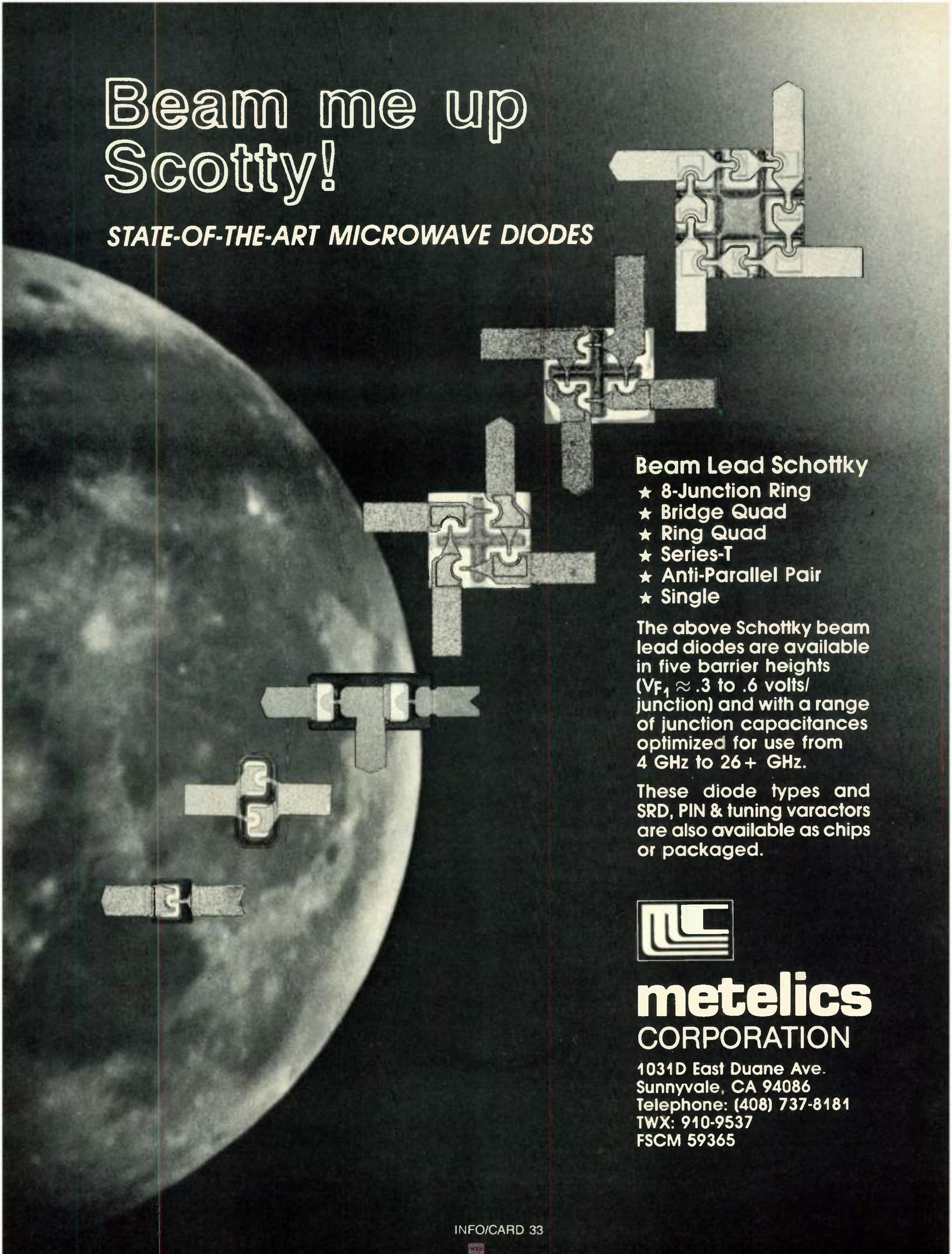
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A Varactorless VCO

Analysis and Performance Characteristics of Oscillators Utilizing Voltage-Dependent Transistor Junction Capacitances

By George D. O'Clock, Jr., Howard V. Kill,
Gregory T. Erickson, Mankato State University, and
Larry Reutzel, E.F. Johnson Co.

The term "voltage controlled oscillator" (VCO) usually brings to mind a variety of transistor oscillator configurations which are tuned by one or more varactor diodes (1, 2, 3). In contrast to this month's Special Report featuring diode technology, this article presents an analysis of oscillators which do not use varactors. The authors' research into the behavior of oscillators which are tuned using the junction capacitances of bipolar transistors provides new insight into the operation of RF transistors, even beyond their use as oscillators, through the characterization of these capacitances.

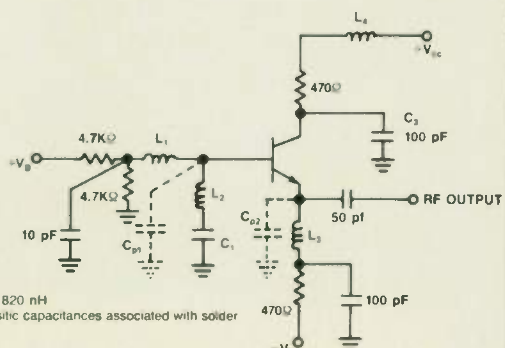
Varactor diode tuning is often utilized in voltage controlled oscillator (VCO) applications where fast tuning characteristics, minimal hysteresis problems, small size and light weight are prime requirements. However, other forms of reactance tuning are available to provide frequency control for VCOs. Several candidate techniques are available to provide oscillator frequency control by utilizing voltage sensitive variations associated with the input or output capacitances of certain bipolar transistors. These parametric variations are useful in other applications such as transistor frequency multipliers (4). On the other hand, the parametric variations can be a problem for amplifier circuits because they produce spurious outputs in Class A amplifiers at high input levels (5).

Figure 1 shows the schematic of a varactorless VCO utilizing a modified Clapp oscillator configuration (6), together with some data on type of transistor, circuit values and operating frequencies. A modified Colpitts VL-VCO has also been evaluated (7), but the modified Clapp VL-VCO provides certain advantages over the modified Colpitts circuit. The modified Clapp VL-VCO offers both base and emitter voltage tuning and it also appears to yield a more linear and reproducible tuning characteristic above 200 MHz.

Equation (1): Impedance Matrix.

$$Z = \begin{bmatrix} \{j\omega(L_2 + L_3) - j/\omega C_{be} + R_b\} & \{j/\omega C_{be} - R_b\} & \{j\omega L_3\} & \{j\omega L_2\} \\ \{\beta R_c + R_b - j/\omega C_{be}\} & \{j/\omega C_t - (\beta + 1) R_c - R_b\} & \{-R_c\} & \{0\} \\ \{j\omega L_3 - \beta R_c\} & \{R_c (\beta + 1)\} & \{R_c - j/\omega C_3 + j\omega L_3\} & \{0\} \\ \{j\omega L_2\} & \{0\} & \{0\} & \{j/\omega C_{p1} - j\omega L_2\} \end{bmatrix}$$

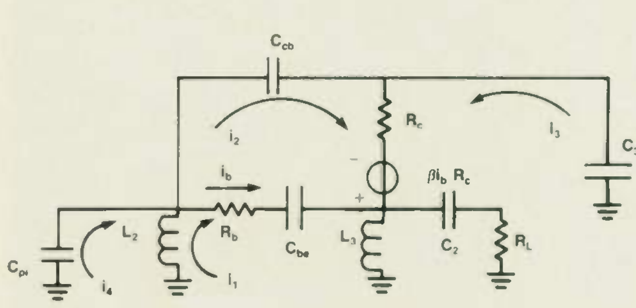
where: $C_t = C_{be}$ and C_{cb} in series.



- L_1 and L_4 — 680 — 820 nH
- C_{p1} and C_{p2} are parasitic capacitances associated with solder pads

L_2, L_3	Transistor	C_1	Frequency of Oscillation
120 nH	2N4124	470 pF	310 MHz
70 nH	MRF 901	470 pF	700 MHz
50 nH	MRF 901	470 pF	800 MHz

Figure 1. Modified Clapp varactorless VCO (VL-VCO).



- $i_b = i_1 - i_2$
- R_L very large
- Parasitic capacitance C_{p2} and case capacitance not included.

Figure 2. Modified Clapp oscillator circuit equivalent.

Analysis

The equivalent circuit of the modified Clapp VL-VCO is shown in Figure 2. Analysis of the modified Clapp VL-VCO, based on the equivalent circuit shown yields the impedance matrix shown in equation (1) on page 41.

Assuming a β approximately equal to 1 and R_c very large, the impedance matrix yields the following solutions for the modified Clapp oscillator output frequency:

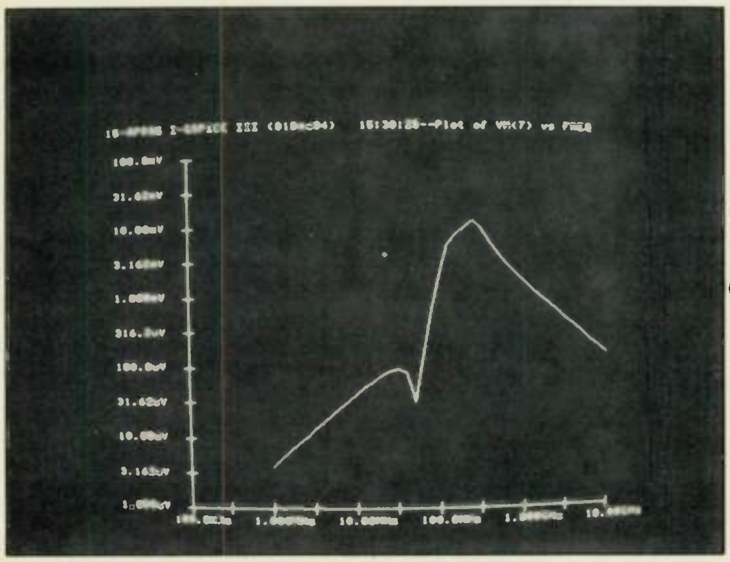
$$f_o \approx \frac{1}{2\pi}\sqrt{\frac{1}{L_2\,C_{be}}} = \sqrt{\frac{1}{L_2\,C_{P_1}}} \qquad (2)$$

where: $L_2 \approx L_3$ and $C_{be} \approx C_{P_1}$.

Computer Models

Computer models for a modified Colpitts VL-VCO and a modified Clapp VL-VCO were generated to obtain information on the sensitivity of the oscillator circuits to variations in output impedance and component aging.

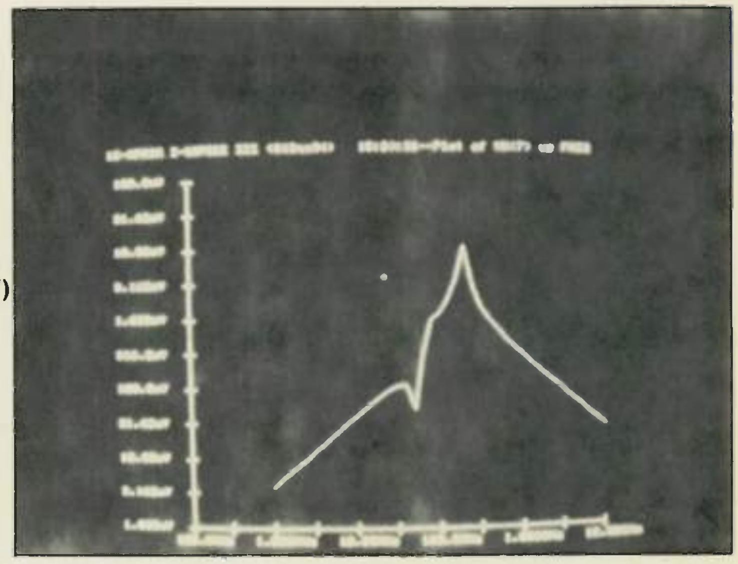
Figure 3 shows the results of a SPICE 2 computer analysis for a modified Colpitts VL-VCO (Figure 3(a) and 3(b)) and the actual output from the oscillator circuit (Figures 3(c) and 3(d)) under conditions where the load capacitance has changed from 10 pF to 100 pF. The 10 pF output capacitance tends to promote a relatively low-Q response (Figure 3(a)) resulting in a relatively gradual slope in the upper part of the output vs. frequency characteristic. The low-Q response tends to produce an oscillator waveform that has a high level of harmonic content and a tendency to pass low frequency spurious outputs (Figure 3(c)). A higher capacitance yields a relatively high-Q response (Figure 3(b)) that produces a lower frequency oscillator signal and a



V_o (mV)

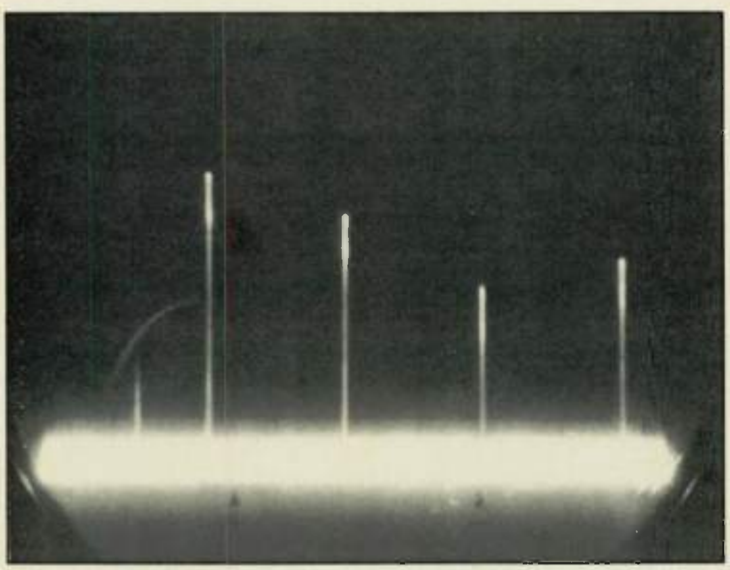
1.0 10 100 1000 f (MHz)

Figure 3(a). Response of modified Colpitts VL-VCO with 10 pF capacitance across load (SPICE 2 model).



1.0 10 100 1000

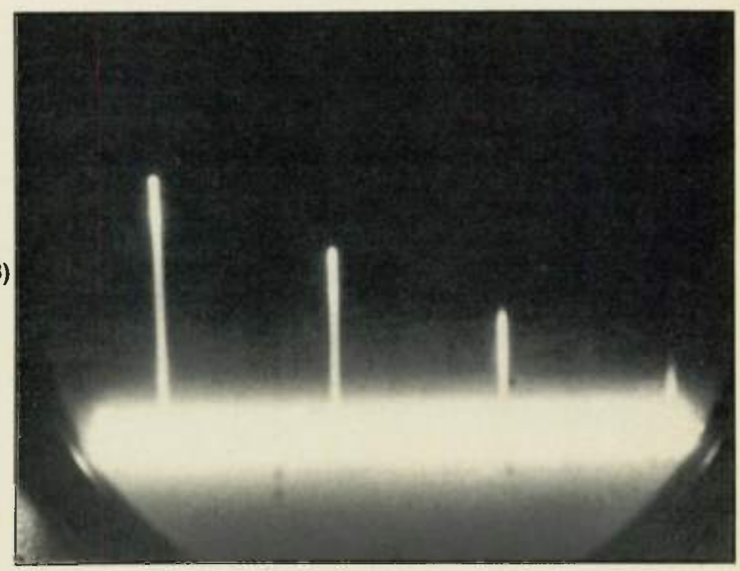
Figure 3(b). Response of modified Colpitts VL-VCO with 100 pF capacitance across load (SPICE 2 model).



P_o (dB)

220 450 900 1350 1800 f (MHz)

Figure 3(c). Actual response of modified Colpitts VL-VCO with 10 pF capacitance across load.



310 620 930 1240

Figure 3(d). Actual response of modified Colpitts VL-VCO with 100 pF capacitance across load.

relatively steep slope in the upper part of the output vs. frequency characteristic. This response tends to produce an oscillator waveform that has a lower level of both harmonic content and low frequency spurious outputs (Figure 3(d)). The SPICE 2 computer analysis for the modified Colpitts VL-VCO predicts the response of the oscillator quite accurately with respect to changes in parameter or component values.

Performance

Figure 3 shows the fundamental and harmonic output for a modified Clapp VL-VCO. Figure 4 shows the FM spectra of the output at two different base bias voltage settings.

The variation of frequency with respect to base-bias control voltage can be derived for the modified Clapp VL-VCO:

$$\frac{df}{f} \approx -\frac{1}{2}\frac{dC_{be}}{C_{be}} \quad \text{(f is the frequency of oscillation)} \qquad (3)$$

and

$$K = \frac{df}{dV_B} \approx -\frac{D}{4}\frac{f}{(V_1 - DV_B)}, \quad \text{(frequency deviation constant)} \qquad (4)$$

for,

$0 < DV_B < V_1$

(D is the ratio V_{be}/V_B associated with the voltage divider network in the base circuit.)

Figures 4(a) and 4(b) show the FM spectra of a 450 MHz modified Clapp VL-VCO using the base circuit as the input for frequency modulation. The frequency response curve for this particular oscillator indicates a frequency response slope of approximately 10 MHz/V using V_B as the frequency control parameter (See Table I). If $D \approx 0.05$, $V_1 \approx 0.7V$, $V_B \approx 2V$ and $f \approx 450$ MHz, Equation 16 indicates that df/dV_B should be approximately 10 MHz/V. This agrees closely with the measured data of Table I.

TABLE I
Measured performance data for several modified Clapp varactorless VCOs

f (MHz)	$\frac{df}{dV_E}$ (MHz/V)	$\frac{df}{dV_B}$ (MHz/V)	$\frac{df}{dT}$ (MHz/°K)	P_o (mW)
310	0.6-4	6-12	0.1	10
450	2-10	5-11	—	10
625	3-12	2.5-7.5	0.6	10
1,250	5-15	3-6	—	12.5
1,640	20-24	2-4	—	8

The VL-VCO modulation indices shown in Figures 4(a) and 4(b) can provide data that will yield the magnitude of the VL-VCO frequency deviation constant along with providing information on the frequency response characteristics of the VL-VCO input circuit. The FM modulation index (m_f) is a function of the frequency deviation constant (K), the attenuation coefficient (α), modulation frequency (f_m) and VL-VCO base modulation voltage (V_B):

$$m_f = (\alpha K)\, V_B/f_m, \qquad (5)$$

where α is the attenuation coefficient due to the frequency response of the VL-VCO modulation input circuit. In this case, α will vary with f_m. Considering the modulation indices shown in Figures 4(a) and 4(b), assuming 10 MHz/V for K and a V_B of approximately 2V, the attenuation coefficient for this circuit at a modulation frequency of 3.23 MHz is approximately 0.08.

The data concerning df/dV_B of Table I does not appear to agree with Equation 4. Equation 4 indicates that as the center frequency increases, df/dV_B should also increase. Table I shows just the opposite. However, if Equation 4 is examined closely along with the circuit of Figure 1, it is quite clear that the parameter D will be frequency sensitive and can decrease with an increase in frequency of oscillation. As the frequency of oscillation increases, variations in the transistor input impedance can cause significant reductions in the magnitude of D.

The performance of several VHF VL-VCOs utilizing UHF transistors emphasized the importance of selecting the proper transistor for a specific operating frequency. If a UHF transistor is utilized in the VHF operating frequency range, C_{be} may not be large enough to provide a significant tuning bandwidth (7). In other words, if the operating frequency range is at VHF, a VHF transistor is the appropriate choice, and at UHF, utilize a UHF transistor.

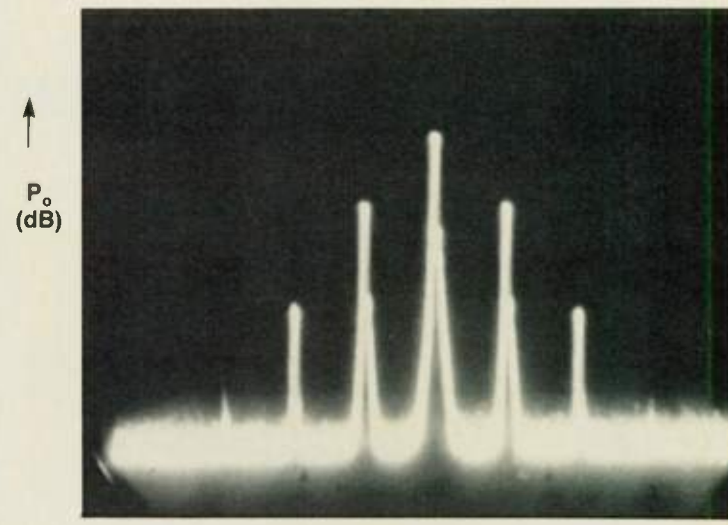


Figure 4(a). Spectral output for the 450 MHz modified Clapp oscillator using the base bias for frequency modulation. Modulation index is 0.5, modulation frequency is 3.23 MHz. Scale: 3 MHz/div.

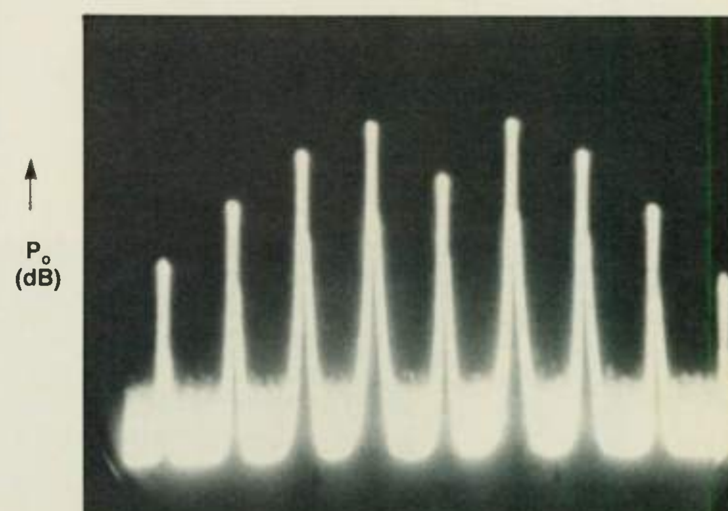


Figure 4(b). Spectral output for the 450 MHz modified Clapp oscillator using the base bias for frequency modulation. Modulation index is approximately 2.15, modulation frequency is 3.23 MHz. Scale: 3 MHz/div.

The modified Clapp VL-VCO was evaluated at frequencies ranging from 120 MHz to 1.9 GHz. At frequencies below 500 MHz, output powers were typically 10 mW to 20 mW with collector bias voltages of 10 V to 15 V. Supply currents were typically 10 mA to 15 mA. DC to RF conversion efficiencies ranged from 7% to 20% and total harmonic distortion was typically less than 12%. The reproducibility for the modified Clapp VL-VCO tuning bandwidth curve from one oscillator to the next appears to be within ±3% over the linear portions of the tuning curve.

One of the more important aspects of circuit layout was the relationship between spurious outputs and distance between components. The more closely packed VL-VCOs tended to produce higher levels of spurious outputs and frequency drift than those that allowed for wider spacing between components.

The VL-VCOs were fabricated using microstrip techniques. Chip resistors, capacitors and inductors were utilized in each circuit. The inductor values ranged from 100 nH to 240 nH, the inductor consisting of a very fine wire wound around a ceramic chip. Removing the inductors (L_2 and L_3) and replacing them with a short section of microstrip transmission line increased the output frequency response from the 350 MHz to 650 MHz range to the 1.1 GHz to 1.9 GHz range.

Acknowledgements

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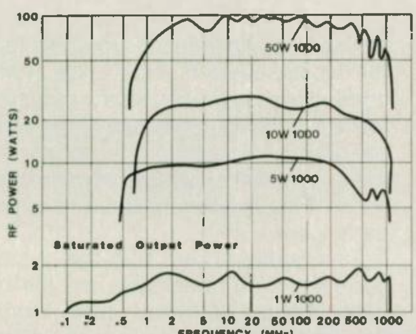

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A Coordinate Conversion and SWR Nomogram

By Vaughn D. Martin

This nomogram should prove to be valuable for the engineer who requires quick information to assist with designs or modifications. All that is required is a pencil, straightedge, and an inexpensive compass. The nomogram enables admittance values in rectangular coordinates to be converted to impedances in polar coordinates with accompanying phase angles. Additionally, standing wave ratios (SWR) can be found on a transmission line of known characteristic impedance Z_o with a mismatched load. This particular nomogram was developed for 50 ohms; however, any impedance may be used and a procedure is included showing how to convert this to another characteristic impedance. The accuracy of this graphical method is typically better than 98 percent.

Let's look at a typical circuit and make some calculations and try to verify them graphically by use of this nomogram. The circuit in Figure 1 has the following parameters:

$R = Z_R = 50$ ohms

$G_R = 20$ millimhos

$C = 0.8\mu F$

$X_c = 1/j\ (2\pi fC) = 1/j\ (19.90)$ ohms ($f = 10$ kHz)

$B_c = 1/Xc = j\ 50.24$ millimhos

$L = 2$ millihenry

$X_L = j\ (2\pi fL) = j\ 125.6$ ohms ($f = 10$ kHz)

$B_L = 1/X_L = 1/j\ 125.6 = -j\ 7.96$ millimhos

$Y = G + jB = 20 + j\ 50.24 - j\ 7.96$ millimhos $= 20 + j\ 42.28$ millimhos

Now refer to the nomogram (Figure 2). Notice that admittance is represented by the hypotenuse of the right angle in which conductance is the base and susceptance is the altitude. But there are numerous situations in which it is more useful to have the admittance expressed in polar coordinates. This is accomplished graphically as follows:

First, strike an arc with the compass corresponding to and through the complex admittance, in this case A on the nomogram. This arc's origin should be at 0 on the nomogram. Note where this arc passes through the conductance or X axis on the nomogram. This point, which we

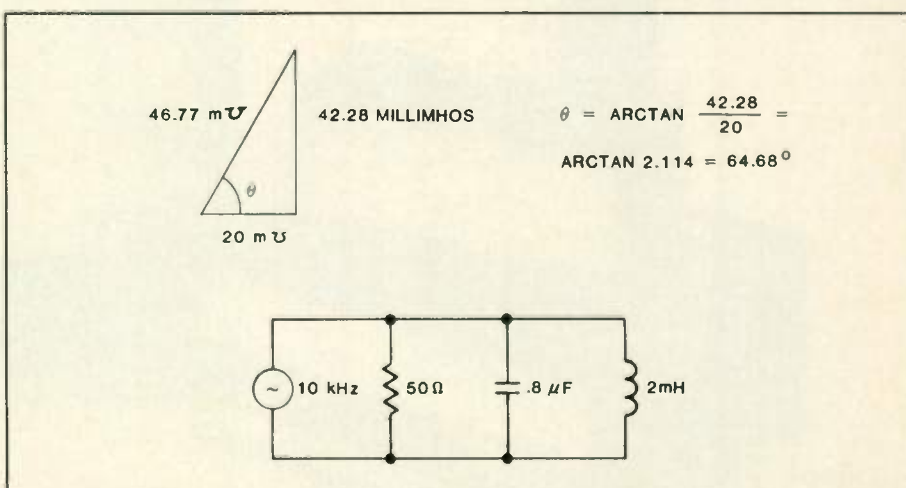

Figure 1. Calculation circuit schematic.

shall call B, is the admittance. The impedance or reciprocal quantity of this is represented by drawing a vertical line directly from B and extending it to point C on the impedance scale. Point C here should be the reciprocal of 46.77 millimhos or 21.38 ohms, and it is. To find the phase angle, extend a line beginning at the nomogram's origin through Point A until it strikes the upper X axis representing admittance in millimhos. This point, which we shall call point D, represents the phase angle.

If the value of susceptance is negative, in the rectangular coordinate form, the polar version is plotted in exactly the same manner as just described, you need only to change the sign of the angle to a negative sign.

The preceeding has been a conversion procedure for rectangular to polar, but you can also convert from polar to rectangular

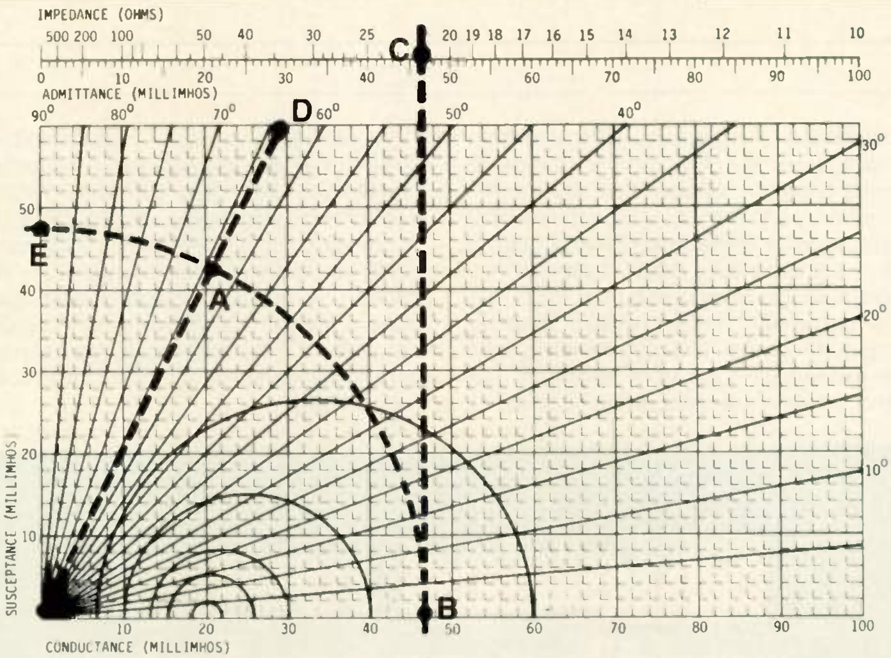

Figure 2. Rectangular admittance to polar impedance relationship (based on a nominal $50\Omega Z_o$)

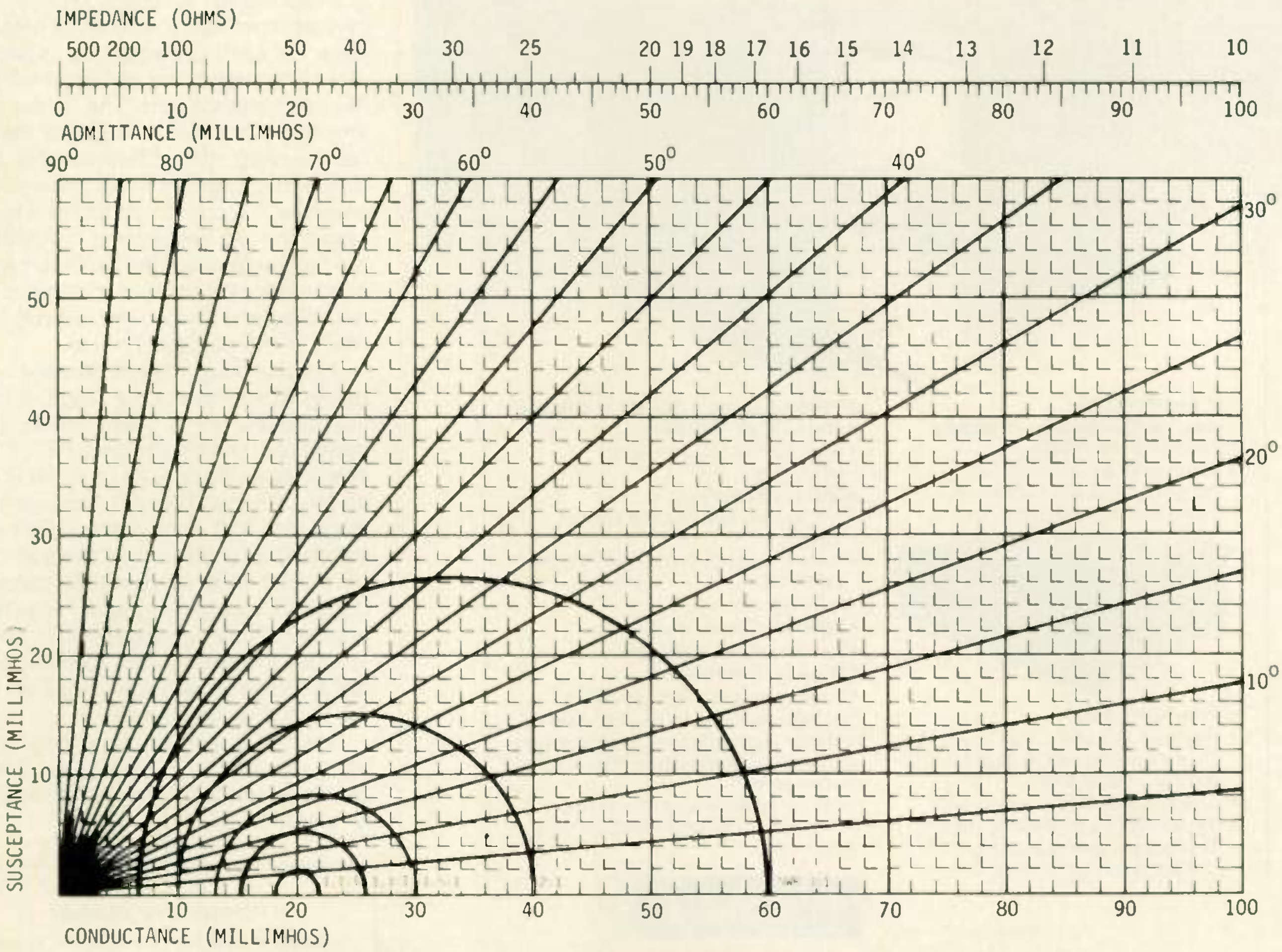

Figure 3. Rectangular admittance to polar impedance relationship (based on a nominal $50\Omega Z_o$)

coordinates. First, draw a vertical line from point C, representing the impedance, to point B on the X-axis. Then strike a 90° arc from point B to point E on the vertical axis, again with the center point of this arc at the nomogram's origin. Lastly, with a straightedge, draw a line from the origin to the known phase angle (point D) at the top of the graph. The admittance is read in rectangular form from where the arc and this line intersect, namely point A.

As previously noted, it is also possible to find SWR with this nomogram. Note the semicircles sweeping out from the 20 millimho (50 ohm) point on the conductance axis. These are lines of constant SWR for a transmission line with Z_0 = 50 ohms. If such a transmission line should have a load of 100 ohms, then its SWR would be 2. The reciprocals naturally of 50 and 100 ohms are 20 and 10 millimhos, respectively.

The 20 millimho point on the conductance axis represents the 50 ohm characteristic impedance; the load resistance's conductance of 10 millimhos at point F, is one end of the semicircle for SWR = 2. The other end of the semicircle at 40 millimhos (point G), corresponds to a load of 25 ohms.

For loads that are not purely resistive, the compass is again used. For example, if the point A is the load admittance, the arc through that point centered on the origin (just as in the coordinate conversion) cuts the conductance axis at point B. This is about a third of the way between the semicircles for SWR = 2 and SWR = 3 which would translate into a slightly greater than 2.33 SWR. Actually, refer to Figure 1 and note that a 46.77 millimho admittance is a 21.38 ohm impedance. Therefore, if the 50 ohms is divided by 21.38 (50/21.38) it yields a 2.338 SWR. This is indeed close to the graphical result of 2.333 SWR, validating the accuracy of the nomogram.

Other sets of semicircles can be drawn corresponding to characteristic impedances other than the 50 ohms presented here. For each characteristic impedance of a transmission line, its center will lie on the conductance axis. The center of the smallest semicircle is exactly at the point representing the characteristic impedance. Each successively larger circle is centered at a coordinate which is half the sum of the two intercepts of the circle with the horizontal axis. The two intercepts, in turn, are the characteristic conductance, multiplied and divided respectively by the SWR of the particular circle.

If all of this sounds complicated or confusing let's try examples which will make this clearer. For a characteristic impedance of 50 ohms and an SWR of 3, the intercepts would be G times 3 and G divided by 3. This is 60 and 6.7 so one-half of this sum is 33.3. For a characteristic impedance of 75 ohms and an SWR of 2.5 we have 13.33 times 2.5 and 13.33 divided by 2.5 for 33.3 and 5.33, respectively. Taking one-half of this sum yields 19.315 and this is where the center of the 75 ohm characteristic impedance circle would fall upon the X-axis (conductance).

Figure 3 is a plain nomogram uncluttered with arcs and straight lines. Permission is given to reproduce the nomogram for personal use. rf

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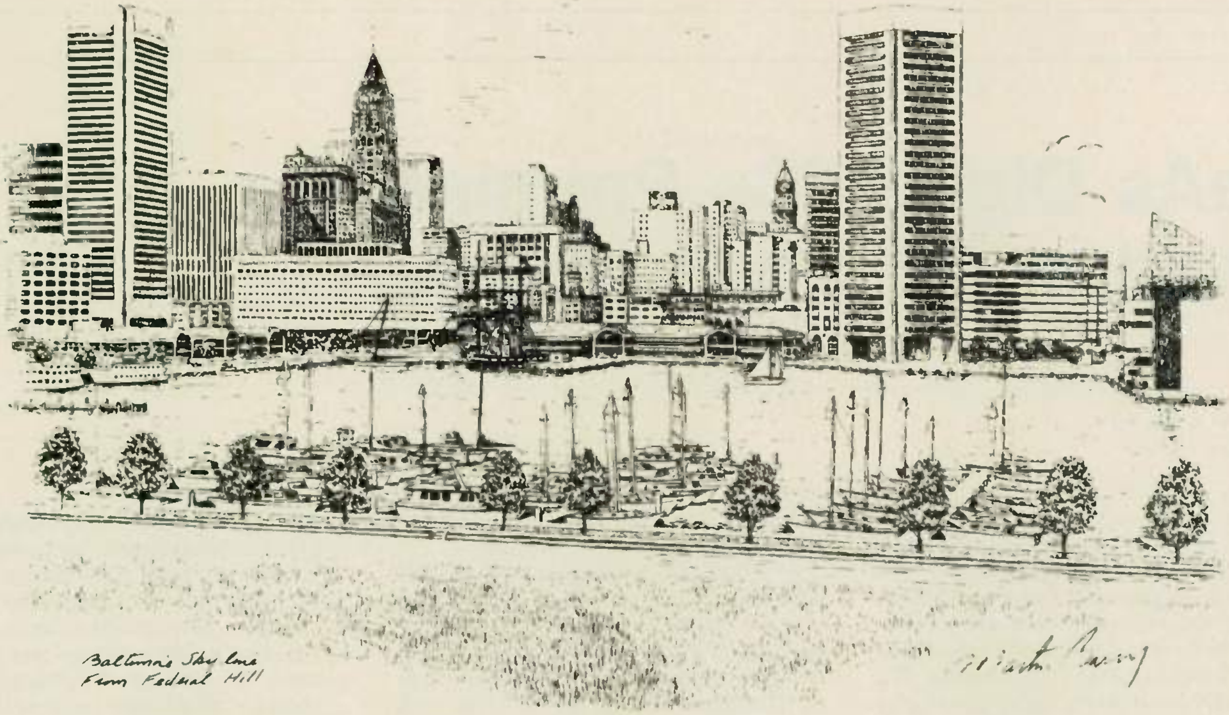

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INFO/CARD 37

GaAs Digital ICs Promise Exciting RF Applications

By Gary A. Breed
Technical Editor

Speed. . .clock rates up to 3 GHz for currently available products — is the calling card of gallium arsenide (GaAs) digital integrated circuits. Even purely digital applications require RF design and construction techniques at these speeds, creating an interdependence between digital and RF technologies. GaAs digital ICs have been available for about a year, and development is still in the early stages. Now is the time for engineers to understand their importance for RF applications, to begin the development of those applications alongside the technology that will make them possible.

Several inherent advantages of GaAs material have provided the impetus for rapid development. The products available now have demonstrated the speed advantage of GaAs over silicon, and begin to exploit other advantages. Mother Nature defines the properties of materials, and she has given GaAs high electron mobility for speed, a semi-insulating nature for fabrication ease, and a wide band-gap for built-in radiation hardness and high temperature operation.

Also on the plus side are compatibility with established fabrication techniques, and the potential for much lower power consumption than emitter-coupled logic (ECL). Analog and digital functions can be fabricated on the same chip, with possibilities for a wide range of RF-related applications.

Current depletion-mode MESFET realizations have the main disadvantage of complexity, requiring three (or more) power supply voltages in a circuit which interfaces with ECL. It is likely that some of these voltages will be generated on-chip in later versions, and that future developments will minimize the need for multiple power busses. Other disadvantages are all related to speed/frequency, including packaging difficulties, uniform performance specifications, and the cost of manufacturing devices which need decoupling at the chip and require expensive microwave test systems.

RF Applications

Although manufacturers of GaAs digital ICs like to characterize their components as part of the next supercomputer, it is more likely that RF applications will be some of the first production items. Among the devices available are dividers and prescalers for frequency synthesizers or counters. Comparators, memories, shift registers, and various logic gates are applicable to many signal processing schemes, as are the analog-to-digital (A/D) and digital-to-analog (D/A) converters that are under development. Custom gate arrays or standard-cell arrays allow design flexibility.

Frequency synthesizers are obvious beneficiaries of high-speed logic. As shown in Figure 1, a 3 GHz synthesizer is greatly simplified when the VCO does not require multiplication to a final operating frequency. Every multiple of the VCO frequency adds 6 dB phase noise to the output signal, so the direct synthesis circuit will be cleaner, as well as simpler.

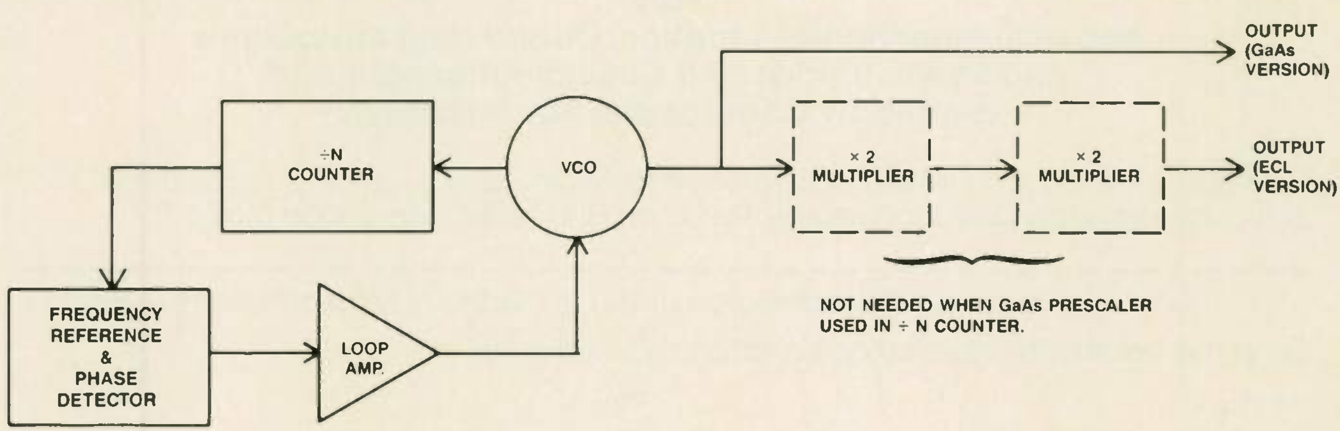


Figure 1. A 3 GHz phase-locked loop (PLL) frequency synthesizer. Using only ECL logic in the ÷ N counter, the maximum VCO frequency is around 750 MHz, requiring multipliers to obtain the final output. With GaAs devices in the counter, the VCO can operate at the desired output frequency.

Direct digital synthesizers will undoubtedly follow from the development of GaAs D/A converters and memory devices. Gigabit Logic will introduce a 256 × 4 random access memory (RAM) this year, and already has developed comparators which could serve as the basis for D/A and A/D products.

Frequency counters and *frequency dividers* are obvious uses of GaAs prescaler and ripple counter ICs. As reported in the January 1986 issue of *RF Design* (p. 61), the Stanford Linear Accelerator Center (SLAC) utilized Harris Microwave Semiconductor devices in a ÷16 circuit to obtain a phase-coherent, triggerable 178.5 MHz signal from their 2856 MHz primary acceleration frequency. Before high-speed GaAs digital devices became available, this simply was not possible!

Digital signal processing (DSP) is easily the most exciting area where speed, digital logic, and RF applications come together. In general, complex signal processing has been limited to frequencies in the tens of MHz, but systems operating in the hundreds of MHz range will be possible very soon. Figure 2 illustrates a digital RF memory (DRFM) used in electronic counter measures (ECM) and electronic warfare (EW) applications. The ability to process the enemy signal at a higher frequency eliminates some IF complexity, reducing time delays and phase shifts, resulting in a more accurate response (and more effective countermeasures).

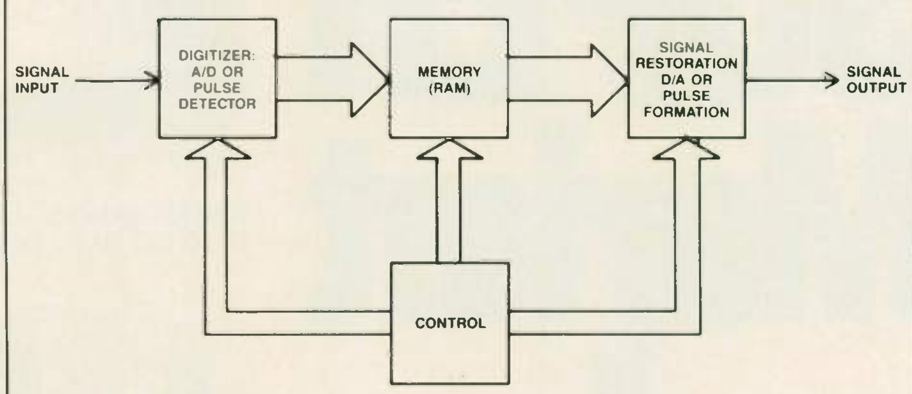


Figure 2. Digital RF memory (DRFM) system used in electronic countermeasures (ECM) applications. The received radar signal is modified and re-transmitted to alter an enemy's perception of the target.

Higher frequencies for digital modulation, demodulation, filtering and frequency or time-domain analysis will re-define the concept of an intermediate frequency (IF). A great deal of analog circuitry can be eliminated if fewer frequency conversion stages are needed in a design. Many applications will allow processing without frequency conversion, digitizing the signal at the operating frequency, performing all signal manipulation or analysis in the digital realm. Like the DRFM application, phase and time errors will be minimized in such a system. Currently, such direct digital processes are limited to about 20-30 MHz, maximum. Designers should be very excited about the possibility of extending that upper limit to 100 MHz and higher.

Industry Directions

GaAs digital technology may very well avoid many of the deadends, shakeouts, and surprises that confront every young technology. The companies developing GaAs technology have been cautious, partly due to the economic uncertainty in many aspects of electronics. Also, the main suppliers of GaAs digital products have tried to respond to customer requirements, rather than preparing products based only on their ability to produce them. TriQuint Semiconductor has chosen (at this point) to emphasize custom or semi-custom products. Other companies which have "standard" devices also emphasize their custom capabilities.

Another advantage that GaAs has is experience with the material itself: discrete components and analog ICs have existed for a longer time than the digital products, providing a base of information to build on.

The future of GaAs is very exciting. The depletion-mode technology used now is not the highest performance type of device which can be constructed on a GaAs wafer. The next step is enhancement-mode devices, which will offer similar speed with lower power consumption when used in combination with depletion devices.

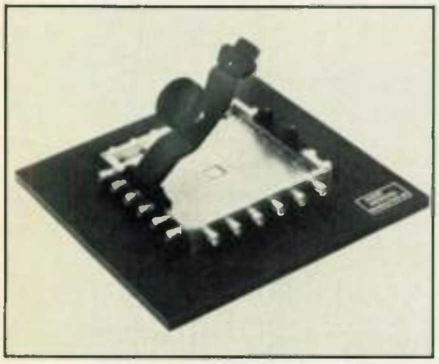
Both Gould and AT&T Laboratories have developed high electron-mobility transistors (HEMT), which utilize those characteristics of GaAs material which are its greatest advantage. In time, these techniques will be developed at the integrated circuit level and offer another level of speed performance. Investments in these development efforts are substantial, indicating faith in the technology by a large number of companies.

Gallium arsenide digital ICs represent a truly hybrid technology, offering speed formerly considered to be only in the realm of RF, and requiring RF design and construction techniques for applications which were formerly considered to be solely digital. rf

rf products

Fixture Tests GaAs ICs in Leadless Chip Carriers

Augat Microtec has introduced a series of test fixtures to accommodate GaAs leadless chip carrier devices. Originally designed for Triquint Corp. for use in testing their devices, the units are operational to 16 GHz. All signal lines, 20 or 24, are



coax construction. The fixture is offered as a complete assembly with Microtec's Polyimide multilayer board, thermal mounting plate, high frequency RF connectors and a positive locking device. The fixture exhibits such electrical characteristics as less than 2 pF capacitance and 2 nH inductance. **Augat Microtec, Newbury Park, Calif. INFO/CARD #176.**

Spectrum Analyzers Designed for Laboratory Use

Tektronix is announcing the 2754 and 2755 spectrum analyzers. These new analyzers are Tek's first spectrum analyzers designed specifically for the system environment. These new spectrum analyzers have center and marker frequency accuracy of 1×10^{-5}, and a frequency range of 50 kHz to 21 GHz, and resolu-

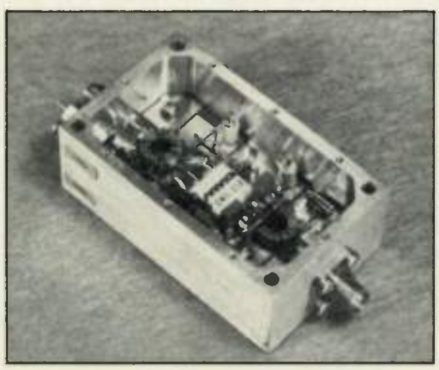
tion bandwidth of 1 MHz to 1 kHz. The 2755 covers up to 325 GHz with external mixers. The 2754 and 2755 have built-in signal processing and markers for easy repeatability, accuracy, speed and ease-of-use. The 2754P and 2755P versions are GPIB Programmable, the 2754 starts under $23,000 and the higher-performance 2755 under $30,000. **Tektronix, Inc., Beaverton, Ore. INFO/CARD #175.**

Video Amplifier Hybrid Has 2.9 nS Rise/Fall

TRW RF Devices introduces its new Hybrid Video Amplifier with 2.9 nS rise and fall time with a 40V output video signal. This amplifier provides a low power dissipation solution to achieving video amplifier speed. Many of the 1280 × 1024 pixel, 64 kHz horizontal sweep rate CRTs that are used in CAD/CAM and high resolution graphics have not realized their potential performance because of the speed of their video amplifiers. The TRW CR2424 and CR2425 solve these problems with a compact package design mounted on a heatsink. At 5000 piece level, the price of the CR2424 and CR2425 is $25.00. **TRW, RF Devices Div., Lawndale, Calif. INFO/CARD #174.**

Receiver Amplifier Modules Feature Ultra-High Dynamic Range

The HDM family of amplifier modules combine a third order intercept point greater than +50 dBm with noise figures less than 4 dB, input/output VSWRs of



1.25:1, and gains of 15 dB. The modules are suited for HF/VHF multicouplers, distribution amplifiers, RF front end and first stage IF applications. **Microwave Modules & Devices, Inc., Mountain View, Calif. INFO/CARD #173.**

High Speed Memory Supports Digital Video Processing

NEC Electronics Inc. has announced two new high-speed image processing memories, the uPD41101 and the uPD41102, capable of storing digital video signals for one television scan line. The devices are available in 24-pin 300 mil plastic dual-in-line packages. They sample and store data at a frequency four times the color subcarrier frequency. The uPD41101 is a 910 word by 8 bit device intended for use in NTSC standard television systems. The uPD41102 is a 2,235 word by 8 bit device intended for use in PAL systems. Prices range from $20 to

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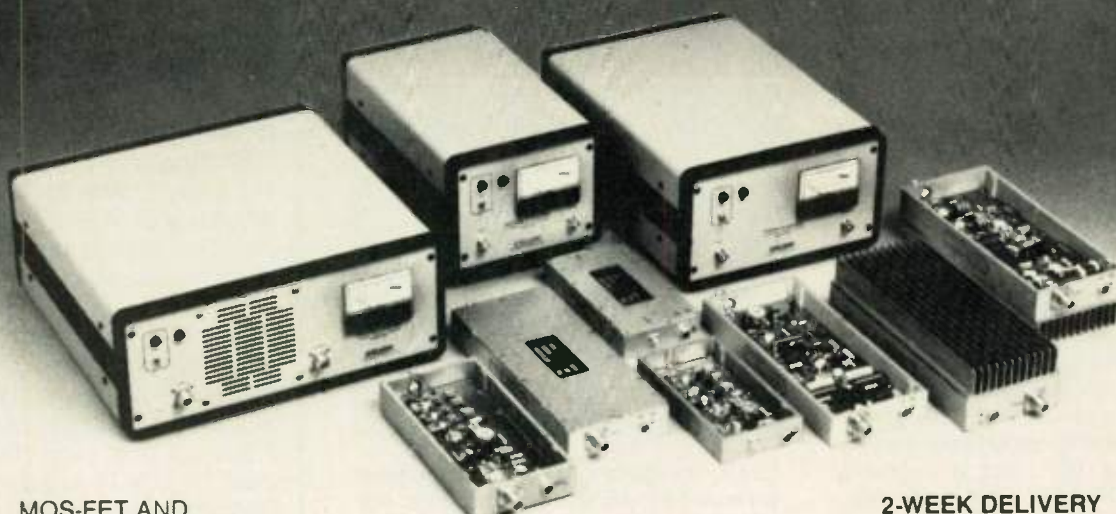

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NEW PRODUCT

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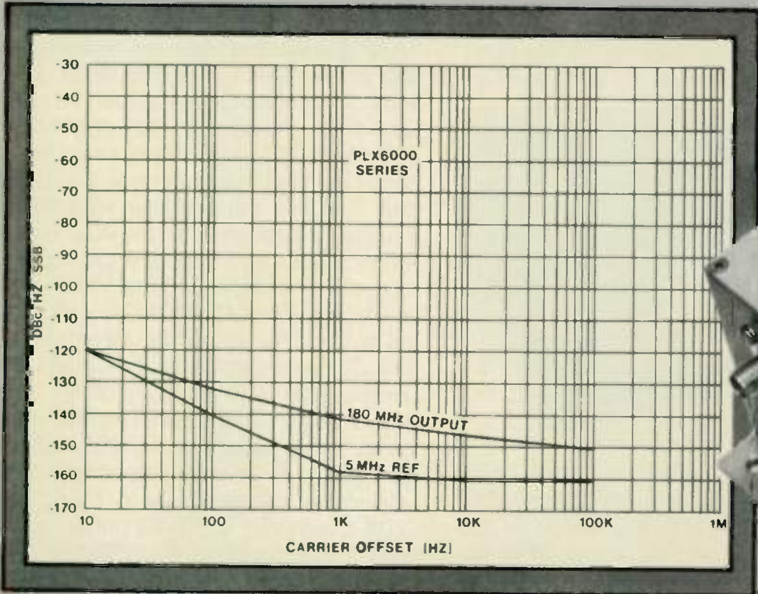

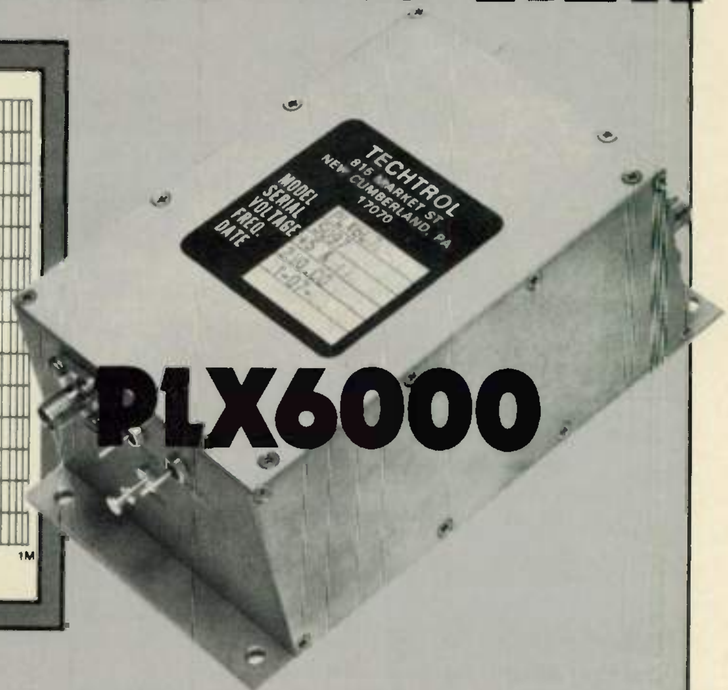

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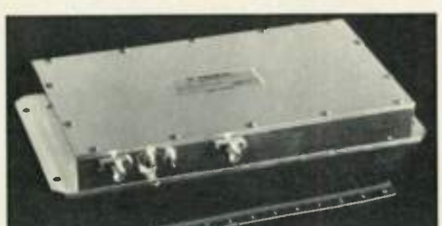
$35 each (100's), depending upon model and performance. **NEC Electronics Inc., Mountain View, Calif. INFO/CARD #172.**

Calibrated Attenuator Set Covers DC-18 GHz

JFW Industries, Inc. introduces their new DC-18 GHz calibrated attenuator set, model 50KFA-008. Each set is supplied with one each of a 3, 6, 10, and 20 dB attenuator with N connectors. Calibration data is supplied for each attenuator at DC, 4, 8, 12.4, and 18 GHz. Model 50KFA-008 sells for $385.00 (1-9 pieces). **JFW Industries, Inc., Indianapolis, Ind. Please circle INFO/CARD #167.**

SAW Subsystem Provides Spectrum Analysis/Signal Processing

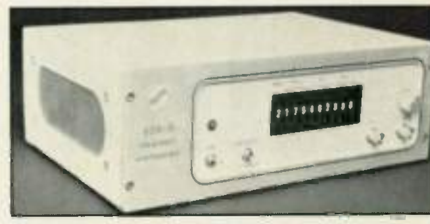
Model AS4-8-6.67 is a 32 point SAW Spectrum Analyzer Subsystem, with features such as frequency range (0-8 MHz), low power consumption (3.5 W), time sidelobes (30 dB), and small size (<20 in ^{3}).



It is particulary well suited for high speed signal processing or Doppler analysis when small volume and low power consumption are required. Manufactured by Thomson-Sintra France. $18,500.00 ea. (1-4). Delivery: five months. **Phonon Corporation, Simsbury, Conn. Please circle INFO/CARD #165.**

Synthesizer Offers High Resolution, Phase-Shifting

Sciteq's VDS-3 synthesizer (patent pending) offers a 0.36' per step phase-



shifting option in a basic unit which covers DC to 3 MHz in 1 milliHertz steps. Spurious performance is better than −55 dBc, and phase noise if > −136 dBc/Hz at 1 kHz offset. Phase-continuous switching is faster than 500 nanoseconds. Local control is via a thumbwheel switch, and remote is through a 38-bit BCD control word. IEEE-4888 interface capability is optional. Remote-controlled phase reset to 0' is standard. The VDS-3 is a true digital synthesizer, and while the signal is in the digital domain, data manipulation is inexpensive and very accurate. The VDS-3 design is vailable as an instrument or at board level for the OEM. Semi-custom products include upconversion to any center frequency up to 1 GHz. The VDS-3 is $1,995. IEEE-488 option is $500 and phase rotation is $500. **Sciteq Electronics, Inc., San Diego, Calif. Please circle INFO/CARD #162.**

Tempest Connectors Provide 90 dB Isolation

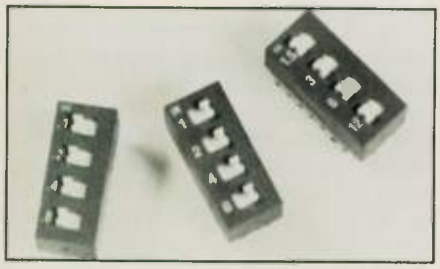
EMI filter connectors are offered in female BNC (Model SFC-101) and dB-25 format. The connectors include TEMPEST gaskets and ground lugs and afford an excess of 90 dB isolation down to 100 MHz. Insertion loss below 1 MHz is less than 5 dB. The dB-25 configuration, for RS-232 applications, is offered with both plug and sock or with either alone. These connectors are also available in various configurations per customer requirements. Prices begin at $25.00 for the SFC-101. **S.T. Research Corporation, Newington, Va. INFO/CARD #161.**

Software Provides Interactive RF System Design

SYSCAD 2.1 has been released by Webb Laboratories, providing antenna-to-hardware analysis of RF systems. Included in SYSCAD 2.1 are spurious product analysis, including the capability of generating a user-defined spurious look-up table; and a phase noise analysis which calculates phase and frequency jitter. The program runs on IBM-PC or compatible machines with at least 128 K RAM. **Webb Laboratories, North Lake, Wis. Please circle INFO/CARD #160.**

DIP Attenuators Designed for 75 ohm Broadcast Use

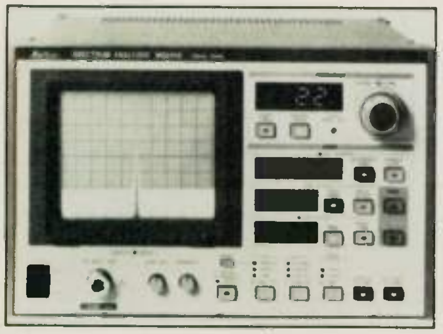
New 75 ohm Attenuator DIP Switches from Grayhill, Inc., are combined resistor networks/DIP switches designed for use in broadcast applications. The series 78 Switches provide 16-step attenuation in three dB ranges. Standard attenuation ranges include zero to 1.5 dB in 0.1 dB steps, zero to 15 dB in 1.0 dB steps and zero to 22.5 dB in 1.5 dB steps. Also available from Grayhill are 50 and 600 ohm impedance Attenuator DIP Switches.



The price for the 75 ohm attenuator is $7.25 (100's). **Grayhill, Inc., La Grange, Ill. INFO/CARD #159.**

Portable 10 kHz to 2 GHz Spectrum Analyzer is Inexpensive

An inexpensive wideband spectrum analyzer is currently available from Anritsu America, Inc. The MS610A, offers a GP-IB interface for remote operation, a coupling function for greater measurement efficiency, a marker for indicating



center peak values, digital display and a compact lightweight design. Measurement level range is –115 to +20 dBm, dynamic range is 70 dB, resolution bandwidth is 1 kHz to 1 MHz. The base price for the MS610A is $7,350. **Anritsu America, Inc., Oakland, N.J. INFO/CARD #158.**

Microwave Substrates For Thick Film Circuits

KDI Electronics has announced the availability of custom thick film microwave substrates. Product performance can be specified for frequencies from DC to 5.0 GHz. A variety of metalizations including gold, platinum gold, paladium silver and platinum paladium silver are available and can be intermixed. The thick film resistive portions can be resistors or attenuators in lumped or distributed configurations. Computerized laser calibration can provide accuracies to 0.1 dB. **KDI Electronics, Inc., Whippany, N.J. Please circle INFO/CARD #157.**

IF/RF Amplifiers Feature True Log Response

Log Tech, Inc. announces the introduction of the CLA/RF series of true IF/RF log amplifiers. Since the amplifiers use a direct logging technique and not successive detection, the output is a true logged representation of the input signal, allowing the RF pulse to maintain both its amplitude and phase response characteristics. The standard amplifier is a PC board mountable unit, 1.9 × .9 × .3 inches. The device exhibits input and output VSWRs of 2:1 and can be supplied with logging ranges from 20 to 80 dB, with a frequency range from 10 MHz to 1.3 GHz. The price range is $700 to $1,500, dependent upon requirements. **Log Tech, Inc., Newbury Park, Calif. INFO/CARD #156.**

Power Dividers Operate From 0.4 to 900 MHz

A series of wideband power dividers operating over the frequency range from .4 MHz to 900 MHz has been announced by WI-COMM Electronics Inc. All units are mounted in a die cast aluminum housing

with 4 or 8 output ports. Output to output isolation is 25 dB min., VSWR is 1.5:1 min., connectors are BNC female and maximum input power is 2 watts. **WI-COMM Electronics Inc., Massena, N.Y. INFO/CARD #155.**

System Tests Radiated EMP Effects

A low-cost radiated EMP test system, introduced by Amplifier Research, has been specially designed for testing of rack-mountable or similarly sized electronic subsystems. The Model EM 102 simulates electric-field conditions generated by full-threat high-altitude burst. The system's radiated-output characteristics meet requirements of MIL-STD-461C. The radiated field strengthof 80 kV/m is ample for simulation of high-altitude EMP for equipment hardening under this standard. The system's pulse generator (Model EM 103) is suited also for other EMP procedures, including direct and indirect cable and pin injection to 100 kV, using both damped-sine and exponential-decay waveforms. **Amplifier Research, Souderton, Pa. INFO/CARD #154.**

Synthesizer Generates 90-120 MHz in 0.1 Hz Steps

PTS introduces the PTS 120 Satcom Synthesizer, one of their line of direct synthesizers that cover 40 to 500 MHz. The PTS 120 is a generator of precision frequencies. It transfers the accuracy and stability of a frequency standard (built-in

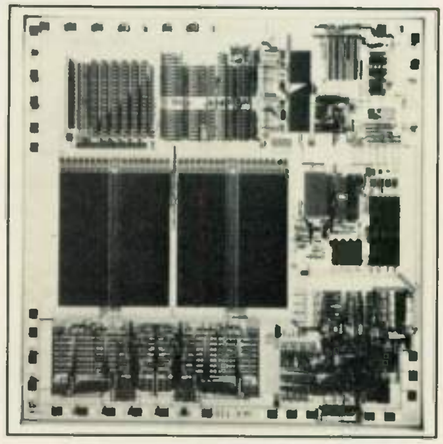
or external) to any output frequency between 90 and 120 MHz. Steps as fine as 0.1 Hz are available and all functions are remotely programmable. **Programmed Test Sources, Inc., Littleton, Mass. INFO/CARD #153.**

Software Features Comprehensive Filter Design and Analysis

An integrated package of programs has been designed by a filter consultant for filter people in the real, practical world. It covers virtually all phases of synthesis, design, analysis and optimization of linear AC networks (such as filters and equalizers), and can be used on almost any PC with at least 192 K of RAM, but works best on those which are IBM-compatible. Programs are not automatic, and require an experienced filter designer who is lready familiar with the forms, structures and capabilities of the components to be used. The package incorporates a large number of utility routines (root-finding, complex number, Foster network conversions, minimum-coil transformations). Price is $15,000 complete, including a week of on-site instruction. **William B. Lurie, Pompano Beach, Fla. INFO/CARD #152.**

DPS Chip Features Voice-Band Processing

A digital signal processing chip with architecture and instruction set optimized for voice-band processing is now avail-



able from Stantel Components. The DSP 128 Cascadable Real-Time Integrated Signal Processor (CRISP) is designed for use as a stand-alone processor, cascaded on a common system bus to provide multiprocessing, or it can be interfaced with general-purpose microprocessors. The chip includes an on-board DMA controller, two separate blocks of 256 × 16-bit word internal RAM, 16/32-bit microprocessor architecture, and 16-bit multiplication to

rf products Continued

provide full 32-bit product per instruction cycle. Price is $88.00 (sample qty.). **Stantel Components, Inc., Schaumburg, Ill. INFO/CARD #151.**

GaAs MMIC RF Switches Feature DC-2GHz Range

M/A COM Advanced Semiconductor Operations announces its new GaAs MMIC SPST and SPDT switches for operation up to 2 GHz. These RF switches (MA4GM201 and MA4GM202), use FET-based technology to reduce power consumption to near zero, while enhancing reliability. A series-shunt configuration combines broadband insertion loss with broadband isolation, plus adding multi-throw capability. Switching time is less than 3 nS, and intermodulation products are typically better than 50 dBm 3rd order intercept point. **M/A COM Advanced Semiconductor Operations, Lowell, Mass. INFO/CARD #150.**

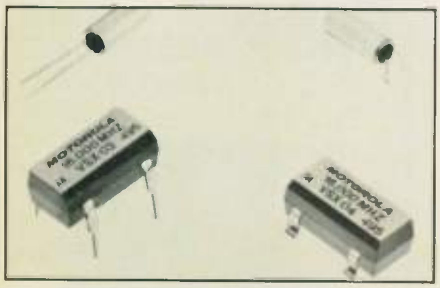
Test Kit is Offered

Dynaloy, Inc. has introduced the SM Series of one-component electrically conductive silver and silver alloy filled epoxy adhesives. The silver alloy SM 175 and

SM 160 offer lower cost than the SM 200 pure silver. The Dynaloy SM Series is available in 50, 500 and 5000 gram quantities as well as special order plastic syringes. The manufacturer is offering a test sample kit containing 50 grams each of the three versions now available, at $100.00 per kit. **Dynaloy, Inc., Hanover, N.J. INFO/CARD #149.**

Crystals Feature Auto-Inserting SMD and DIP Mount

The VSX crystal is available in four different configurations to suit application needs. VSX-01 is a 3 × 8 mm tubular crystal with standard 11 mm leads for through-hole insertion and minimum board space. VSX-02 features gull-wing leads for surface mounting and is available in carrier tape and reel. The VSX-03



crystal is compatible with 8-pin DIP mounting for through-hole applications. Surface mount version VSX-04 can be placed on surface-mount boards by automatic pick-and-place machines. It features gull leads. **Motorola Inc., Components Division, Franklin Park, Ill. INFO/CARD #148.**

SMA Adapter Provides Strong Flange Mounting

A bulkhead type SMA adapter is often not strong enough to retain a non-rotating position in a panel due to the small flat area on the bulkhead section. Flange mount connectors are used to give that added strength via two or four screws. Coaxial Components Corporation has introduced COAXICOM Models 3132-1 and 3145-1 which are two hole and four hole flange mounted SMA female to SMA female adapters. Construction is gold plated

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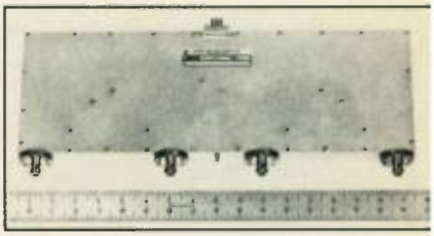
stainless steel. These adapters have a VSWR of 1.05 + .005f (GHz) through 18.2 GHz. **Coaxial Components Corp., Huntington, N.Y. INFO/CARD #147.**

4-Way High Power Combiner Operates at 1.7-1.9 GHz

Sage Laboratories has developed a specialized high-power, 4-way combiner (Model FP3812) capable of combining four 180 watt average power signals into 700 watts output. With the combiner body held at 85°C, the internal terminations of the first two combiners will each dissipate 150 watts without damage to the unit. The output combiner is terminated in a 50 ohm SMA connector to allow use of an external high-power load. The result is a high-power, 4-way combiner that operates without damage even with one of the input signals absent. Designed for the 1.7 to 1.9 GHz frequency range, typical performance specifications include a VSWR of less than 1.25:1, insertion loss of less than 0.2 dB, and an isolation specification of greater than 25 dB between inputs. **Sage Laboratories, Natick, Mass. INFO/CARD #145.**



rf literature

Crystal Filters and Oscillators

An eight-page catalog features PTI's commercial and military product lines. The monolithic and discrete filter line includes linear phase and spectrum clean-up filters and phase/amplitude matched filter sets. Oscillators include PTI's tactical miniature crystal oscillator (TMXO), temperature compensated crystal oscillator (TCXO), oven compensated crystal oscillator (OCXO), and the voltage controlled crystal oscillator (VCXO). **Piezo Technology, Inc., Orlando, Fla. INFO/CARD #144.**

Near-Field Measurement Brochure

Scientific-Atlanta has published a brochure describing the spherical near-field measurement system and its capabilities, discussing theory, applications and specifications. The spherical near-field system tests antennas automatically. Test data is measured in the near-field and transformed to far-field, where it can be analyzed, plotted and listed as conventional far-field data. **Scientific-Atlanta, Inc., Atlanta, Ga. INFO/CARD #143.**

VCO and Crystal Oscillator Products

New brochures have been published by EMF Systems describing features and performance of their line of voltage controlled oscillators (VCOs) and crystal oscillator products. Both product specifications and applications data are included in this literature. **EMF Systems Inc., State College, Pa. INFO/CARD #142.**

Power Line Monitor Newsletter

A quarterly newsletter, *The Monitor,* is offered to interested readers. Covering a range of topics from monitoring and analysis of power line problems, complex operations and processes, to effective energy cost reduction techniques, *The Monitor* includes application information, new product announcements, and service and maintenance techniques. **Dranetz Technologies, Inc., Edison, N.J. INFO/CARD #141.**

RF Switch and Relay Catalog

The latest release from Dow-Key Microwave is an 80-page catalog describing improvements and additions to their line of coaxial microwave switches and RF relays, containing specifications, drawings, applications notes, technical data and QA/Manufacturing/Test capabilities. A section devoted to special products includes switches for use in EW, ECM, C^3, Avionics, Test Equipment and special commercial environments. The new SMART SWITCHES line from SPDT to SP16T, using electronic circuitry for computer-programmable switching, is also included. **Dow-Key Microwave Corp., Carpinteria, Calif. INFO/CARD #140.**

Small-Signal FET Data Book

The *FET Data Book* from Siliconix provides complete specifications and performance data for more than 350 FET products. It updates the company's earlier publication with 41 new high-performance industrial and military FETs, including the new line of DMOS products. Eight new application notes feature FETs used as amplifiers, current protectors, constant current sources and analog switches. The book also provides die process, topography and package information and a small-signal FET cross reference. **Siliconix Inc., Santa Clara, Calif. INFO/CARD #139.**

Catalog Features Measurement Primer

The new 40-page catalog from Matec Instruments includes a primer on pulsed RF, ultrasonic and NMR/NQR measurements. Their products cover a 100 kHz-1.1 GHz frequency range and this catalog includes data on gated amplifiers, pulsed oscillators, receivers, preamplifiers, computer-controlled modular systems, and special purpose accessories. In addition, information is provided covering Matec's new ESA system for studies of charged particles in suspension and colloid stability. **Matec Instruments, Inc., Warwick, R.I. INFO/CARD #138.**

PIN Switch Brochure

The complete line of PIN diode switches is detailed in a brochure just published by The Narda Microwave Corporation. The standard absorptive and reflective switches cover the frequency range from .5 to 40 GHz. These solid state switches incorporate both chip and beam lead diodes in a tuned RF circuit to achieve the required RF performance and are available with and without TTL compatible drivers. Comprehensive information, including specifications, power supply requirements, outline drawings, and ordering information are included for all units. **The Narda Microwave Corporation, Hauppauge, N.Y. INFO/CARD #137.**

Attenuator and Test Equipment Catalog

A new catalog describes Kay Elemetrics Corp.'s full line of RF attenuators, switches and test equipment. The attenuator product line includes miniature and standard in-line step, rotary, continuously variable, audio and programmable attenuators for use in either bench of OEM applications. Also described are the RF Mega switches, pulsed carrier generators, and sweep frequency generator. The catalog describes complete electrical specifications, product dimensions, options and ordering information. **Kay Elemetrics Corp., Pine Brook, N.J. INFO/CARD #136.**

Amplifier Characterization Application Note

The great demand for FET amplifiers has caused manufacturers to search for an alternative to slow, power-meter-based amplifier tuning and testing. In addition, systems engineers are imposing stringent requirements on amplifier gain flatness and output power, both of which require improved gain compression characteristics. Wiltron's new application note describes a low-cost solution to slow and inefficient amplifier tuning and testing: the Model SM3519 Gain-Compression Test Set which accurately measures amplifier gain, gain-compression and impedance match. **Wiltron Company, Morgan Hill, Calif. INFO/CARD #135.**

Chip Capacitor Catalog

A catalog describing multilayer ceramic chip capacitors was recently published by the Kyocera Electronic Components group. This catalog contains technical data regarding the ceramic properties, electrical characteristics, terminations and solderability of Kyocera chip capacitors. Also provided is information regarding dielectric characteristics, dimensions, mechanical specifications and packaging. Available in values from 1.0 pF to 1.0 μF, these chip capacitors feature PPM quality levels and optional non-leaching nickel barrier terminations for IR, dual wave and vapor phase soldering. **Kyocera International, Inc., San Diego, Calif. INFO/CARD #134.**

Microcircuit Equipment Catalog

The 1986 catalog including data, photos and pricing on microcircuit equipment and tooling is now available from Aremco Products. The catalog includes 7 sections: thick film and SMT screen printers, dicing saws, substrate drill units; diamond wheels, drills and scribers, hot gas solder re-flow equipment, vacuum encapsulators and hi-temperature furnaces. **Aremco Products, Inc., Ossining, N.Y. INFO/CARD #133.**

EMI Shielding Application Updates

Chomerics has introduced a series of EMI shielding tips for electrical packaging engineers. Each update describes an actual case where a company approached Chomerics to provide a cost-effective shielding solution to an unusual packaging problem. These tips include copper foil/film laminate as a low impedance ground plane, rapid cure conductive EMI coatings for flex circuits; CHOSEAL® 1215 elastomer mounted on a plastic clip and a plastic/copper laminate which acts as an ESD shield. **Chomerics, Inc., Woburn, Mass. INFO/CARD #132.**

Mixer Components

A brochure describes complete double balanced mixer specifications between .1 to 26 GHz. Units covered include mixer modules, connecterized mixers, quadrature IF mixers, TVRO mixers, miniature wideband double-balanced mixers, biasable double-balanced mixers, wideband double-balanced mixers with Microwave IF, and waveguide balanced mixers. **Norsal Industries, Inc., Central Islip, N.Y. INFO/CARD #131.**

Test Instruments and Accessories

A short form catalog featuring bench test instruments is now available from O.K. Electronics Division. The catalog includes descriptions, specifications and photos of their line of instruments, including function/pulse/sweep generators, frequency and universal counters, DMM's, mini-scope, thermometers, probes and pulsers. There is also an array of accessories such as thermocouples, test lead kits, carrying cases, bench rack and test clips. **O.K. Industries, Inc., Electronics Division, Bronx, N.Y. INFO/CARD #130.**

rf opportunities

Advertiser's Index

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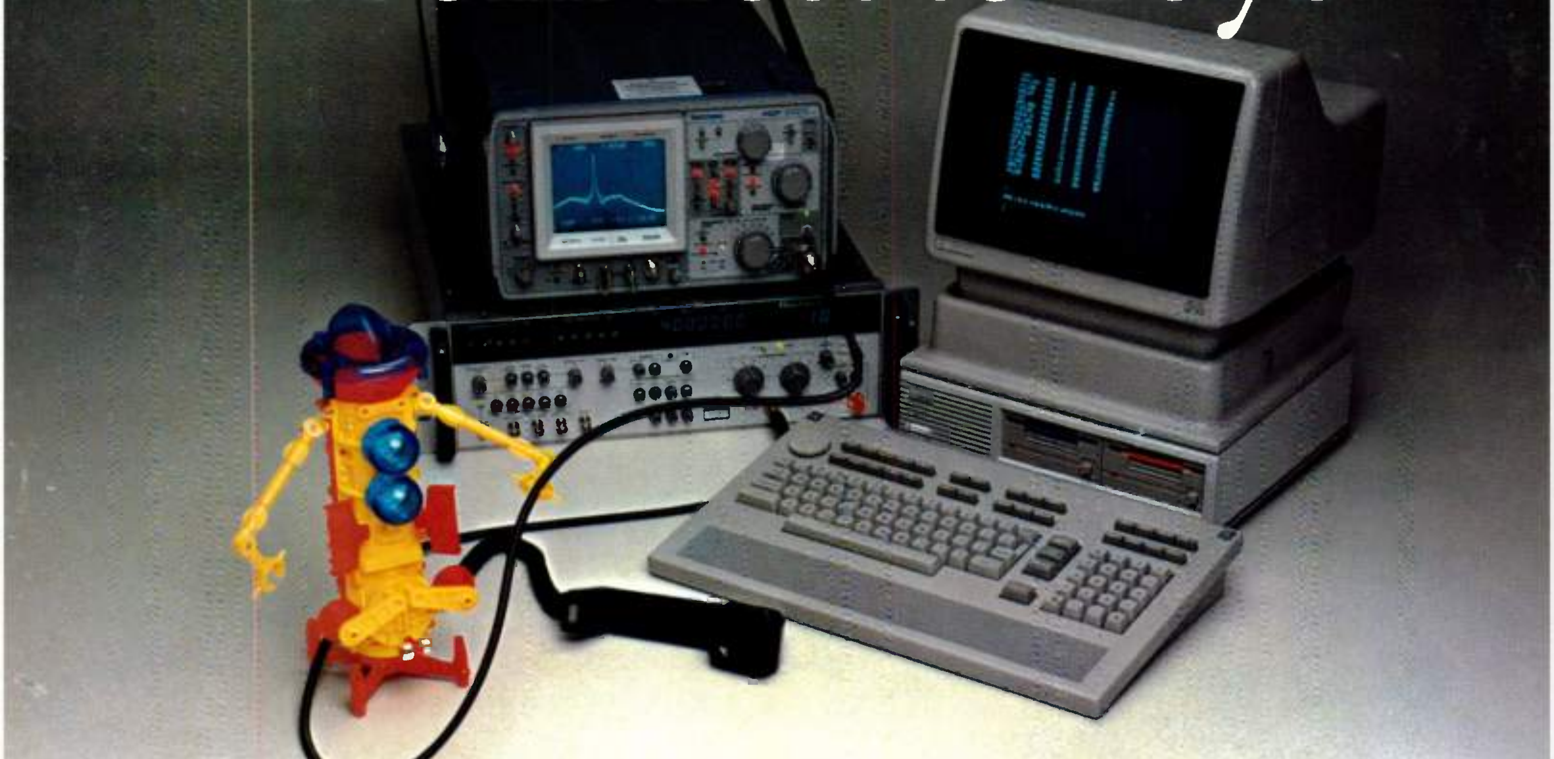
From Test to Toys



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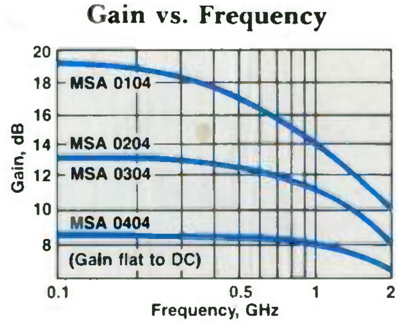

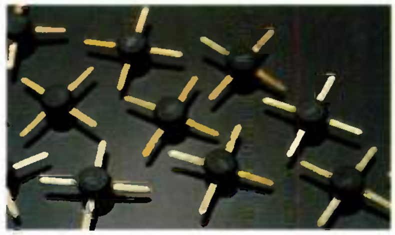

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