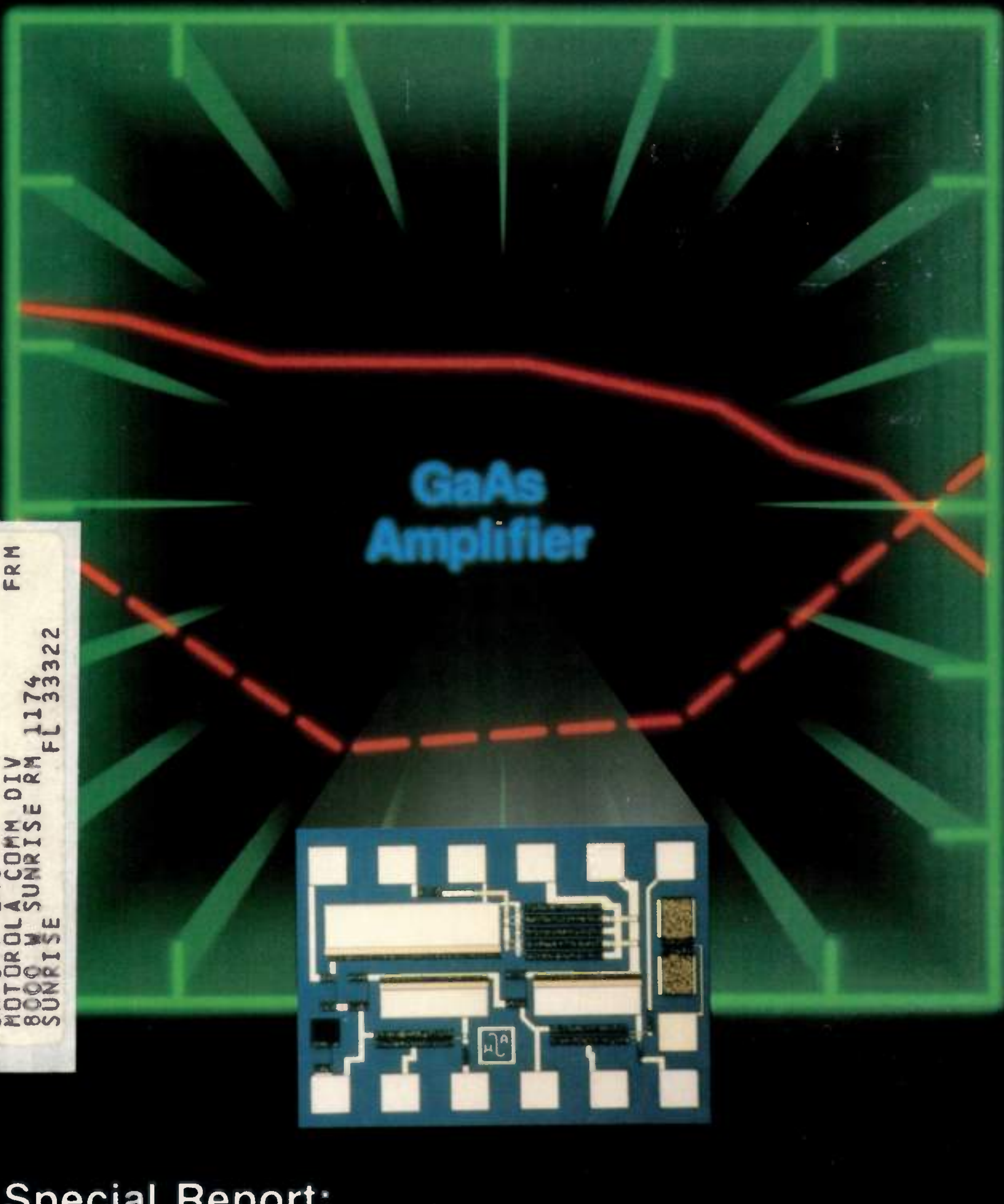
rf design

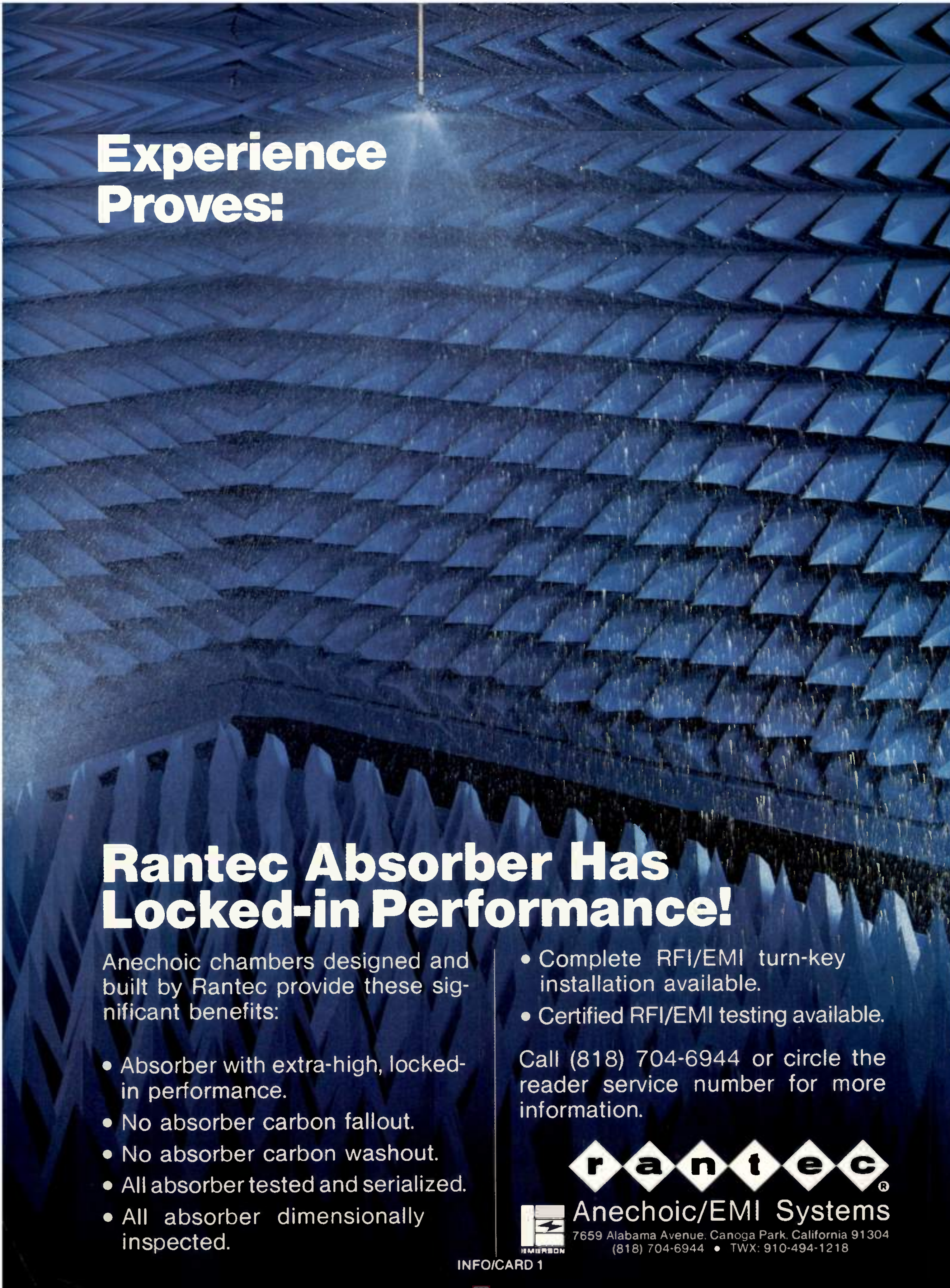
ideas for engineers

August 1985



Special Report:
The New Look in RF Circuits — Miniaturization

Surface Mounting Makes It Possible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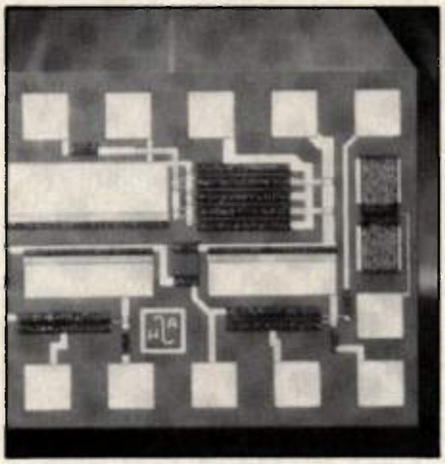
INFO/CARD 2

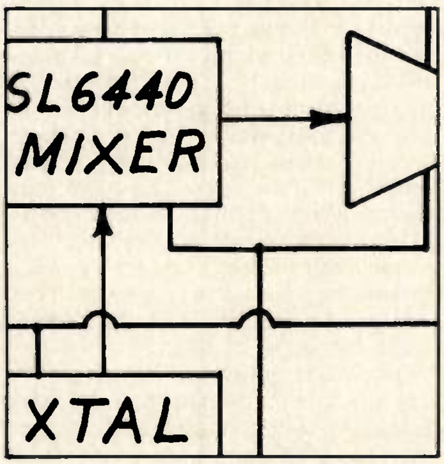
rf design

August 1985

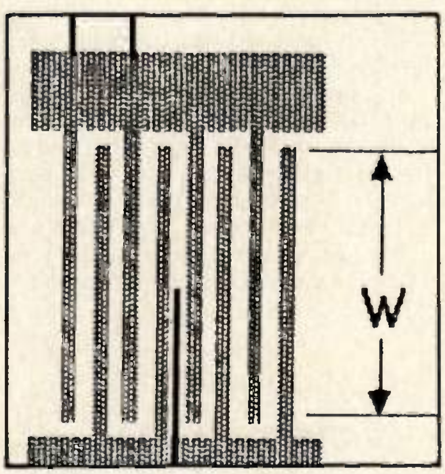


Cover

This month's cover features a GaAs monolithic VHF/UHF amplifier currently being developed by M/A-Com Advanced Semiconductor Operations, Lowell, Mass. This feedbacked, three-staged amplifier outperforms conventional silicon monolithic amplifiers in terms of gain and noise. It is one of a series of broadband and narrowband GaAs MMIC circuits currently under development at M/A-Com.



Features



Departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in August. August 1985, Volume 8, No. 8. Copyright 1985 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6530 S. Yosemite Street, Englewood, CO 80111 (303) 694-1522. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802, (1-800-346-0085). Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $22 per year in the United States; $29 per year in Canada and Mexico; $33 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $5.50 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.
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rf editorial

A Technology Whose Time Has Come

James N. MacDonald
Editor

In this month's Special Report we mention a company with a vision of incredibly tiny electronic devices for consumer use. This is just one of many companies we have visited with amazing R&D projects for components and devices. Project managers will only talk in the vaguest terms, of course, since much of the work is experimental, but the excitement and optimism are apparent.

Also apparent is a healthy caution about raising public expectations for advances that might not occur. As one executive put it, "We try to avoid the 'magic dust' syndrome — the new development that is supposed to solve everybody's problems but turns out to be another five years down the road."

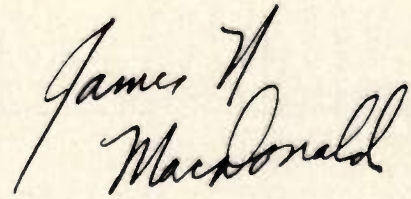
With this realistic attitude, RF designers and manufacturers will avoid the situation the computer industry finds itself in. The home computer market that showed such great promise is now floundering. There are many theories for this slump, but the underlying problem is that the mass market has not materialized. Although small computers are a big help in small businesses, they have not proved very useful in the home. Ordinary people with an interest in technology and those who like to be among the first to have new gadgets have bought them. Those without the time and inclination to learn how they work have avoided purchasing them.

It seems likely that home computers are a technology ahead of their time. Carried along by rapid advances in miniaturization and reductions in cost, manufacturers began producing home computers as soon as they were able. They knew the amazing power and capability of these little machines and, apparently, expected the average consumer to see quickly how useful they could be. What they did not study thoroughly enough was whether the average consumer needed a computer.

Some critics saw this problem. One columnist wrote sarcastically that soon there would be a computer in every closet. "Necessity is the mother of invention," but in the case of computers for the mass market the invention came before there was a need for it. The RF industry could make the same mistake.

The major companies we have talked to lately seem to be determined to avoid producing for markets that are not there. We hope all RF companies will learn from the experience of the home computer industry and avoid a competitive rush to bring electronic devices on the market just because they have learned how to make them.

Two important points can be learned from the experience of the computer manufacturers: there has to be a need for the new technology and it has to be easy to use. Thanks to the cumulative experience of RF design engineers, new consumer devices are easy to use. Let's also be sure the consumer wants them.



INFO/CARD 5

rf publisher's note

Let's Hear It For The Radio

Keith Aldrich
Publisher

I was born in 1929 — just 56 years ago, July 29. While that year may be better known as the year of the crash that launched the Great Depression, I prefer to think of it as the eve of the era of radio. . . a golden, miraculous new medium that informed, entertained and even bolstered a beleaguered people for free, when they couldn't afford nothing else noways.

The first round-the-world broadcast was heard in 1930. It would be difficult for younger readers to appreciate how quickly and completely after that the little broadcast box became the focal point of world civilization. One might be inclined to say I was a little young to remember that myself, but that's just the point. Even the haziest memories of the thirties are replete with radio references: Fiorello LaGuardia, New York City's Mayor, reading the Sunday funnies to me, a kid in Shawnee, Oklahoma; the family coming together as if for prayer to hear Franklin D. Roosevelt's latest, tender, Fireside Chat; a news announcer, McLuhan-cool, suddenly shrieking in anguish when the Hindenburg bursts into flames; the careful reading of code messages on Orphan Annie, invariably decoded as "Drink your Ovaltine." The pervasiveness was more complete, I think, than that of TV, since all this brave new world went with you in your car, stayed with you on the job: I shall never forget the muted, bitter, on-the-spot account of the Nazi occupation of Vienna after the Anschluss, heard during a Saturday afternoon drive in the country.

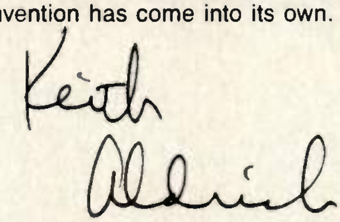
A favored hobby among scientifically-minded youths of the time, I remember well, was building "crystal sets," or radios, and operating them as radio "hams." Such enthusiasts were the closest approximations at the time to today's electronics engineers. The word "electronics" itself did not exist. It was invented after World War II by McGraw-Hill to re-title its magazine called, till then, *The Radio Engineer.*

This experience, nostalgic to older readers, may seem quite foreign to younger ones. Instead of a crystal set, they may have fooled around as youngsters with a computer kit. And instead of trying to reach China by short wave they may have been writing programs to balance Mom's checkbook.

Ironically, those same computer kids may now be working as RF engineers, developing incredibly sophisticated versions of the old crystal sets. As Levy-Strauss observed, history has a way of moving in cycles, not in a linear progression — and today, radio is in again, not to bring us Jack Benny, but to give us cordless phones, pagers, over-the-horizon radar and sonobuoys. It is probably no exaggeration to say that RF technology today is the most flourishing market in the entire electronics industry. It is certainly no exaggeration to say that the computer sector, so long and so recently the star of the show, is not.

I have noticed a slight tendency, on the part of some high-tech people, to look down on hams and ham activity — as if such a hobby somehow lessened the professionalism of those whose livelihood is RF engineering. I challenge that notion. Quite to the contrary, experience as a practical operator cannot but deepen one's understanding of electromagnetic wave generation and propagation. In fact, if there are any computer kids among our readers who are not hams, we urge you to give it a try. It will give you much of the education, in this strange "new" field, that you're looking for.

In the meantime, old and young alike, let's hear it for radio. Guglielmo Marconi's invention has come into its own. Again.



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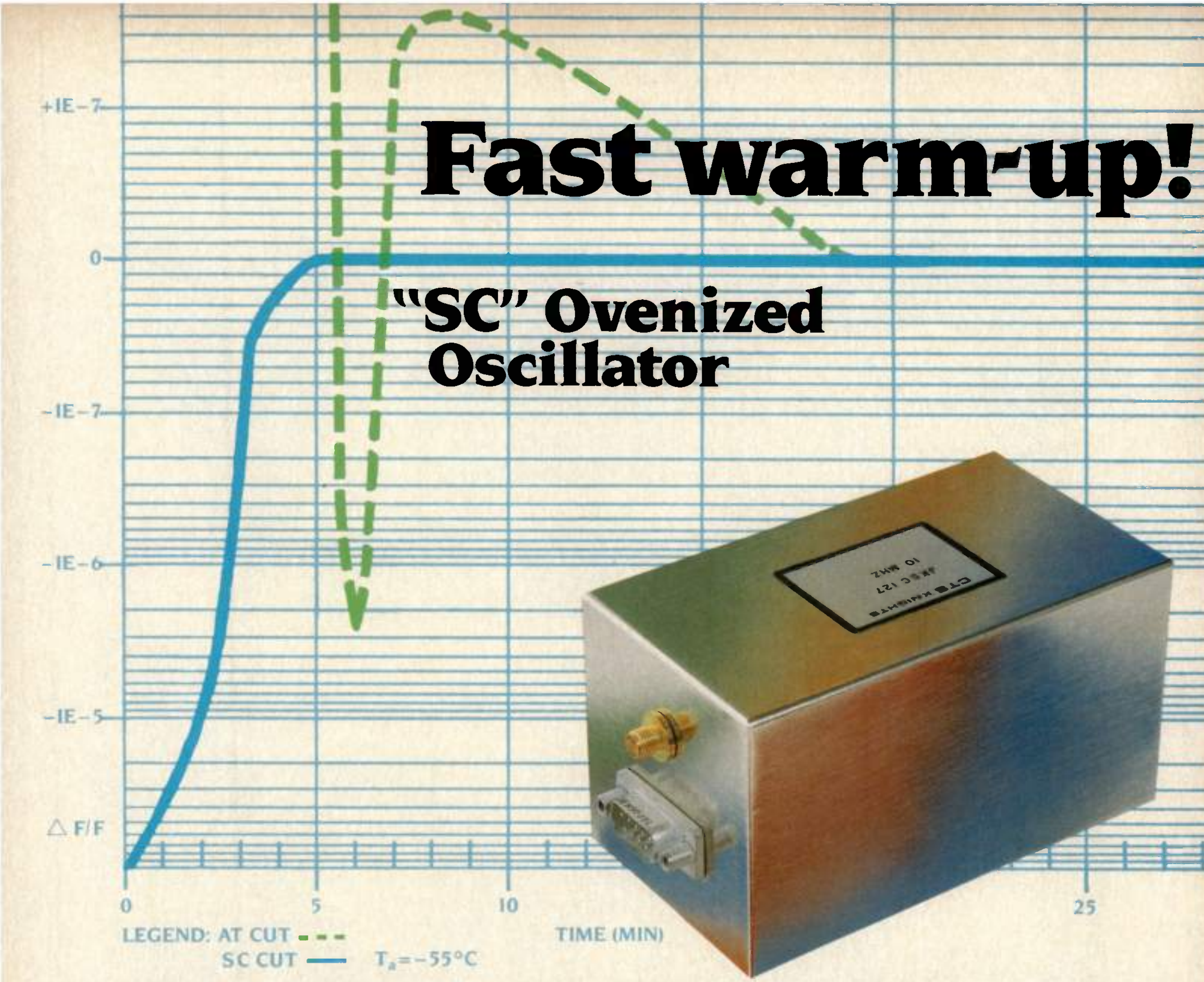

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Input Power	Oven @ turn on 1.2 A maximum @ +28 V Oven @ 25°C 125 mA typical @ +28 V Oven @ −55°C 240 mA typical @ +28 V Oscillator 20 mA maximum @ +15 V
Frequency Stability Vs. Temperature	±5 x 10^{-9} from −55°C to +71°C
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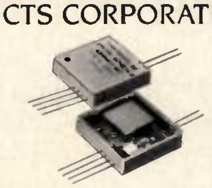

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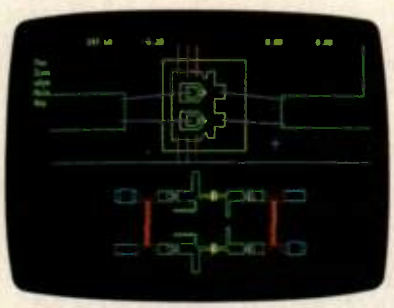

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INFO/CARD 7

Editor:

Thanks for publishing my article "Smith Chart Calculations on Your Microcomputer" in your June issue. I've had my magazine only one day and already have received three inquiries about copies of the program. To save unnecessary phone calls, please inform other readers who may be interested in the program but do *not* have Simons' BASIC that I have a version which will run on a standard Commodore 64 (stated in my manuscript but edited out).

Thank you.

L.A. Gerig

Editor:

In addition to comments I sent on a recent issue of *R.F. Design*, there are two additional comments I wish to offer on the May issue.

The first is that amateurs in the 1920s learned the importance of use of BFOs as a consequence of the use of regenerative and super-regenerative detectors. But the spectrum analyzer engineers *still* don't understand the importance of BFOs. I tried to get the message across to the Hewlett-Packard design engineer on the design of their first spectrum analyzer in the 1960s, but was unsuccessful. Needless to say, deep-space probes would be useless without the product detectors that are vital to the basic BFO principle.

The second is that the central location of the "Y" parameters in the drawing on page 49 in the May issue is not accidental. Only Y parameters are basic with bipolar transistors, as well as FET devices and electron tubes, as was shown on page 287, Lo et al, "TRANSISTOR ELECTRONICS," published in 1955. The H parameters, both hf and hi, depend on the small difference in emitter and collector currents, whereas device transconductance is a direct function of either the collector current (common-emitter configuration), or the emitter current (common-base configuration). One almost always can discard H parameters, Z parameters, and A parameters. The small-difference of large currents is endemic in the H parameters, and has caused continuing difficulties in circuit design over the years. My books point this out clearly, and they also present the basics for the parameter relations given by this author.

All active device conductances take the form:

$$y=K^*(q/kT)^*I$$

Where the kappa(K) has the value unity with bipolars under low-current conditions (this is also true with FET devices at very small currents, and also for electron tubes under similar conditions), and may have a value as high as 1.6 for NPN transistors and 0.6 for PNP transistors under high-injection conditions.

I published the conversion formulae for all but the S parameters in my Handbook of Transistor Circuit Design (1962, Prentice-Hall) and in Reliable Military Electronics. The former was published before the S parameters were developed, but I didn't add them to the latter. It is evident from the chart that the Y parameters, if used properly, usually will meet one's needs in RF applications. The principal point is that for stability, voltage gain must be limited, typically to less than 10, and the only way it can be assured is through the use of the Y parameters.

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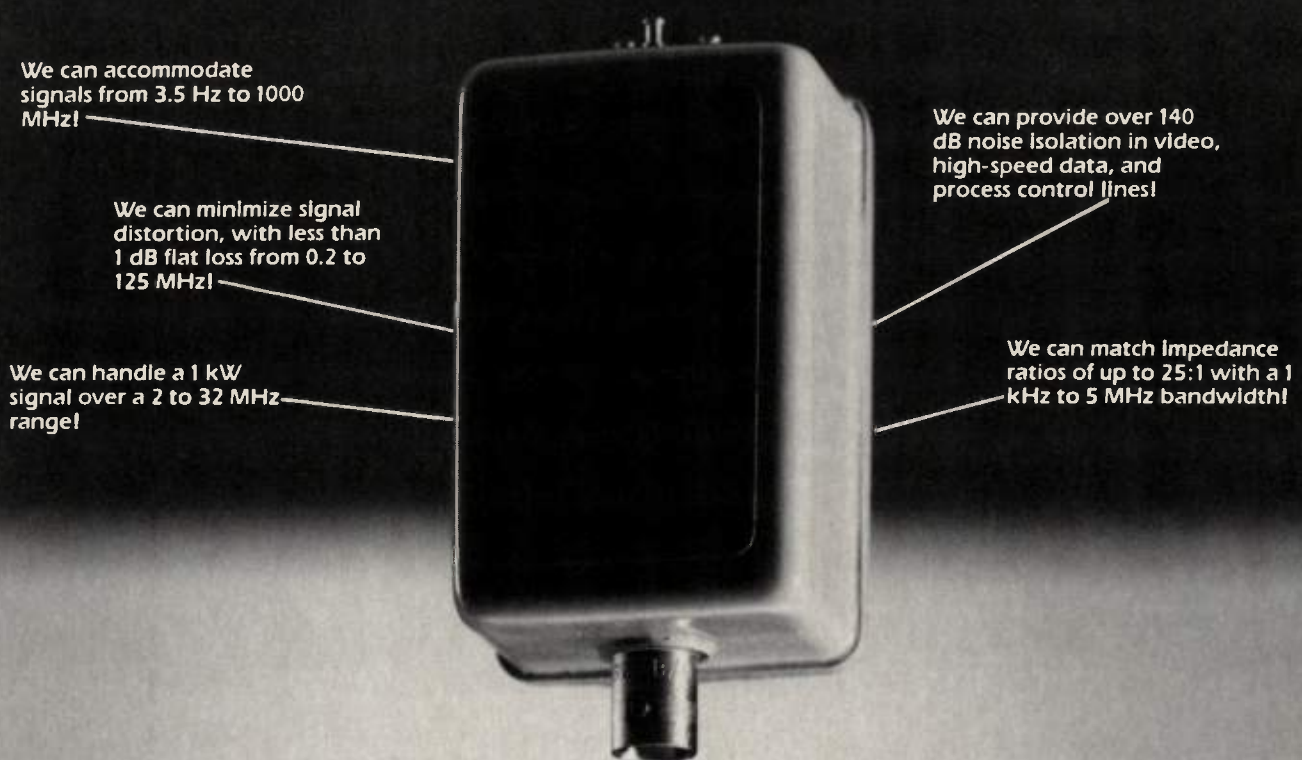

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rf letters *Continued*

Editor:

As per our telephone conversation, may I point to a misprint in the Transistor Parameter Conversion Program.

Line 2160 should read:

```
2160 PRINT INT (R(K)*E)/ETAB(10)INT(I(K)*E)/E,INT(M(K)*E)/
ETAB(30)INT(A(K)*E)/E
```

Keep these beautiful RF programs coming for the Commodore 64. We enjoy them very much.

Al Goldberg
Circuit Designer
Spectrum Enterprises, Miami, Fla.

Editor:

Two subjects here: first, in response to Keith Aldrich's note regarding advertising — I agree that "... advertising is one of the most useful aspects of a magazine..." *However,* there is one aspect of your advertisements that I find both frustrating and indefensible — the omission of PRICE information in both the advertising and New Products areas.

Second, I would really like to see an in-depth (or a series) article on *practical* spread-spectrum pulse techniques using SAW devices. I would like such an article to:

1) be written in practical, working level terms
2) discuss (with figures and photos) both time and frequency domain signal characteristics
3) give examples of pulse compression, expansion
4) use *simple* math (save the triple-integrals and the exponentials of the exponentials for the IEEE transactions)
5) discuss trade-offs in choosing a SAW device
6) present a complete design example for a simple compression, expansion.

Thank you for listening.

Sid G. Knox
Pacific Missile Test Center
Code 3421
Point Mugu, CA 93042

ERRATUM:

Lines 650 and 660 were accidentally left out of the article "Helical-Resonator Filter Design — A BASIC Program" in the July issue. They are:

```
650 QD=.5*Q1*(FO/BW3)::RZ=(PI/4)*((1/QD)–(1/QU))

660 SN=SQR((RZ/2)*(RT/ZO))::RAD=180/PI
```

RF Design regrets the omission.

rf calendar

August 27-29, 1985
Quartz Devices Conference & Exhibition

The Westin Crown Center
Kansas City, Missouri

Information: Convention Manager, Westin Crown Center, Kansas City, MO.

September 10-12, 1985
Midcon/85 High Technology Electronics Exhibition and Convention

O'Hare Exhibition Center
Rosemont, Illinois

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

September 11-12, 1985
Mid-Atlantic Electronics Design & Production Exhibition

Valley Forge Convention Center
King of Prussia, Pennsylvania

Information: International Mktg. Services Ltd., 1719 S. Clinton St., Chicago, IL; Tel: (312) 421-7000.

October 8-10, 1985
Electronic Imaging Expo

Sheraton Boston
Boston, Massachusetts

Information: Kathie Hallberg, IGC, 375 Commonwealth Ave., Boston, MA; Tel: (617) 267-9425.

October 22-24, 1985
Northcon/85 High Technology Electronics Exhibition and Convention

Portland Memorial Coliseum
Portland, Oregon

Information: Electronics Convention Management (see Midcon/85).

November 19-22, 1985
Wescon/85 High Technology Electronics Exhibition and Convention

Moscone Center, Brooks Hall
Civic Auditorium
San Francisco, California

Information: Electronics Convention Management (see Midcon/85).

January 21-23, 1986
Electrical Overstress Exposition

Anaheim Hilton and Towers
Anaheim, California

Information: Jim Russell, EOE, 2504 N. Tamiami Trail, Nokomis, FL 33555; Tel: (813) 966-3631.

January 30-February 1, 1986
RF Technology Expo 86

Anaheim Hilton and Towers
Anaheim, California

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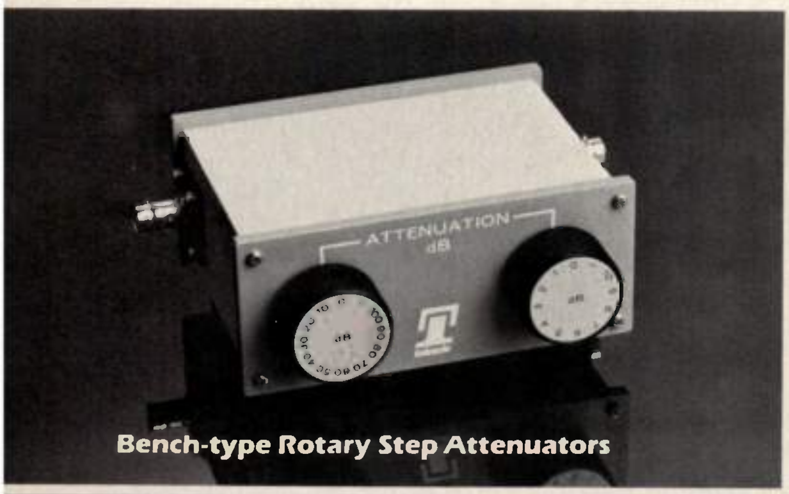

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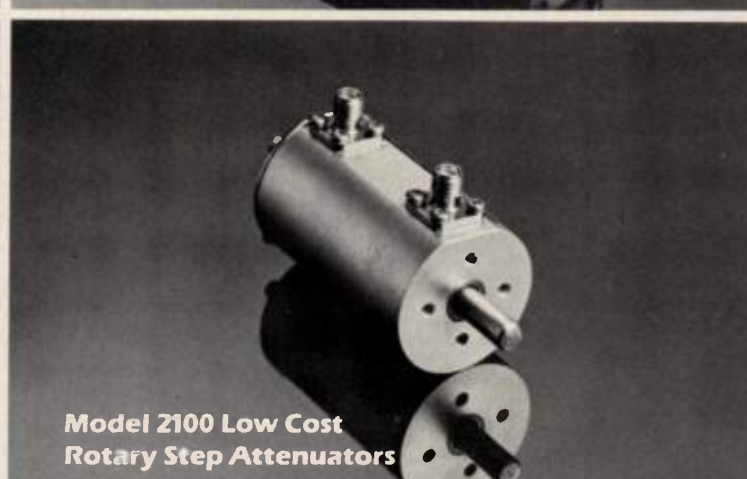
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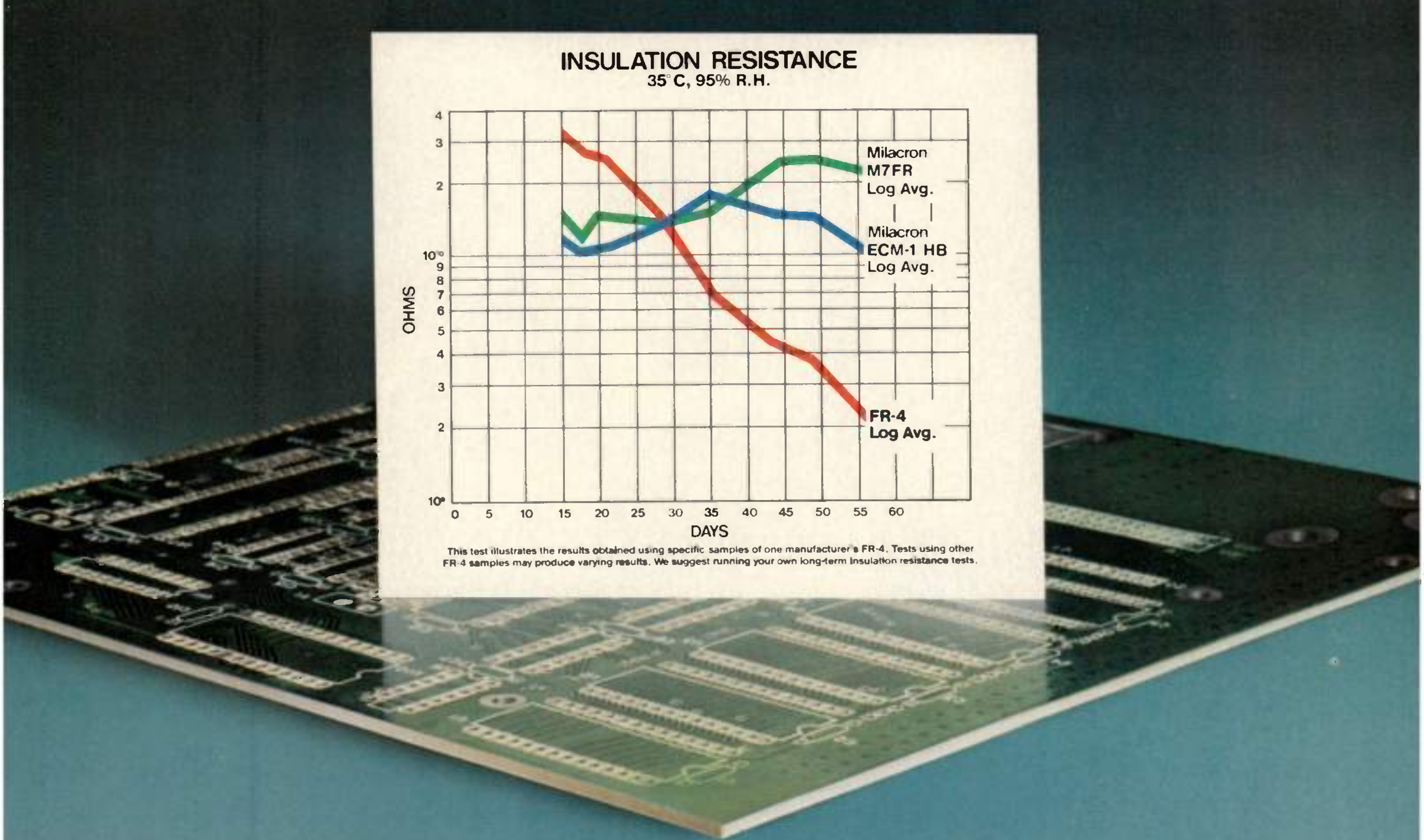
INFO/CARD 14

What Good Are Good Electricals If They Don't Stay That Way?



Milacron all-glass laminates.

Electricals that are reliable... over the long run.

As a designer, you know that one of the most important functions of a PWB laminate is to provide good insulation resistance. So you want to be sure you specify a laminate that performs well in this crucial area. That's where Milacron laminates excel.

As illustrated in the test results above, Milacron laminates maintain stable insulation resistance over time, even in conditions of high temperature and humidity. *More stable than the FR-4.*

That's right — over the several weeks of the test period, the FR-4 lost a considerable amount of its insulation resistance, while Milacron laminates remained steady throughout the test period.

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Our conclusion: Milacron laminates — single- and double-sided — perform exceptionally well in these difficult environmental applications.

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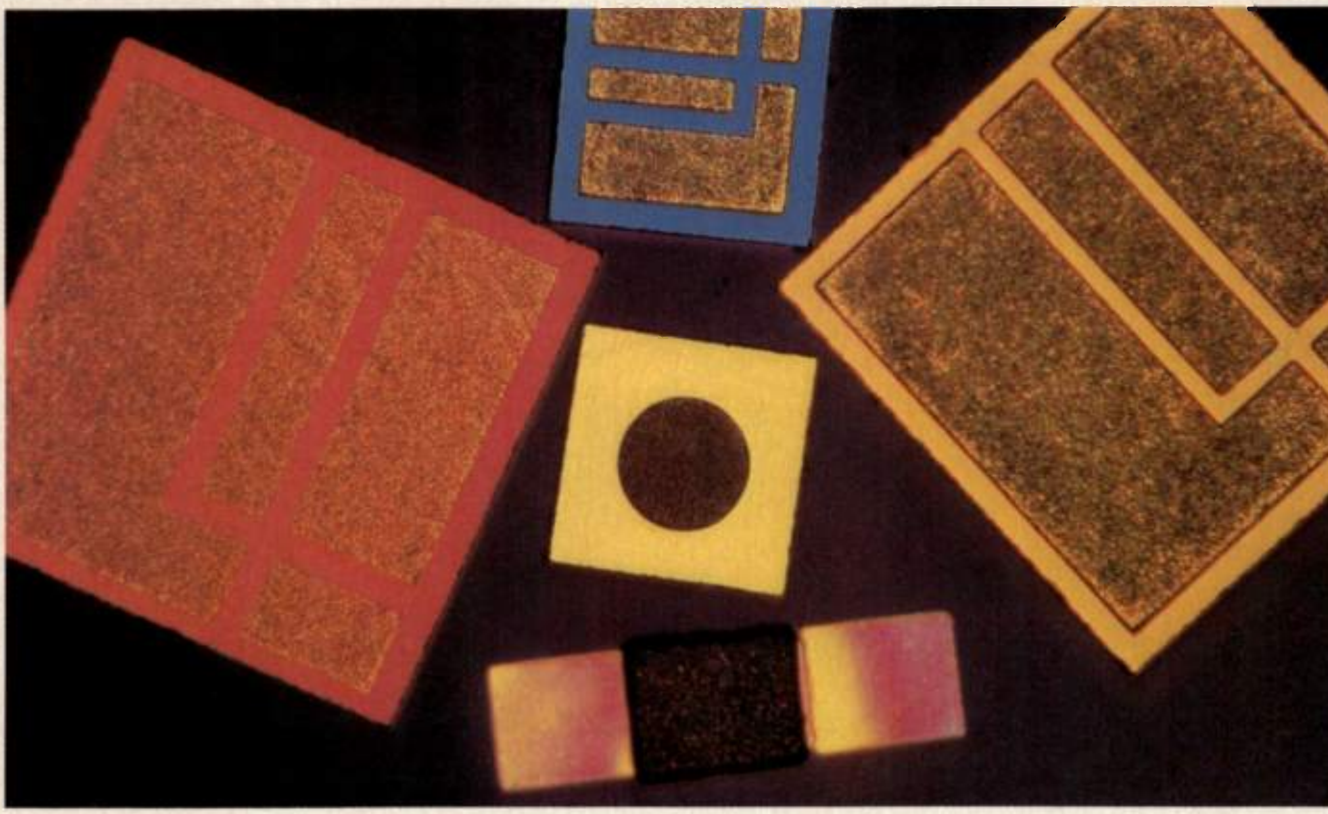
Electronic Circuit Materials Division

INFO/CARD 15

MIS CHIP CAPACITORS



Up to Millimeter Wave.

A wide selection of high-Q, space-qualified devices, *from .1 pf to 1000 pf*. Applications include... amplifiers, mixers, detectors, switches, filters, and synthesizers.

General Features
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- Insulation resistance—10^6 MΩ, typical.
- Capacitance temperature coefficient—50ppm per °C, typical.

Millimeter Wave Beam Leads
- Low inductance (.02nH) assures ripple free, broad-band response, up to 100GHz.
- Narrow beam width (.003 inches) compatible with thin microstrip.
- Symmetric construction permits easier mounting. Suitable for mounting on sapphire circuits.

Beam Lead MIS
- Low inductance assures ripple free broad band response.
- Easily mounted on microstrip.

Binary Trimming
- Four devices on a single chip in a binary weighted configuration that produces 15 different capacitance values.
- Ideal for research as well as production for those finicky circuits.
- Wide range from 0.25pf to 90.0pf.

Chip MIS
- Low cost for DC blocking and RF bypass applications.
- Ideal for hybrid microelectronic applications.
- Round and rectangular contacts for minimum chip size and low inductance.
- Low capacitance temperature coefficient.

FET Chip Mounting
- Serves as a carrier for FET amplifier chips.
- Maximum packaging benefit permits use of short wire lengths to minimize lead inductance.

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INFO/CARD 16

Tektronix to Sell Microwave Technology Components

The Microwave Technology Organization of Tektronix, Inc.'s Frequency Domain Division has begun to sell components to customers outside the company. The decision to make Microwave Components available to outside customers through outside sales representatives, Tektronix announced, is predicated on the belief that application of this technology extends far beyond the company's own instrument lines.

Components to be marketed include a 500 MHz surface acoustic wave resonator and resonator oscillator, a DC to 40 GHz 4-port coaxial switch and custom high to medium performance surface acoustic wave transversal filters.

Tektronix, Inc., headquartered in Beaverton, Ore., is a leading manufacturer of high performance test and measurement equipment and has been heavily involved in Microwave Component design and manufacture for over ten years.

Air Force Lifts Alpha Suspension

The Air Force has agreed to terminate the suspension it had imposed on Alpha Industries on February 1, 1985, having concluded that Alpha is a responsible contractor and that there are compelling reasons for continuing to do business with the company. The Air Force has also agreed not to initiate debarment proceedings against Alpha based on the circumstances involved.

The company and one of its vice presidents had been charged with violations of the Federal Anti-Kickback Act and related statutes in the purchase of a marketing study from A & H Associates, a California firm controlled by an employee of a government contractor, which was also a customer of Alpha.

Under the settlement, Alpha has agreed to continue certain measures and to institute additional procedures to ensure full compliance with federal law and government procurement regulations, including internal and external audits of its contracting activities and a comprehensive employee training program. The company has also agreed to terminate the vice president who was charged.

Andrew S. Kariotis, president and chief executive officer of Alpha, has been granted a one year leave of absence from the company and has resigned as an officer and director. This action was part of the conditions for settling the suspension. The resignation was accepted with "deep regret" by Alpha's board of directors, who felt that they had no reasonable alternative but to agree to the Air Force requirement. Alpha's new order rate for government contracts has dropped substantially since the suspension and a settlement was necessary to protect the interests of shareholders and employees. Andrew S. Kariotis plans to return to Alpha when his leave of absence is over.

George S. Kariotis, Alpha's founder and chairman of the board, has assumed the additional responsibilities of chief executive officer. Martin J. Reid, senior vice president, has been elected president and chief operating officer.

As a result of this settlement with the Air Force, Alpha is now free to participate in unclassified government contracts and subcontracts without restriction. Alpha expects that its security clearance, which was invalidated based solely on the suspension, will be promptly reinstated.

In a related agreement, the company also announced that it had reached an out-of-court settlement with the U.S. Attorney in the case pending in the Federal District Court for the Central District of California. Under the terms of the settlement, the company has agreed to plead guilty to one count of violating the Federal Anti-Kickback Act.

Alpha expects to pay a fine of $10,000 and a civil settlement to include restitution and punitive damages totaling $87,000 as a result of the plea.

Boeing Consolidates Electronics In New Division

The Boeing Company has consolidated its electronics operations into a new operating division of the company, the Boeing Electronics Company. Boeing senior vice president Robert W. Tharrington was named president of the new operating unit.

The nucleus of the new electronics organization, according to Tharrington, is made up of employees from the former Boeing Electronic Systems Division, Boeing's Dallas, Texas, electronics manufacturing subsidiary, Boeing Electronics, Inc., and elements of Boeing's commercial and military airplane companies.

The new division operates military and commercial/industrial electronics factories, a printed wiring board fabrication facility, a hybrid microelectronics manufacturing plant and complete developmental electronics support facilities.

"We're structuring Boeing Electronics to serve the aerospace and industrial markets," Tharrington said.

The hybrid circuits designed and manufactured by Boeing Electronics can incorporate up to 200 chips on a single multilayered substrate and are manufactured to military specifications. According to Boeing Electronics' microelectronics product manager, Bette Zimmerman, the company will provide circuit, packaging and software design as well as manufacturing for hybrids or will build to a customer's design.

Raytheon Wins Air Force MILSTAR Contract

Raytheon Company has been awarded a $256,049,166 contract by the U.S. Air Force for the full-scale development of communication terminals for the military communications satellite program known as MILSTAR. The contract was awarded to Raytheon by the Air Force System Command's Electronic Systems Division located at Hanscom Air Force Base, Mass.

Rockwell International (Collins Defense Communications) and BELL Aerospace are subcontractors to Raytheon and will participate in a leader-follower type program. Under this concept, the follower becomes fully qualified to compete for subsequent terminal production with an estimated value of over $1 billion. The Raytheon/Rockwell/BELL team recently completed a competitive 18-month engineering development program and was selected for the full scale development effort over a team headed by Hughes Aircraft.

The MILSTAR satellite communications system will provide secure and survivable, jam-resistant, wartime communication capability for the strategic and tactical forces of all U.S. military services. The terminals to be developed under this contract are intended for use in airborne command post aircraft as well as in bombers, Air Force ground command posts and at tactical warning and attack assessment sites. MILSTAR is scheduled to be operational in the 1990s.

Work on the program will be performed by Raytheon's Equipment Division, headquartered in Wayland, Mass.

Paperback Book Overview of Microelectronics From Varian

Welcome to Lilliput: A Microelectronics Overview, by Dr. Ronald A. Powell, associate director of the Varian Research Center's Materials and Equipment Laboratory, describes the fast-moving field of semiconductors. Written for a general audience, the book provides the lay reader with a brief and entertaining look at the emergence of microelectronics, the building of high-performance integrated circuits (ICs) and the challenges faced by the semiconductor industry as it enters the era of very large scale integration (VLSI).

The 60-page paperback highlights some of the problems the IC industry must overcome as it builds increasingly more complex chips. It also previews things to come, both for the technology and for consumers.

A copy of the handbook can be obtained from a local Varian Semiconductor Equipment Group sales office by writing on company or university letterhead to: Varian Semiconductor Equipment Group, Box J-105, 611 Hansen Way, Palo Alto, CA 94303

K & L Microwave, Inc. Acquires Oscillatek, Inc.

K & L Microwave, Inc. acquired the business assets of Oscillatek, Inc. in a cash purchase transaction in May. Oscillatek is an emerging leader in the manufacture of high quality TCXOs and custom hybrid clock oscillators primarily serving the military market. The acquisition will complement K & L's crystal and crystal filter operation — K & L Quartztek.

Oscillatek will continue under the leadership of its president and founder, Abdul Ghafoor. Oscillatek will function as a division of K & L Microwave and continue to operate at its present location in Olathe, Kan. The acquisition provides Oscillatek a ready source of funds for continued growth and expansion.

Business Use of Government Procurement Information Increases

The Federal Procurement Data Center (FPDC) is gaining wider use across the country as more businesses learn about this invaluable information resource. Created by an act of Congress in 1974, the FPDC has been collecting data on nearly every item the government buys with appropriated funds since 1979. The FPDC master file now contains detailed information on contracts awarded for goods and services by over 60 federal agencies for the past six years. All individual contracts over $10,000 ($25,000 for the Department of Defense) are included in the system.

FPDC offers the business person two basic products. As an overview to contracting activities in the government, the FPDC can send a free quarterly standard report of procurement data. It includes a list of the top 100 contractors who sell to the government, as well as several charts and graphs which compare procurement activities by state, by major product and services, and by federal agency. For many businesses, however, this basic data is not enough. Many need a more detailed analysis of procurement data and trends to assess their own chances of winning government contracts, to identify their competitors, to target new markets for their products or services or to develop marketing plans for themselves or their clients.

Available upon request for a fee, these special reports can be compiled in numerous ways. Some examples of the kind of special information available from an FPDC special report include:

- Who a business's competitors are and the volume of business they do with the federal government. For example, a company could request a special report on the volume of business a competitor did with the federal government last fiscal year, broken down on an agency-by-agency basis.
- Which agencies are buying the products or services offered by a company and from whom. The FPDC system has more than 5,000 codes for services and products and is capable of compiling contracts by product in a given geographical area. This information can be further broken down by agency, contract number, and purchasing office that made the award.
- The amount and percentage of contracts awarded to small, minority, women-owned, or non-profit businesses.
- Whether a contract was formally advertised or negotiated, competitive or non-competitive, and which statutory requirements apply.
- Extent of competition in negotiation (e.g. small business or labor surplus set-aside).

In addition to the popular special report, the FPDC also provides, on a reimbursable basis, other information useful to the business person. For example, mailing lists of contractors who sell to the government purchasing offices and their addresses.

The FPDC is an invaluable tool for companies which do or would like to do business with the government. For information call (703) 235-1326 or write Dept. GB, Federal Procurement Data Center, Suite 900, 4040 N. Fairfax Drive, Arlington, VA 22203.

Gentner Electronics Corp. Acquires Leonine Technology

Russell Gentner, president of Gentner Electronics Corp., Salt Lake City, Utah, and John E. Leonard Jr., president of Leonine Technology of San Jose, Calif., have jointly announced the acquisition of Leonine Technology by Gentner Electronics Corporation. Leonine Technology has been renamed Gentner RF Products Division and will be headed by Leonard.

Leonine Technology was founded in 1984 by Leonard to design and manufacture innovative RF related products for the broadcast and communications industries. Leonard, former president of Moseley Associates and M/A-COM Land Mobile Communications, has been associated with these industries for 26 years.

Gentner Electronics Corporation is a Utah-based, publicly held corporation specializing in the broadcast and telecommunications industries. A wholly owned division, Gentner Engineering Company, Inc., is a leading manufacturer of telephone interface and audio routing equipment for these industries.

Contact: Russell Gentner, president, (801) 268-1117. Salt Lake City, Utah.

Business Guide to Silicon Valley Lists 2300 High Tech Companies

The 1985 edition of *Rich's Business Guide to Silicon Valley* contains the latest facts about more than 2300 manufacturing and service firms in 32 cities. Indexed alphabetically, by product, by city and by names of individuals, the guide simplifies search for high tech companies.

Details about each firm include the address, phone, year established, product description, number of employees and the names of key executives. More than 65 detailed street maps show the location of each firm as well as conveniently located restaurants, hotels and motels.

This 3rd edition of *Rich's Business Guide to Silicon Valley* is the most up to date and complete "source" of information on Silicon Valley, according to the publishers. For information contact Business Directories, Inc., 101 First Street, Suite 426, Los Altos, CA 94022, (415) 949-1471.

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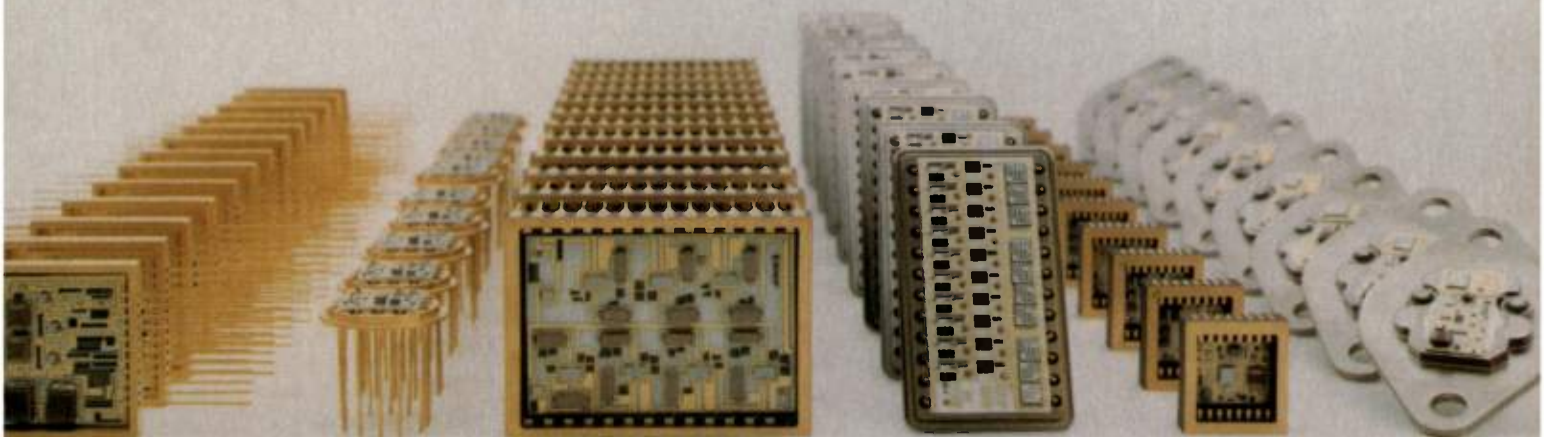

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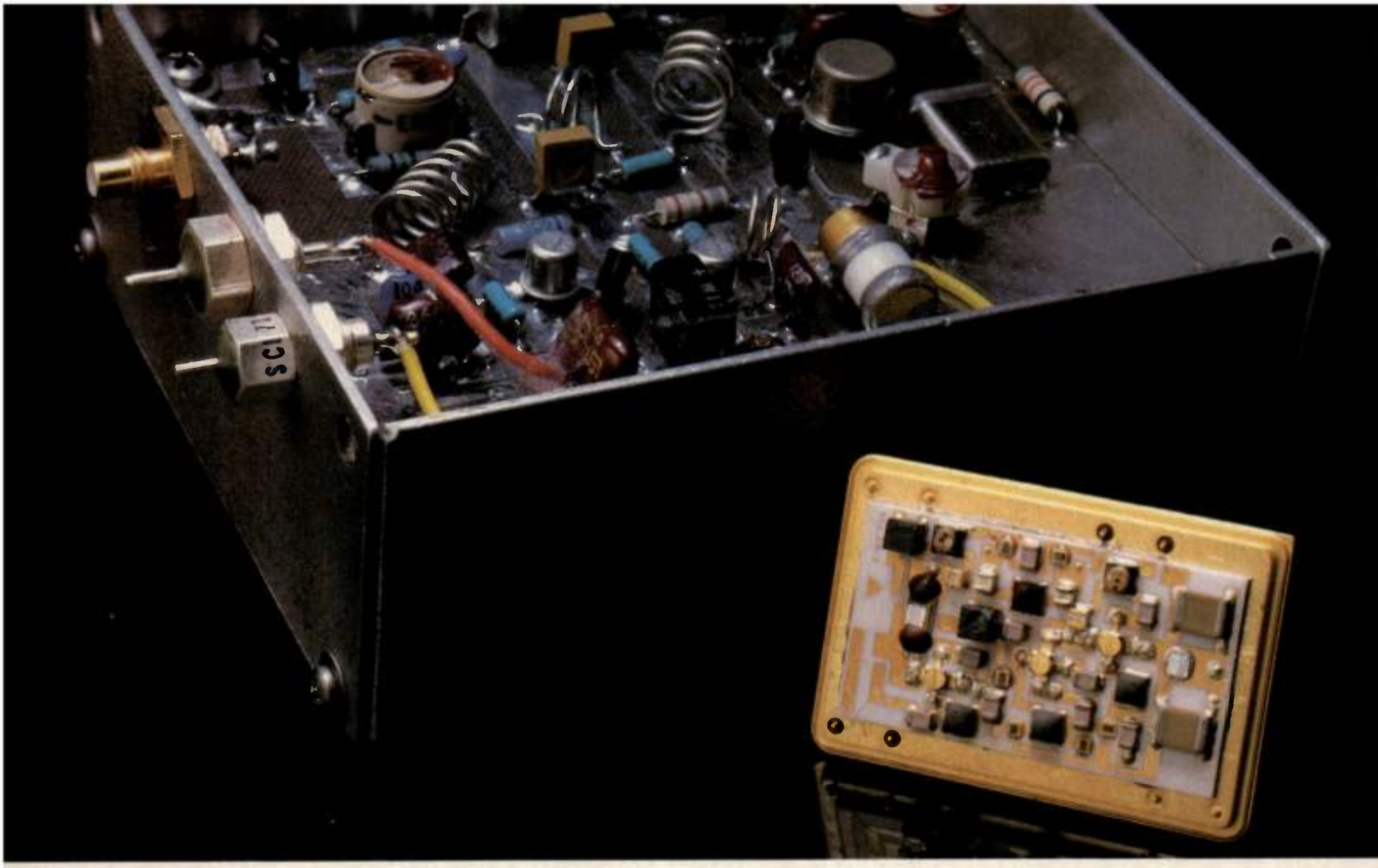

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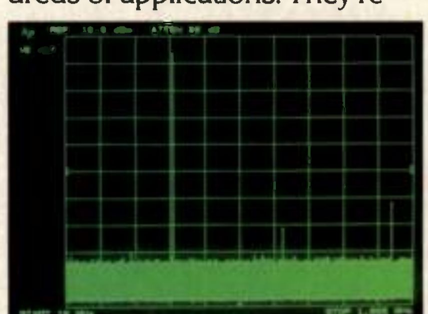

Frequency spectrum of Andersen Model SO-314-600-V Oscillator over 0 to 1 GHz range. Fundamental frequency is 314 MHz. Second harmonic is −65dBc, third harmonic is −55dBc. Spurious responses are essentially nonexistent.

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INFO/CARD 21

The New Look in RF Circuits — Miniaturization

By James N. MacDonald

Those of us who built crystal sets and read Dick Tracy when we were young used to dream about someday having a wrist radio like his. Looking at the oatmeal box on the breadboard it didn't seem possible that a radio ever could be contained in something the size of a wristwatch. Today, engineers at Avantek, Inc., Santa Clara, Calif., are talking seriously about putting a receiver in the button of a wristwatch. It doesn't take much imagination to combine the recent accomplishments in miniaturization with the cellular radio concept and foresee the day when we will have individual pocket or wrist radios for world-wide, two-way communication.

This is only one of the fascinating promises of RF technology. As the quantum leaps in microprocessor technology showed us, it is almost impossible to predict the rate of technological advancement in electronics. One thing can be safely predicted: we are about to enter a very exciting era for RF design.

While computer companies are having to adjust to a softening of sales RF component manufacturers are talking about expansion and new products. Any RF companies that are not looking toward the future and planning how to be part of the changes taking place may find themselves part of the past.

The changes taking place can be summed up in the word "miniaturization," but the driving force is not just to make things smaller and lighter. After all, a one cubic inch television set would have little appeal. The most important result of miniaturization is being able to put more functions in a given space. The telephone is a good example of how this has happened in another technology.

Last month we wrote about some of the new materials contributing to the miniaturization of RF circuits. One of them is gallium arsenide, used for quite a few years in microwave integrated circuits. A few companies have brought this technology into the RF frequencies.

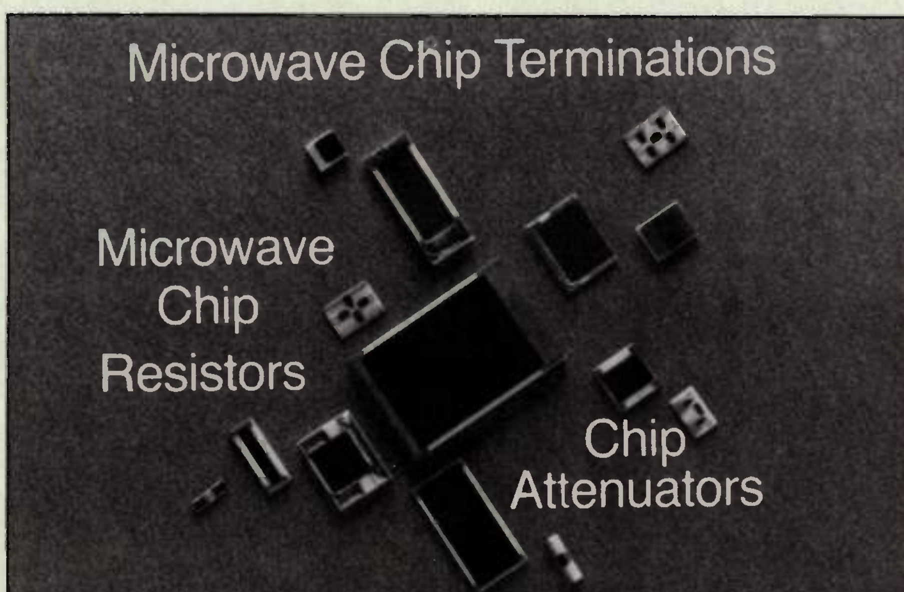
This month's cover features a new GaAsFET monolithic amplifier designed by M/A-Com Advanced Semiconductor Operations, Lowell, Mass. The major advantage of GaAs is low noise compared to silicon, making GaAs semiconductors attractive in receiver front ends.

M/A-Com ASO sees this GaAs RF amplifier as a meeting of the minds between microwave and RF. Cost is still an important factor with GaAs, of course, but the company thinks this may be balanced by the advantage of putting more functions on a chip, lowering the unit cost. Generally, the volume is much higher in RF manufacturing, which is primarily commercial, than it is in microwave manufacturing, which is more military oriented.

A major factor in volume production of RF devices is surface mounting, which allows high-speed automated assembly. Surface mounting devices, now mostly resistors and capacitors, can be picked up with suction heads and placed on printed circuit boards. Type 2 circuit boards have surface mounted devices (SMD) on both sides, combining both active and passive components. Type 1 boards use SMD only and only on one side.

SMDs are held in place with adhesives until they are soldered, usually by either acrylic or epoxy based adhesives. Using acrylic based adhesive requires that some of the adhesive project out from under the SMD so it can be cured by ultraviolet light. This requirement can be troublesome as SMDs are mounted closer together. Emerson & Cuming Inc., a Canton, Mass. adhesive manufacturer, reports that their customers by a wide margin prefer epoxy-based adhesives.

Epoxy adhesives can be contained completely under the SMD because they are heat-cured by infrared radiation. The



Surface mounted chip resistors made by TRX, Inc., Attleboro, Mass. Shown are chip resistors, attenuators and terminations.

major disadvantage of epoxy adhesives is a lengthy curing time, as long as five minutes at 150-160° C. However, Amicon Corp., Lexington, Mass., has developed an epoxy adhesive that cures in as little as 90 seconds at 150° C. Amicon D124 has the proper consistency to flow through a syringe at 3-5 drops per second, for fast application, but will not flow out of place on the board. It was developed for the high volume commercial market.

Amicon and others are working on silicon adhesives, which would have the advantage of a thermal expansion nearly identical to silicon semiconductor chips and would be conductive. The biggest problem to be overcome so far is unacceptably long curing times of 15-20 minutes. Looking farther in the future, researchers hope to develop conductive adhesives that can replace solder, holding devices as firmly and curing in less time than that required by solder.

The most common surface mounted RF components are leadless chip resistors and capacitors. These leadless devices are encased in a variety of ways to make contact with printed circuits. TRX, Inc., Attleboro Falls, Mass., produces standard resistors for inline connections and a line of chip terminations and attenuators. Harvey Smith, vice president for marketing, says TRX makes the smallest chip resistors available, as small as 2 mils square.

Thick film chip resistors are the SMDs most likely to be used in RF circuits. They are often used to dissipate high power levels in a small area. Because a large area of the chip is in contact with the substrate, heat is dissipated more readily than from leaded resistors, an important factor in device miniaturization.

Chips are made in a wrap-around or flip chip configuration. In the wrap-around configuration metal is wrapped around each end of the chip to provide solderable terminations. In the flip chip configuration metal is attached to each end of the chip but does not wrap around the ends of the chip. This gives the designer flexibility in coupling the resistor with other components, either placed on circuit termination pads on the surface or flipped so leads can be wire bonded.

Chip components like these can simplify circuit design, since the shapes are simple and relatively standardized. They are well adapted to computer aided design techniques.

Chip capacitors have similar geometries, with metallization on both sides, either solid or split. A chip capacitor can also be made as a capacitor array, with various capacitance values provided by various sized electrodes on the top side of the chip. Chip resistors and capacitors can be used in stripline, printed circuit or bonded lead connection designs.

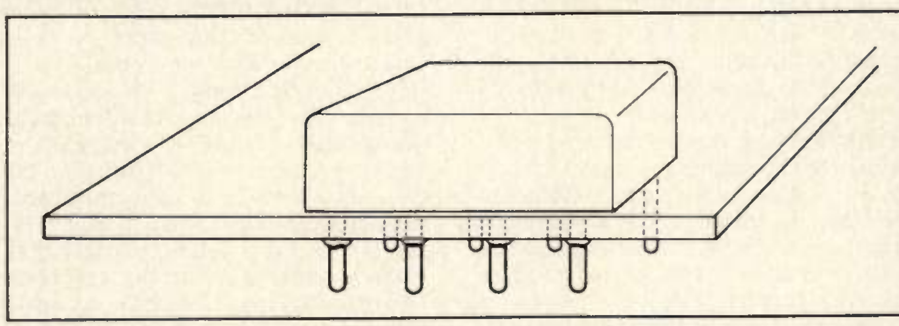
As miniaturization techniques have allowed designers to produce smaller and smaller circuits more complex devices are being packaged for surface mounting. Midland Ross Corp., Burlington, Wis., manufactures surface mounted oscillators from 244 Hz to 100 MHz and crystals from 1 kHz to 100 MHz. Product Manager Hank Nechvatal said his company is one of the first to build surface mounting oscillators. He believes the whole industry will eventually produce only SMDs.

Nechvatal explained that SMD design costs less and is more easily automated even for devices mounted on feet because more precise alignment is necessary to insert leads through holes than to place feet on pads. The manufacturing process costs less, he said, because it is not necessary to flip the board and solder leads.

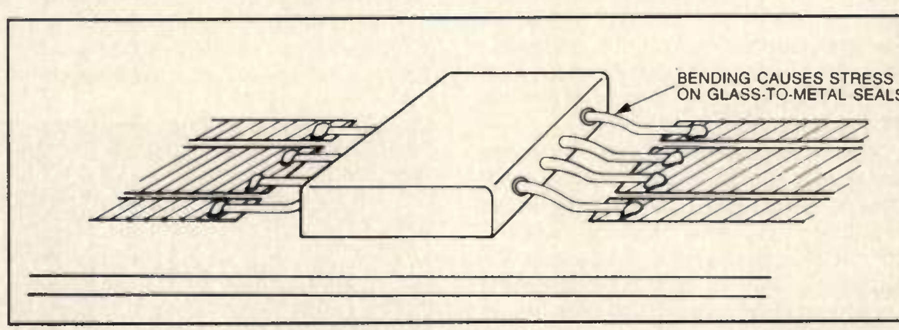
It is generally accepted that devices using surface mounting give superior electrical performance, Nechvatal said, because SMDs can be placed closer together than through-hole components. This means shorter paths between components and faster operating speed.

Synergy Microwave Corp., Paterson, N.J., recently announced what they call the first true surface mounted mixers. The company calls them true SMDs because they are leadless devices that do not require holes, cutouts or special lead handling. RF, LO and IF ports are available as wrap-around contacts.

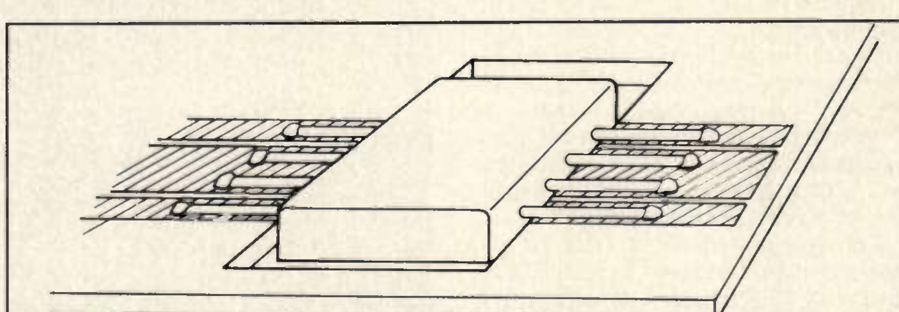
(continued on page 32)



(1) Through-hole SMDs require precisely aligned holes and pins and must be soldered on the other side of the board.



(2) Flatpack SMDs with leads projecting from the side require the leads to be bent for soldering to printed circuits.



(3) Flatpacks can be mounted so leads are flush if a cutout is made in the board. (Illustrations courtesy of Synergy Microwave Corp., Paterson, N.J.)

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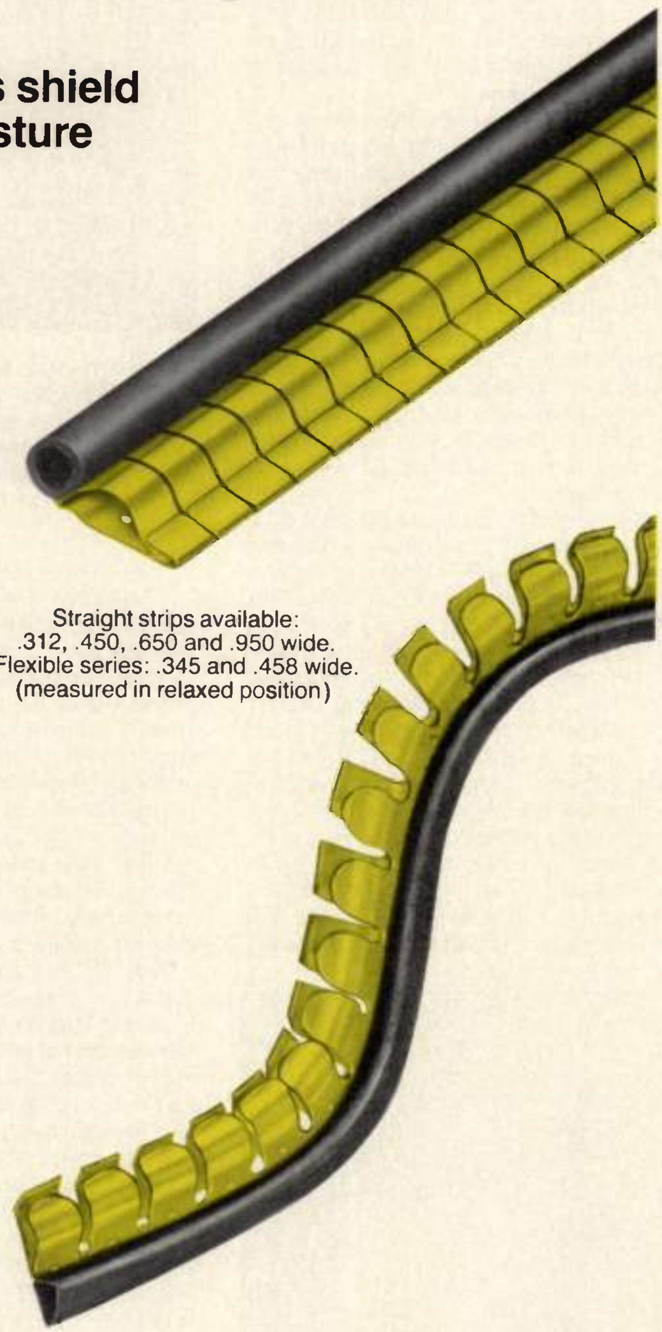
Catalog E^3-58 provides complete information, including exact specifications, dimensional drawings, etc., on these and other Instrument Specialties shielding strips. Use this publication's Reader Service Card, or write to us directly at Dept. RFD-19.



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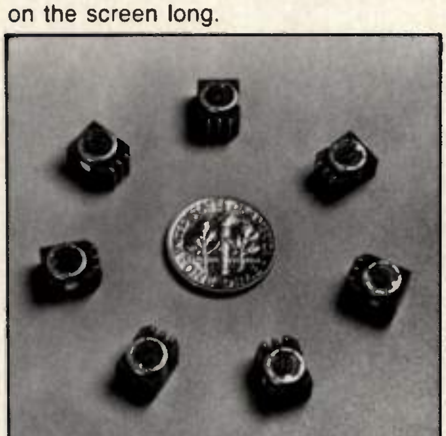
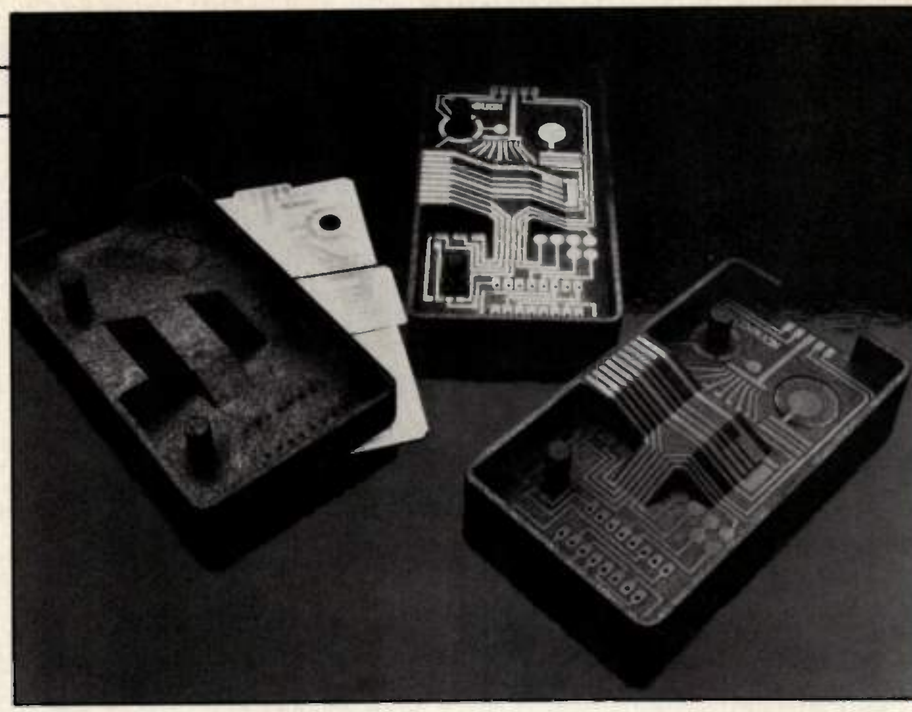
Howard Levine, sales manager, says true surface mounting is superior to flatpack design. The flatpack has eliminated the operations required by through-hole connections but requires cutouts in the substrate or board so leads, which project from the sides of the package, can sit flush on the surface. The alternative is to bend the leads, which causes stress on the glass-to-metal seals where the leads enter the package.

One of the largest manufacturers of chip components is Murata Erie North America, Inc., Marietta, Ga. The company has developed a variety of components in "square" chip configurations for high density surface mounting, including capacitors, resistors, trimming potentiometers and capacitors, inductors and piezoelectric filters and resonators. The company has produced a Surface Mounted Device Application Guide to share the experience they have gained in the application of surface mount technology by building connectors, tuners and hybrid ICs with chip components.

SMDs must be connected to other devices on the board or substrate. A common method for laying RF circuitry on a ceramic substrate is thick film screening. This involves forcing a metallized ink through a fine-mesh, stainless steel or polyester screen onto the surface of the substrate. Solvents in the ink evaporate, usually under heating, leaving a resin and metal filler residue. The method works well but has some problems. As the solvent dissolves the volume of the ink decreases, so the line becomes thinner. This is compensated for by laying a thicker line to begin with. Another problem is that the ink tends to dry on the screen unless precautions are taken, and the ink cannot be left on the screen long.



Sealed cermet chip potentiometers for surface mount devices.



Three-dimensional circuitry by the Konec process. At left is the injection molded Radel PCR 3-D printed circuit board substrate. Behind it is the circuit pattern as screened by the Konec process on special release paper. At right is the completed board with circuitry transferred. With an electroless copper plate to enhance conductivity. The board at top center has an additional nickel plate for added durability.

Researchers at W.R. Grace's Washington Research Center are investigating solventless, radiation curable conductive inks that avoid these and other problems of solvent based inks. They are based on polymer thick film (PTF) technology and cure by chemically linking the molecular components of the ink's resin system under ultraviolet radiation or heat.

The lack of a solvent to evaporate has a number of advantages: PTF ink does not dry on the screen, saving time and ink during production line stoppages; it cures more rapidly and the UV-radiation curing units are smaller than conventional hot air ovens; PTF ink has less tendency to flow out at the edges before curing, allowing lines and spaces as narrow as four mils; the lines do not shrink as they cure, allowing more precise control over thickness; and the cured ink is not susceptible to solvent in subsequent layers of circuitry. This last advantage makes additive multilayer circuitry a practical alternative to etched multilayer circuitry for many applications.

Methode Development Co., Chicago, Ill., a subsidiary of Methode Electronics, Inc., is testing PTF materials especially for multilayer circuitry. The company has developed a method of connecting levels of circuitry with vias. They have shown that any two adjacent layers of printed polymer circuitry can be interconnected by designing a via in the separating polymer dielectric print. Non-adjacent layers can be connected by a combination of pads in conductive prints and vias in dielectric layers.

Methode has shown that base metal can be used as the filler for PTF ink, if the ink is plated. It is necessary, however, to strip away the surface polymer and expose a metal rich surface to allow a good plating bond. The circuit then can be plated with standard electroless materials and equipment. The plating and subsequent solder are the conductive path. Since electroless plating will print whatever is printed and is not restricted to a continuous circuit, Methode believes PTF circuitry shows significant promise for additive circuitry. It is solderable, can be wire bonded and is relatively inexpensive.

Another approach to additive thick film circuitry was announced recently by Union Carbide Co., Danbury, Conn., and Chomerics, Inc., Woburn, Mass. The process, called Konec, uses a new family of resins developed by Union Carbide and highly loaded conductive inks developed by Chomerics. In this process the circuitry is printed on a special release paper and coated with adhesive. The circuitry is then inverted and transferred to the substrate. This brings the metal rich bottom of the circuit trace to the top for electroless plating or soldering. The circuit can be directly wave or vapor phase soldered.

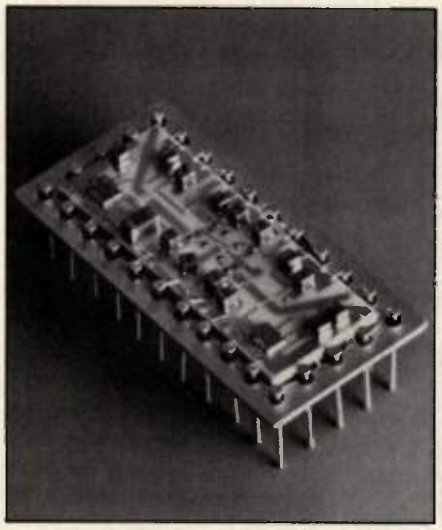
The companies say the Konec process is particularly well suited to 3-dimensional circuitry applied to molded thermoplastic substrates. Leadless plastic chip carriers can be manufactured with the same resin system, with conductors applied by the transfer process. This means chip carriers and PCBs have the same coefficient of thermal expansion, helping to avoid the breakage problem of using ceramic chip carriers.

As circuits become smaller, finer line geometries can be achieved by etching. This is usually done by metallizing the surface of the printed circuit board with copper and etching away everything but the desired connecting lines. Etching, however, tends to remove some of the desired circuit as well as the undesired metal, etching horizontally as well as vertically and leaving circuit lines with somewhat of a trapezoidal cross section. This is especially troublesome where circuit lines are plated with several layers of different metals. Each develops the trapezoidal shape and the overall cross-section resembles an oriental pagoda.

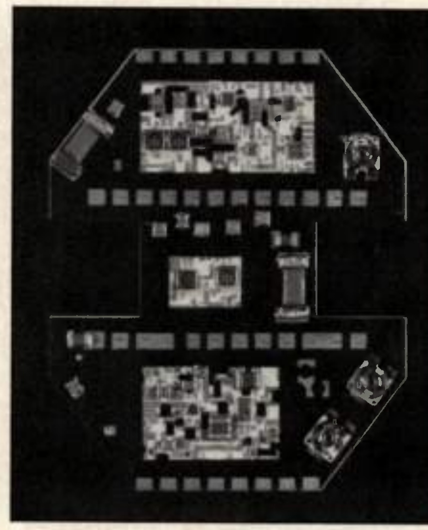
As circuits grow smaller, line thickness becomes increasingly critical. Manufacturers have developed several methods of achieving thinner lines than chemical etching will allow. Materials Research Corporation, Orangeburg, N.Y., is one of the oldest. The company began by making evaporation deposition equipment to lay thin film circuits on masked boards. Now they produce plasma sputtering equipment for the same purpose.

Irwin Drangel, director of product marketing, said there are two ways, other than sputtering, to overcome the problem of chemical etching. One is to use spray etching, where the substrate is held vertically and the etchant sprayed onto it. Since the chemical runs off the substrate, the primary etching is done in the direction of the spray. The other method recently developed is plating up, rather than etching down. With this method the desired circuit is masked and the surrounding area etched away slightly. Then the surrounding area is masked and the circuit is plated up. The edge of the masking acts as a wall to help provide straight sides for the circuit.

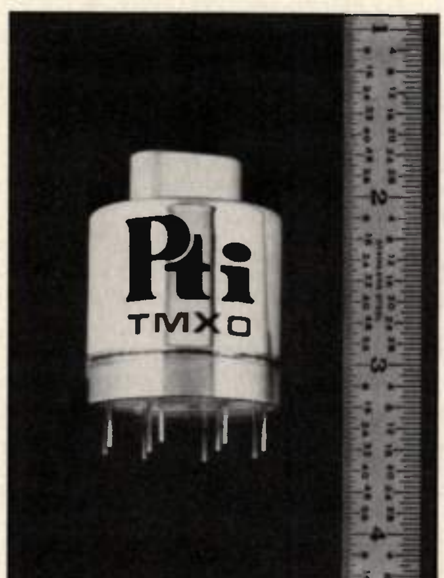
For the thinnest circuitry, sputtering seems to be the method of choice. Sputtering metal onto the substrate in the presence of a plasma causes the metal to react with the substrate and produce a stronger bond than plating can achieve. This characteristic makes the technique attractive for flexible substrate circuitry. Southwall Technologies, Palo Alto, Calif., manufactures a sputtered copper conductor called "Etch-A-Flex," that the company says allows the finest line resolution ob-



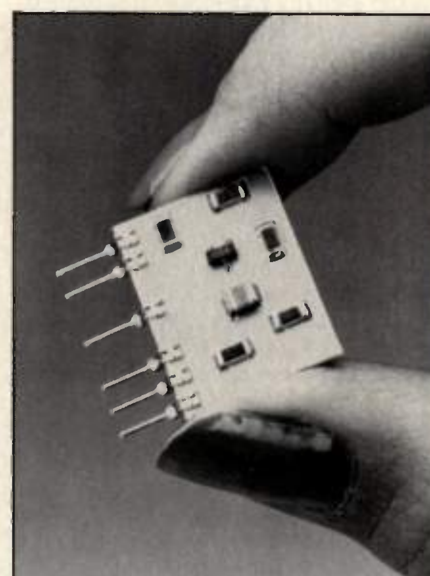
Daico Industries, Inc., Compton, Calif., uses in-house thin film technology to produce SMDs like this SP4T switch with internal TTL driver and 50 ohm termination. Construction consists of thin film nickel, gold and Nichrome deposition on alumina substrate. Components include PIN diodes, IC drivers and chip capacitors. Actual size is 1.17 inch by 0.57 inch.



Miniaturization of hybrid circuitry requires intricate planning. The visual sensing device pictured above is a custom hybrid made by Hitek Microsystems, Inc., Los Gatos, Calif. Christine Sorensen, director of corporate communications, said the unusual shape of the device is possible because of the company's CO_2 laser machining capability.



Piezo Technology, Inc., Orlando, Fla., has developed what they believe is the smallest temperature-controlled crystal oscillator on the market. Called the TMXO (tactical miniaturized crystal oscillator) the PTI device is designed for military use but has commercial possibilities. It is a ceramic hybrid package containing an oscillator, heater, heater controller and regulator. A key feature of this miniature design is a high internal vacuum for fast warm-up and low power consumption.



Allen-Bradley Electronics Group has initiated new manufacturing processes for type BC chip resistors to add mechanical environmental protection. The new processes provide an edge termination of silver-bearing organic material, replacing the silver-bearing cermet material, and a two-layer protective coating of gold organic over a fired glass glaze, replacing the single layer of fired glass. Shown above are A-B Type BC chip resistors surface mounted on a printed circuit board.

tainable. The company says their magnetron sputtering process produces extremely uniform thin film coatings of alloys and compounds, as well as pure copper, that will not crack or craze under repeated flexing. Flexible circuitry can save space and weight to help achieve miniaturization.

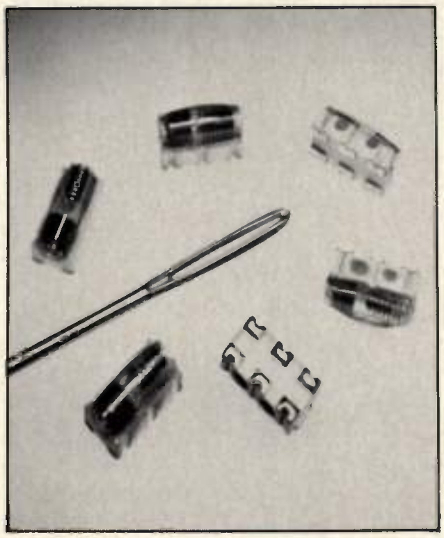
As circuit lines become finer, the substrate surface must be smoother and free of defects. When lines are less than 1 mil, as they often are today, surface imperfections can easily cause an open circuit. MRC produces a high purity "as fired" substrate called Superstrate 996. The substrate is called as fired because it is not lapped and polished after manufacture. The 99.6% alumina is cast from a slurry onto a Mylar tape and baked hard. The Mylar surface is the smooth surface upon which circuitry is sputtered. MRC claims a smoothness of 3 μin average deviation from centerline for their highest grade.

More commonly, substrates are polished to maximum smoothness, especially where ultra-thinline microwave circuits are intended. Accumet Engineering Corp., Hudson, Mass., recommends polished thick film substrates for less variation in thickness, camber and parallelism. This, they say, will improve ink disposition by diminishing the variable introduced in the squeegee pressure. It also will provide better adhesion, they say.

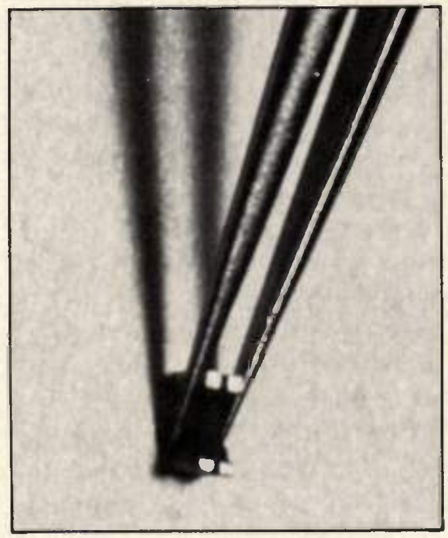
John Snook, Accumet's vice president for marketing and sales, believes fused silica has been unjustly ignored as a substrate. It is amorphous silicon dioxide, and Snook says because it is amorphous the surface finish attainable is 0.1 μin, far superior to anything that can be attained with alumina or any polycrystalline material, which may have microvoids.

There is a handling problem with fused silica. Essentially glass, the substrate is very fragile. Metal adherence can be a problem because it depends on substrate surface cleanliness. Snook believes when manufacturers have learned to overcome these handling problems, as Accumet has, fused silica will provide engineers with another dimension in miniaturization.

Looking again at the larger scale, Cincinnati Milacron, Blanchester, Ohio, produces several all-glass laminate printed circuit boards because of the superior electrical characteristics. The company has just introduced ECM-85, built for double-sided use but well suited for single-sided use, the company says. Ed Ferrara, sales and marketing manager, says ECM-85 produces smooth, smear-free holes with low tool wear, whether drilled or punched. He says the new material has excellent plating characteristics because of its smooth surface and a lower Z-axis coefficient of expansion than FR-4 epoxy/glass laminates, virtually eliminating barrel cracks.



Coilcraft, Cary, Ill., has introduced a line of tuneable surface mounting inductors with ranges from 0.1 μH to 10 μH and Qs up to 40. They are compatible with automatic placement equipment and most attachment methods, including vapor phase, reflow and wave soldering.



The "small outline" configuration is now being used by Dale Electronics, Inc., Columbus, Nebr., to provide thick film resistor networks for surface mounting in a dual-inline molded package. The Dale SOMC networks are compatible with automatic surface mounting equipment.

Summary

The trends in miniaturization include smaller components, easily mounted with automatic equipment, using materials with superior mechanical and electrical characteristics so devices can operate closer together. Next month, in the final part of this series, we will examine some of the ways manufacturers are packaging and connecting these miniature devices for maximum physical stability, electrical performance and heat dissipation.

To receive further information from the companies mentioned in this Special Report, circle the following numbers on the reader service card elsewhere in this issue and mail the card.

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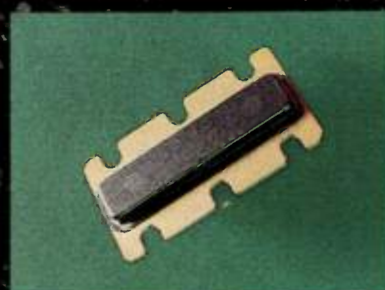

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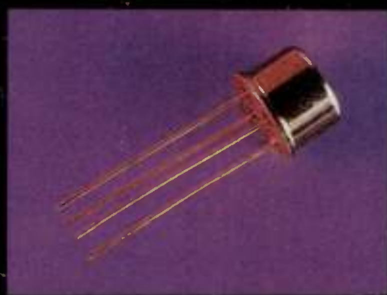

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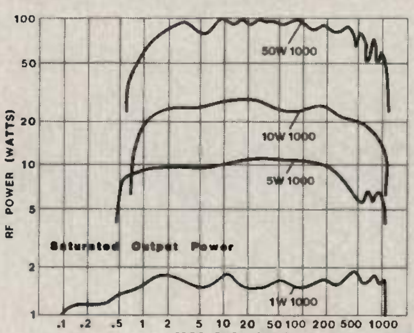

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INFO/CARD 27

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Janel offers a wide variety of standard power dividers. The chart below shows a sampling of what's available. All feature high *guaranteed* performance and yet are competitively priced. Many models are available from stock.

Model	Outputs	Frequency	Isolation	VSWR
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PD7725	4	20-512	25	1.35
PD7726	8	20-512	25	1.35
PD7852	12	2-512	25	1.5
PD7905	4	2-50	30	1.2
PD7848	8	800-960	25	1.35

In addition to Power Dividers, Janel manufactures a wide range of standard Amplifiers and other rf components. Custom designs can be provided for unusual applications. For detailed information, call or write Janel Laboratories, Inc., 33890 Eastgate Circle, Corvallis, OR 97333. Telephone (503) 757-1134.

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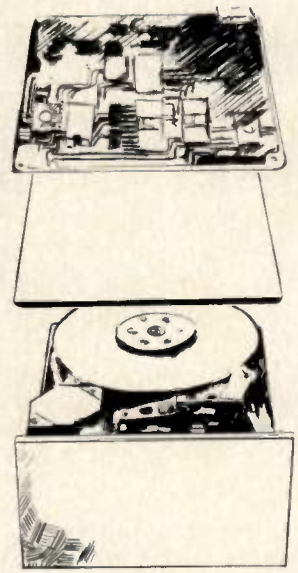
INFO/CARD 28

GST-MC2 Shielding Laminates



When it comes to direct shielding of printed circuit boards, Glasteel Industrial Laminates will help keep you covered with GST-MC2 shielding laminates.

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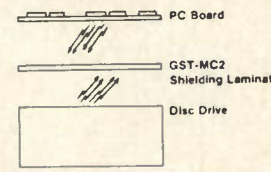

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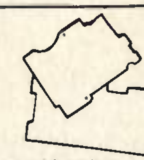

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For more information, call Steve Klein at (818) 365-9411. Or write to SFE Technologies, San Fernando Electric Division, 1501 First Street, San Fernando, CA 91340-2793.

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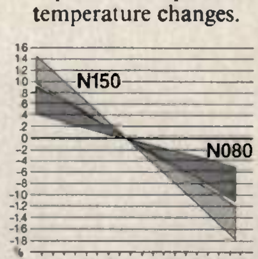
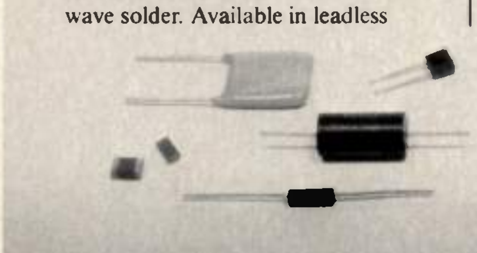


N080 & N150 Capacitance Change (%) vs. Temperature (°C)



INFO/CARD 30

An Ultra-Lightweight HF Transmitter Using High Voltage MOSFETs

By Robert W. Vreeland
University of California
Research and Development Laboratory

Modern solid state transceivers are ideal for battery powered applications. However, the extremely heavy power supplies required make them unsuitable for lightweight, portable AC powered use.

We have taken a lesson from the AC-DC vacuum tube radios of the World War II era and have utilized high voltage MOSFETs in a two pound RF amplifier for the 3.5, 7.0 and 14.0 MHz amateur bands. The transformerless power supply weighs an additional pound and runs on either 220 volts or 117 volts AC. The amplifier is driven by a one pound dry battery powered heterodyne VFO. By using tuned push-pull operation we have reduced all harmonics sufficiently that no low pass output filters are needed. We have used this transmitter to work Japan from San Francisco. The complete station can be carried in an attache case or in a camera gadget bag.

Traditionally, AC-DC receivers have used a half wave rectifier in a transformerless unregulated power supply. The supply bridge is usually in the 150 to 170 volt range. By using a bridge rectifier on 220 volts or a voltage doubler from 117 volts it is possible to develop sufficient voltage to run a simple linear voltage regulator with an output of 200 volts. This is an ideal power supply for an RF amplifier using a pair of 450 volt MOSFETs. The allowable drain to source voltage swing is zero to 400 volts leaving a 50 volt margin of safety.

Some of the older vertical power MOSFETs have a rise time as short as five nanoseconds, making them suitable for use in the 14 MHz amateur band. Unfortunately, the present design trend is toward higher power, lower frequency MOSFETs.

There are obvious safety problems resulting from transformerless design. The amplifier must have RF link coupling in and out. All circuits must be insulated from the metal panel and the panel must be grounded. Since the amplifier cannot be safely keyed, we must key the VFO. The VFO must be dry battery powered because a safe isolated power supply would add unnecessary weight.

These safety requirements were easily satisfied by building the RF power amplifier into a 2 x 4-1/2 x 6-1/2 inch plastic box with a grounded aluminum panel. The box has a plastic cover which closes to form a neat, easily carried two-pound package. Separate 2 x 3-3/8 x 5-1/2 inch plastic boxes contain the power supply and the VFO, which weigh a pound each. The VFO is powered by a pair of 9 volt MN1604 alkaline batteries. This three-package configuration makes the transmitter easy to carry in a variety of containers.

The transmitter is designed to operate in the 7 and 14 MHz amateur bands using 14 foot long inductively loaded dipoles. For 3.5 MHz operation we use a tuned loop antenna formed from a 14 foot length of RG-8/U coaxial cable.

The foregoing looks like a fairly straightforward design problem. Let us now look at the real world of power MOSFETs. They are marvelous devices when properly used but they do present a number of unusual problems. Unfortunately, their true identity has been shrouded in a certain amount of mythology.

Myth Number One:

"Due to the absence of second breakdown and thermal runaway, MOSFETs are virtually indestructable."

This may be true if one adheres strictly to the manufacturer's ratings. However, they will blow in microseconds if the peak current rating or the gate-to-source voltage rating is exceeded. To illustrate, look at the simple series regulator shown in Figure 1. This is a good regulator with one percent regulation from no load to a full load of several hundred milliamperes. However, the pass transistor will blow when the switch is moved from "R" to "S."

The charging current of a bypass capacitor as small as 0.02 μF exceeds the MOSFET's peak current rating. Since the source is momentarily grounded through the capacitor, the gate-to-source voltage rating is also exceeded, resulting in a punctured gate. Obviously some form of very high speed current limiting is required. This is most easily done by the use of series limiting resistors, as shown in Figure 2.

Excessive limiting will defeat the regulation for which the power supply was designed. It is usually possible, however, to divide the load so that the high current position, which does not require much regulation, does not interfere with the low current, well regulated loads. One must remember that the total peak charging current for all bypass capacitors must not exceed the MOSFET's peak rating. The reverse diode (D_o) is built into the MOSFET and need not concern us for normal drain-to-source voltage excursions.

Myth Number Two:

'Due to their insulated gate construction, MOSFETS require virtually no driving power."

While this is true for DC operation, it certainly does not apply to RF amplifiers. In Figure 3 the MOSFET is represented by a resistive channel. Current from source to drain through this channel is controlled by an electric field set up by the gate capacitor plate. As the driving generator frequency is increased, the capacitive reactance of the gate structure goes down, resulting in an increase in driving current into the lossy structure of the MOSFET. Our amplifier is noticeably harder to drive at 14 MHz than on the lower frequency bands. The drive requirements are moderate, however, when compared to a bipolar transistor amplifier.

Myth Number Three:

"Due to their self compensating thermal characteristics, MOSFETs will automatically adjust to share the load equally when connected in parallel."

This is true only when the MOSFETs

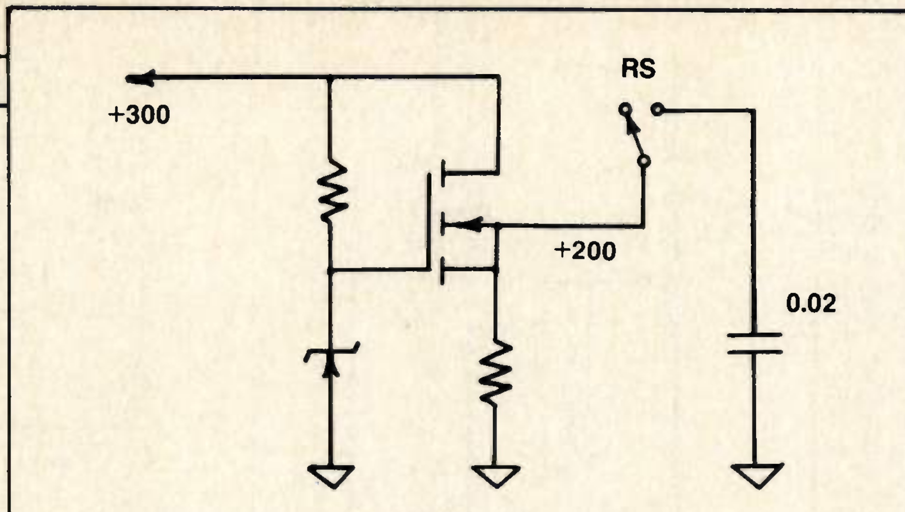


Figure 1.

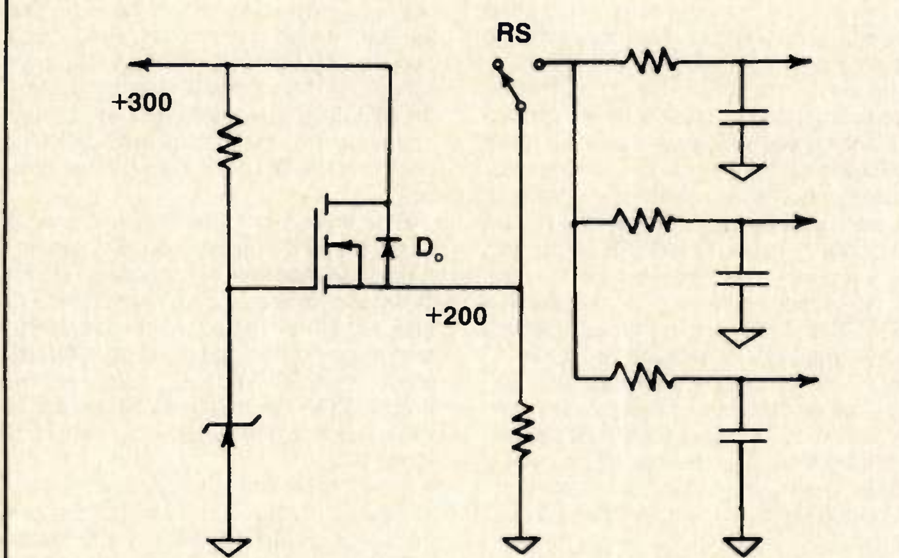


Figure 2.

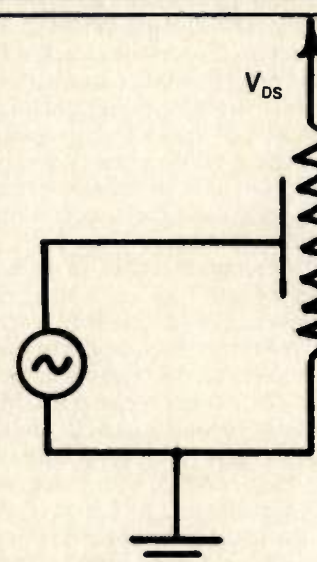


Figure 3.

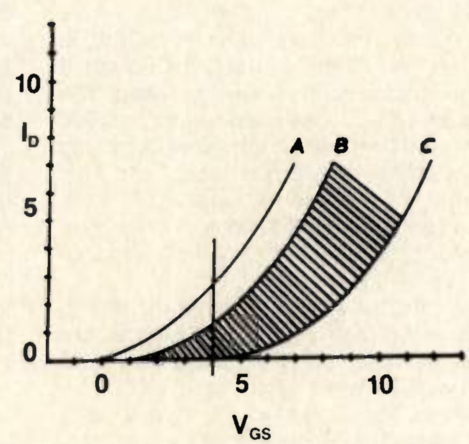


Figure 4.

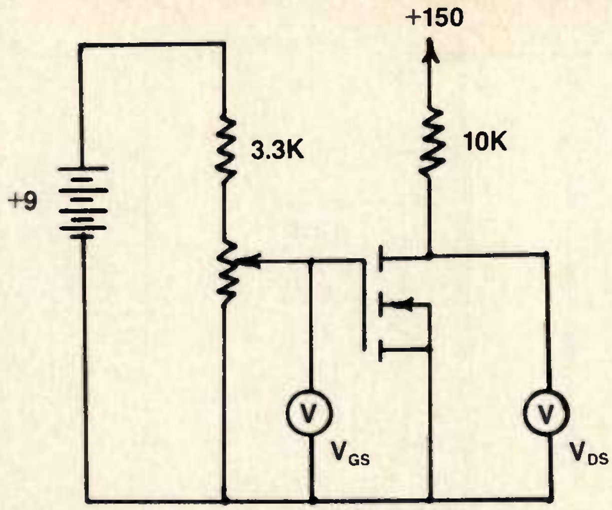


Figure 5.

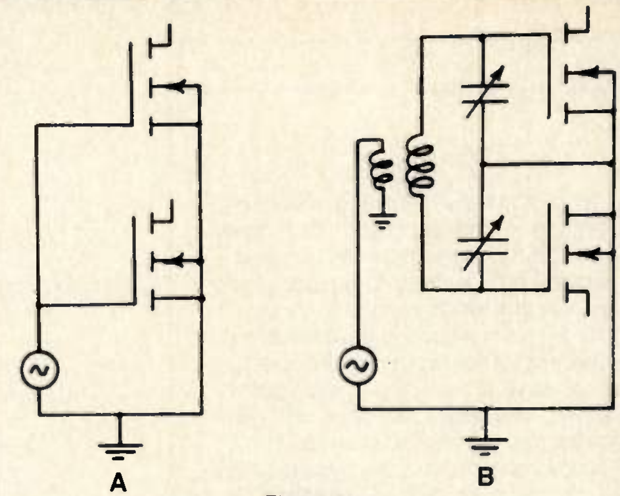


Figure 6.

are selected in matched pairs. Actually the gate threshold voltage may vary from 1.5 to 5 volts from transistor to transistor. For this reason manufacturers print normalized rather than actual transfer characteristic curves. In Figure 4, curve A is the normalized transfer curve. The actual curve may fall anywhere in the shaded region between curve B and curve C. Let us connect a curve B MOSFET in parallel with a curve C MOSFET. If we bias the parallel combination at +4 volts, the curve B MOSFET will carry a current of about 1-1/3 amperes, whereas the curve C MOSFET will not even turn on. Actually, the manufacturer is probably overly conservative in specifying such a wide range of gate threshold voltage. Inspection of Table I will show that the majority of IVN6000KNTs fall within the 2-3 volt region.

In our power supply we use a parallel pair of MOSFETs as pass transistors. The parallel pair was selected using the circuit shown in Figure 5. The gate-to-source voltage (V_{GS}) is gradually increased until the drain-to source voltage (V_{DS}) drops from 150 volts to 100 volts. The V_{GS} meter is then read. This is then the gate threshold voltage; V_{GS} (th).

We did not select matched MOSFETs for our RF amplifier because individual bias voltage controls were provided. The amplifier was designed so that 10,000 ohm load resistors could be plugged into the output transformer jacks. The bias controls could then be used to determine the gate threshold voltages of the transistor pair using the previously described technique.

Drain-to-source voltage, drain current, rise time and input capacitance are perhaps the most important factors to be considered when selecting MOSFETs for RF use. The drain-to-source voltage rating must be high enough to allow the drain to swing up to double the power supply voltage with 50 volts or so to spare. The drain current rating should be sufficient for the desired power level. Also, don't overlook the peak drain current rating, as exceeding this value will instantly destroy the MOSFET. Manufacturers provide safe operating area curves that are helpful for selecting the DC drain current operating point.

Rise time is perhaps the most critical factor affecting high frequency operation. It must be less than 10 nanoseconds for 14 MHz operation. Input capacitance is also extremely important. It can range anywhere from about 200 to 300 pF for a good RF MOSFET, such as the IVN6000KNT, to more than 10 times that value for the low frequency switching MOSFETs.

How to drive an input capacitance even as low as a couple of hundred pFs can be a real problem if two or more MOSFETs are connected in parallel. In parallel operation the input capacitances add as shown in Figure 6A. If, however, we use a tuned push-pull circuit, as shown in Figure 6B, the input capacitances appear in series across the tuning capacitor. This effectively cuts the input capacitance in half. Furthermore, the series combination becomes part of the input tuning capacitor, thereby serving a useful purpose. Push-pull operation effectively reduces the input capacitance by a factor of four over parallel operation.

The gate-to-drain feedback capacitance (Cgd) is important because it introduces positive feedback that can lead to oscillation and transistor destruction. In a tuned push-pull circuit conventional crossed capacitor neutralization can be used as in the case of vacuum tubes. Neutralization must be done with the full operating supply voltage applied because the gate-to-drain capacitance is a function of drain to source voltage. Neutralization is done with an oscilloscope connected across a dummy load on the amplifier output. The gate-to-source voltages are reduced so that no drain current flows. A small amount of RF excitation is then applied and the neutralizing capacitors are adjusted for a null on the oscilloscope. This adjustment is only approximate and must be touched up for stable operation at full output.

Our power supply is packaged in a small covered plastic box (Figure 7, left). Note the cooling fins and the miniature meter, which is shunted for one ampere full scale. The regulated output and the transmitter safety ground are on the four pin connector. Separate grounded three wire power cords are used for 117 volt and 220 to 240 volt operation. Connecting the appropriate power cord to the six pin connector makes the necessary circuit changes.

TABLE I

Measured IVN6000KNT Gate Threshold Voltages (Volts)

4.538	3.897	2.981
4.478	3.815	2.964
4.219	3.804	2.898
	3.243	2.801
	3.199	2.748
	3.129	2.699
	3.079	2.677
		2.666
		2.578
		2.406
		2.403
		2.376
		2.069

A simplified circuit diagram of the power supply appears in Figure 8. Diodes D_1 and D_2 form a voltage doubler with C_1 and C_2 for 117 volt operation. For 220 volt operation, the power cord completes the bridge circuit via jumper J_1. The triangular symbols represent a floating common (not ground). The safety ground is not shown, A pair of Intersil IVN6000KNT MOSFETs. serve as pass transistors and the Zener is a 1N5388. The regulation is one percent from no load to a full load of 500 mA.

Selecting diodes that would handle the inrush current into the 160 μF capacitors (C_1 and C_2 turned out to be a bit of a problem. We finally chose RCA SK3051s. It was necessary to limit the AC inrush current with a series 5 ohm, 5 watt resistor in order to prevent the on-off switch from burning out. Changing the power cord selects a 1-1/2 ampere fuse F_1 for 117 volts or a 3/4-ampere fuse (F_2) for 220 volt operation. Output current limiting is provided in the transmitter package.

For stability we chose a heterodyne VFO (Fig. 7, right). It is powered by two 9 volt alkaline transistor radio batteries (Fig. 9). The signal from the variable oscillator is mixed with one from a crystal oscillator to produce an output in the desired amateur band. The mixer is followed by a tuned output amplifier. Also included is an audio side tone oscillator.

The ground returns for all VFO circuits except the variable oscillator are keyed. An R-C circuit was inserted in the positive 9 volt lead to slow the rise of the keyed signal in order to reduce key clicks. By not keying the variable oscillator we have avoided any chirp problems. Since none of the harmonics from this oscillator fall within the bands used it is left on while receiving. It is, however, very important to keep the harmonics low while transmitting as they will mix with the crystal oscillator to produce spurious outputs.

A simplified circuit of the final amplifier is shown in Figure 10. Since the power supply is transformerless, toroidal isolation transformers T_1 and T_3 are used for the amplifier input and the output. The triangular symbols represent a hot floating common (not ground).

The driver transistor (Q_1 is an RCA SK3044. It is coupled via T_2 to a push-pull pair of IVN6000KNTs (Q_2 and Q_3). Both the primary and the secondary of T_2 are tuned. A separate transformer (T_2) is used for each amateur band. The transformers are wound on toroidal cores and are selected by a band switch (not shown). The positive bias on Q_1 is increased slightly for 14 MHz operation in order to

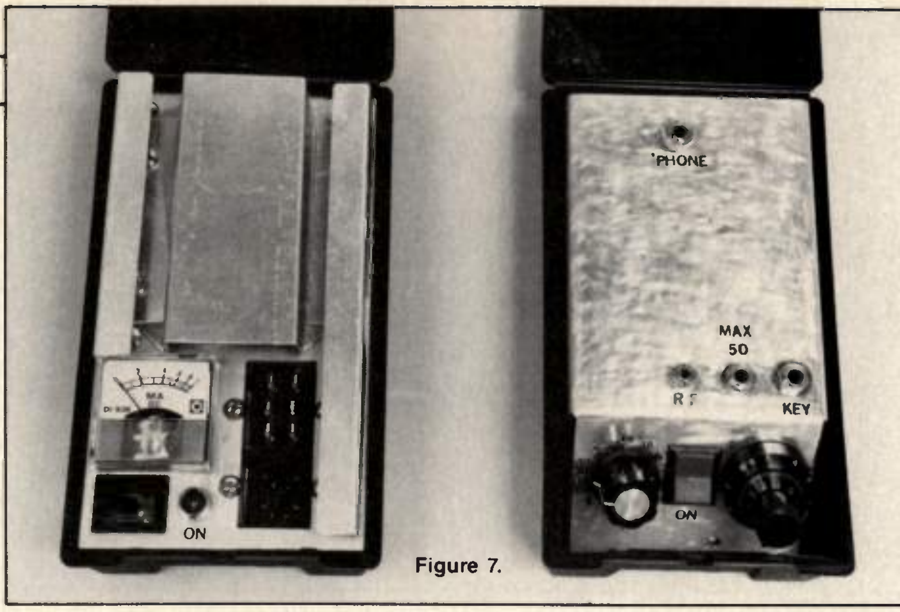


Figure 7.

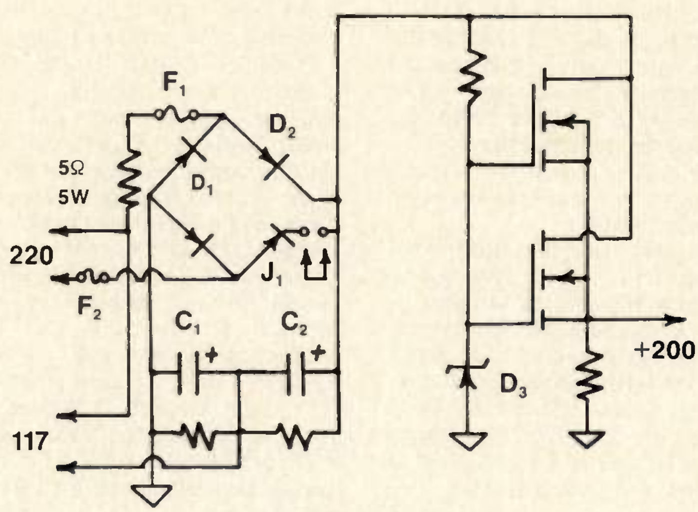


Figure 8.

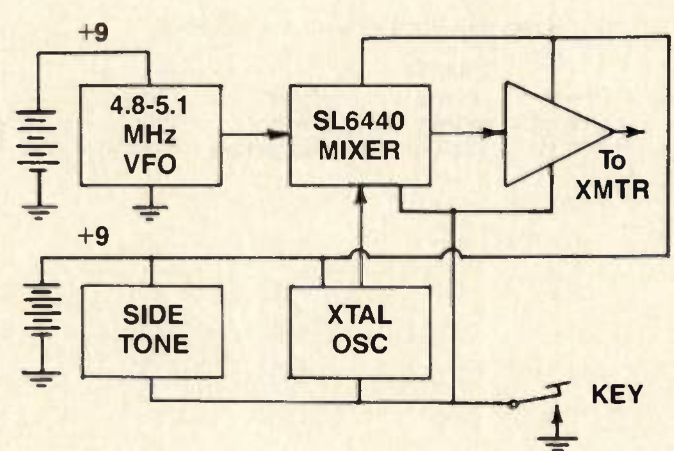


Figure 9.

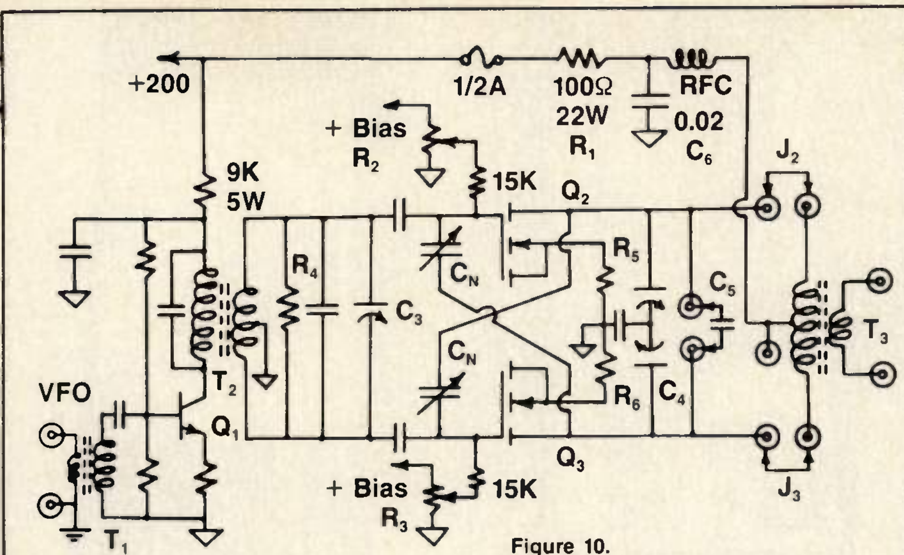


Figure 10.

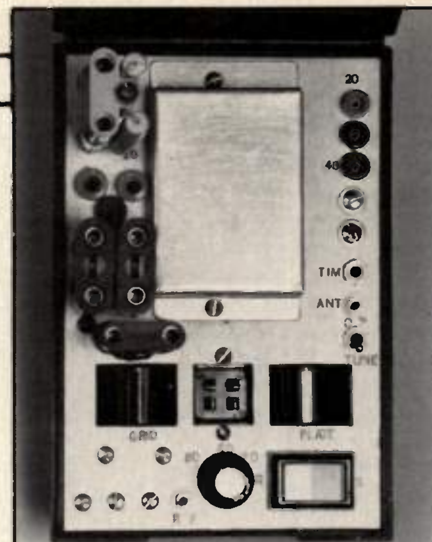


Figure 11.

compensate for the increased drive requirements on that band.

The input of the push-pull pair (Q_2 and Q_3) is tuned by a 365 pF plastic dialectric variable capacitor (C_3). It is shunted by a fixed silver mica capacitor. A two gang 100 pF air varialbe capacitor (C_4) tunes the amplifier tank transformer (T_3). Both C_3 and C_4 are thumbwheel tuned. In Figure 11 the thumbwheels are labeled "grid" and "plate."

Separate toroidal output transformers (T_3) are used for 14 and 7 MHz operation. They are selected by jumpers J_2 and J_3. The jumpers are on double banana plugs. For simplicity only one pair of jumpers and one output transformer are shown in Figure 10. On 3.5 MHz a polystyrene fixed capacitor (C_5)is plugged into another pair of banana jacks to bring the 7 MHz output transformer down to that frequency.

The jack at the center tap of the primary of T_3 is of special interest. It is used to substitute a pair of 10,000 ohm, 10 watt fixed resnators for T_3. A dual trace oscilloscope is connected to monitor the DC levels on these resistors. The individual bias controls (R_2 and R_3) can then be used to find the gate threshold levels for Q_2 and Q_3 in order to set the desired class C operating point. For safety, an isolation transformer should be used for the above adjustments.

A pair of 15 pF air variable neutralizing capacitors (C_N) is used. The neutralizing procedure has already been covered. Additional stabilization is provided by a swamping resistor (R_4). A separate resistor is used for each amateur band. The negative feedback source resistors (R_5 and R_6) are each 3.3 ohms, 1 watt.

As previously mentioned, the 0.02 μF bypass capacitor (C_6) is sufficient to blow a pass transistor in the power supply. This is prevented by the 100 ohm 22 watt resistor (R_1). The resistor is a pair of 11 watt units mounted on a double banana plug. This arrangement permits free flow of air to cool the resistors. Careful insulation of the resistor leads is required for safety. The 1/2 ampere fuse protects the power supply in the event of failure of Q_2 or Q_3. It should be noted that the driver stage (Q_1) derives its power via a separate series resistor so that its power supply regulation is not adversely affected by the heavy current through R_1.

TABLE II

Push-Pull IVN6000KNT RF Amplifier

Frequency (MHz)	Power Output (Watts)	Drain To Source Voltage (Volts)	Drain Current (Milliamperes)	Power Input (Watts)	Efficiency (Percent)
14.10	22.5	182	332	60.4	37.2
7.10	19.5	179	315	56.4	34.6
7.05	22.0	180	345	62.1	35.4
3.75	32.5	176	370	65.1	49.9
3.70	32.0	175	380	66.5	48.1
3.65	27.0	172	415	71.4	37.8
3.60	22.0	173	420	72.7	30.2
3.55	22.0	179	360	64.4	34.1

Output Power

The transmitter puts out about 20 to 30 watts, as shown in Table II. The final amplifier efficiency is typically about 35 percent. While this might not be acceptable for high power equipment it is not a problem for our transmitter, which requires less power than a 100 watt light bulb.

Since the transmitter is not mismatch protected, tuning is done with a combination dummy load and antenna impedance bridge. This also prevents unnecessary radiation while tuning (1).

We are indebted to Frank Rittiman of Intersil for his assistance in getting us started.

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1. Volpe, J. Confidential; For Antenna Tuner Users Only; CQ August 1983: pp.56-59.

About the Author

Robert Vreeland is Senior Development Engineer at the University of California Research and Development Laboratory, 4th and Parnassus Avenues, Room U-10, San Francisco, CA 94143. He received his BSEE from the University of California, Berkeley. He is certified as a Clinical Engineer and has a Commercial Radiotelephone First Class and Advanced Amateur Class License.

The Surface Acoustic Wave Filter

Or, how to get

By Jeff Schoenwald
Contributing Editor

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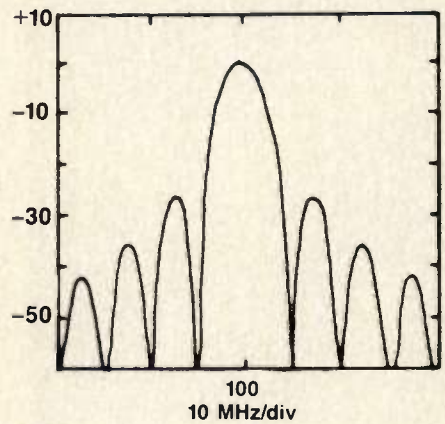

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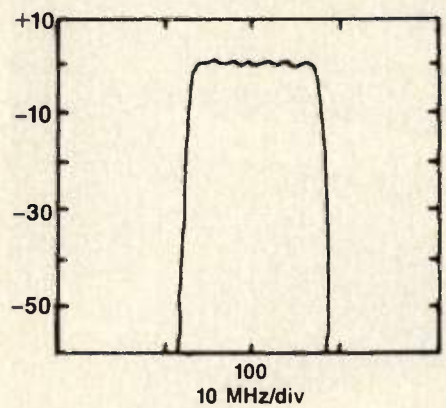


While several books, tutorial collections and journal special issues have been published to treat this topic, these works have mainly targeted audiences of narrower and more specialized interest than the readership of this magazine. In keeping with the editorial goal of serving the needs of a very broad and varied readership, this series will strive to take a balanced approach to the subject. We will make an effort to provide the relèvant mathematics, philosophy upon which design rules are based, rules and procedures from which the design algorithms follow, equivalent circuit properties and how they are treated and fabrication and packaging techniques that must be regarded as integral elements in the successful design and execution of a satisfactory SAW bandpass filter.

The major portion of the discussion will be given to the interdigital transversal filter, although we expect to cover more sophisticated topics such as the unidirectional low loss bandpass filter and the SAW resonator multi-pole narrow bandpass filter, so the reader can develop enough familiarity to recognize which type of device is suitable, and when. Interested readers may go further and develop computer aided design procedures for simulating filter behavior.

Figure 1 is a general description, or roadmap, of the basic elements of SAW filter engineering. It is not unique, since other approaches will become apparent, but it is workable and has proved very successful, even if only as a basis for developing more sophisticated methods required by more sophisticated devices.

Let's start from a neutral point of view. Suppose the user is a systems designer and has some idea that a SAW bandpass filter is just the thing to clean up the signal processing in an IF section. The user develops a specification, calls up several SAW fabrication houses and kicks it around with the first SAW engineer the operator can locate. Even more common these days, the user's purchasing agent is put through to the director of marketing at the SAW house. Since it is not unusual for both persons to have only second-hand knowledge of the design options available, some formal exchange of letters, brochures, business cards and a request for quotation takes place before things get going.

The user will generate a specification for the device. This usually includes the following, (summarized in Figure 2): center frequency, bandwidth (min and max), shape factor, sidelobe level, maximum insertion loss, in-band amplitude and phase or group delay ripple, direct cross-talk, insertion delay, and temperature dependent excursion limits of all the properties just indicated, variation limits at some standard operating temperature, and, of course, the usual salt spray, shelf life, humidity and fungus (fungus?) resistance requirements that often accompany any electronic component requirement; and quantity, naturally.

After absorbing all these details, the SAW designer and marketing director decide if a straightforward response is in order. Years ago, but not so often now, SAW designers had to invest a great deal of time in educating prospective users, since the device was a novelty. Andersen Labs, for instance, periodically issues a brochure describing performance capabilities and system applications of SAW devices in their product line. In fact, the SAW reseach community has provided the largest investment in time, money and effort, redesigning systems to accommodate SAW devices rather than fighting the useless argument that "one filter should be able to replace another, so let's yank out the LC Butterworth and drop in a SAW." The first generation of SAW devices had more insertion loss than conventional filters and had linear phase (fixed delay). This has become less of a constraint as SAW technology has advanced, but problems still abound.

After the specs come in, the first decisions the SAW engineer makes is whether the center frequency presents a problem (too high, too low) and how the bandwidth affects design strategy. These two issues may be easy ones about which to make decisions, but they are still quite important.

Low frequency devices tend to get large, and to not reflect well the intent of microelectronics. The purchaser certainly would like a device smaller than the more conventional ones he might otherwise have to use. Substrate area and thickness will impact the materials cost. If the frequency is uncomfortably high, such as beyond 1 Ghz, the imaging capabilities of the vendor's pattern generation equipment may be hard pressed, driving yield down and production costs up.

Bandwidth requirements will dictate the choice of substrate; large bandwidth requires large coupling substrate material; narrow bandwidth indicates lower coupling efficiency is more suitable. In addition, there are two basic approaches to transducer design that are generally (though not exclusively) specific to each bandwidth domain. These two methods are referred to as apodization (or overlap) weighting and withdrawal weighting.

The interdigital transducer (idt) achieves its filtering characteristics by a weighted sampling technique. A pattern of interleaved electrodes, like two interlaced combs (Fig. 3), are formed on a piezoelectric crystal substrate. The orientation of the surface and direction of propagation determine several characteristics: (a) the electromechanical coupling coefficient which, in turn, affects the equivalent circuit properties, and (b) the velocity of the surface wave, which sets the peak response frequency. This is described in more detail in two articles that have appeared in *R.F. Design* which discussed the basic properties of the idt.

The frequency characteristics of a simple idt, i.e., in which the opposing electrodes have a constant overlap, are derived by taking the Fourier transform of the impulse response of the idt. If a very narrow voltage spike — ideally a delta function — is applied to the opposing electrodes of the idt via the bus pads shown in Figure 3, a facsimile of the electric fields produced at the substrate surface in the form of mechanical stress will be excited under and between the electrodes. A delta function is an excitation containing all frequencies, because it contains no time interval. Time and frequency have this inverse relationship — shorter time intervals imply larger frequency bandwidths and small bandwidths imply temporal signals of large extent.

Since the spike voltage is distributed

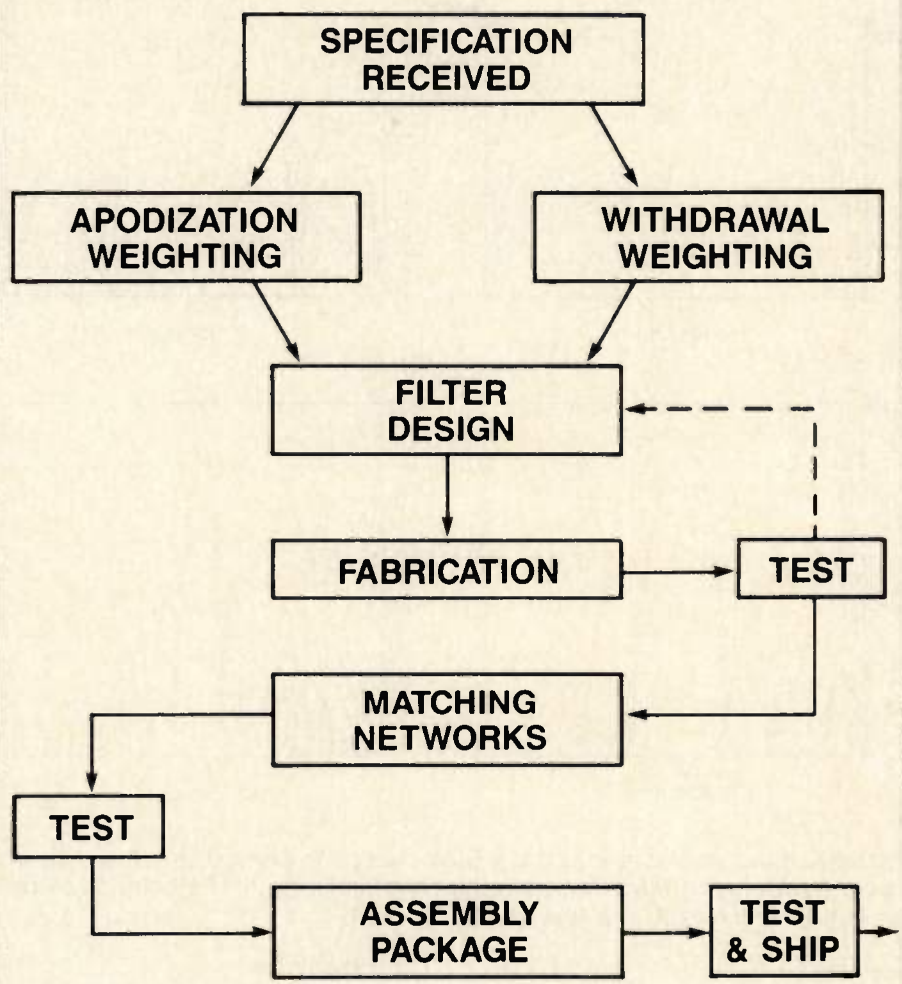


Figure 1. Roadmap of a typical SAW transversal bandpass filter development project.

CENTER FREQUENCY F_O+/–Δf_o
3 dB BANDWIDTH, MIN/MAX
SHAPE FACTOR (40 dB/3 dB) MAX
SIDELOBE LEVEL (dB), MAX
INSERTION LOSS (dB), MIN/MAX
PHASE SLOPE OR GROUP DELAY
PHASE OR GROUP DELAY LINEARITY
OPERATING TEMPERATURE RANGE
TEMPERATURE COEFFICIENT OF DELAY/FREQUENCY DRIFT

Figure 2. A typical list of specifications for a SAW bandpass filter.

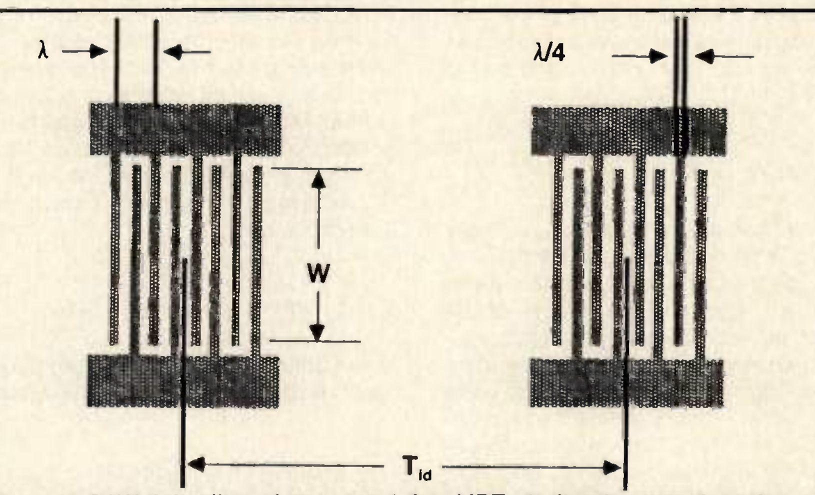


Figure 3. SAW delay line of two unweighted IDTs, indicating wavelength λ, electrode length λ/4, transducer aperture and insertion time delay T_{Id}.

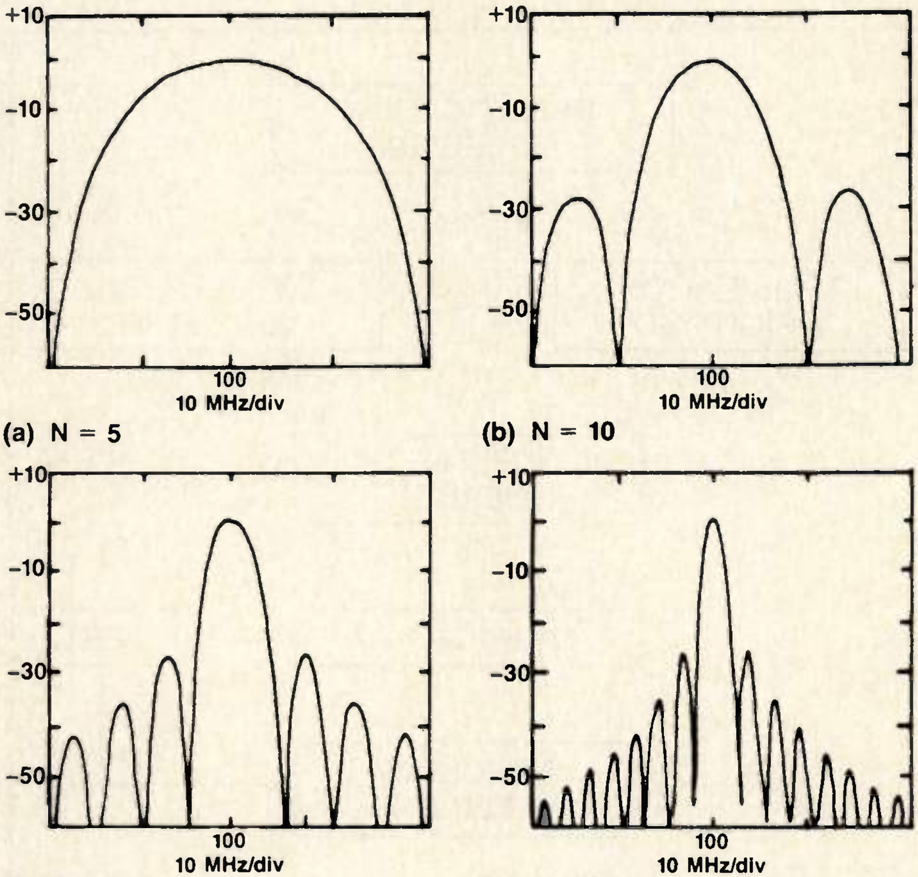


Figure 4. Filter characteristics of a SAW delay line consisting of two identical interdigital unweighted transducers consisting of N electrode pairs. (a) N = 5, (b) N =10, (c) N = 20, (d) N = 40.

over the entire area of the idt, and therefore has a finite spatial extent along the direction of propagation (both forward and backward), the very short voltage spike is transformed into an impulse of finite time duration. The stress field induced will now propagate away from the electrode pattern and travel as two pulses of time duration (Td) determined by the time length of the idt:

$$Td = N^{*}L/V, \text{ where} \tag{1}$$

N is the number of electrode or finger pairs, L is the spatial period (pitch) of the electrode pattern — in effect the wavelength (λ_o), and V is the velocity of the surface acoustic wave, which for all practical situations is constant, independent of frequency. The frequency of the wave (f), is, to first order, given by the relationship $f\lambda = V$. In fact, since the transducer is finite in length, the frequency response is not a single frequency, but spread over a range. We may see this from the following mathematical development.

The Unweighted Interdigital Transducer

Each electrode in the transducer has an excitation or detection strength of magnitude unity and sign + or –, depending on which bus bar (pad) it extends from. This means that the phase of the excitation voltage flips 180 degrees from one electrode to the next. The designation of sign is arbitrary and is usually defined with respect to which pad is wire bonded to electrical ground. If we locate the origin of the X axis at the center of the first electrode, the position of each electrode is located at

$$X = \lambda_o\, n/2 \qquad n = 0, 1, \ldots 2N-1 \tag{2}$$

If we define the frequency dependent wave vector, $k(f) = 2\pi/\lambda$, then the function

$$U = \exp[jKX^n] = \exp[j\pi n\lambda_o/\lambda] \tag{3}$$

contains enough information to determine the magnitude and phase of the excitation strength at each of the electrode positions. Note that $f_o\lambda_o = f\,\lambda = V$, the SAW velocity and f_o is the frequency corresponding to the pitch, or period of the electrode pattern. Staring at equation (3) for a few moments should convince us that this excitation structure should generate a wave even when f is not quite equal to f_o. This statement will be made explicit later.

At synchronism, when $f = f_o$,

$$U = \exp[j\pi n] = +1 \qquad n = 0, 2, \ldots 2N-2 \tag{4}$$

$$= -1 \qquad n = 1, 3, \ldots 2N-1$$

To determine the frequency response (for both excitation and detection) it is necessary to take the inverse Fourier transform of the time domain of this structure. The time domain of the transducer is related to the spatial structure in a simple way. A crest of a stress wave (SAW) excited under one electrode will propagate to an equivalent position under the adjacent electrode (one half wavelength away) in a time t, such that

$$X^n = V_{nt} = n\lambda_o/2 \tag{5}$$

Taking the inverse Fourier transform of the time domain of the transducer (which extends from t=0 to t=T, the time length of the idt) will result in an expression for the frequency domain response:

$$A(f) = \frac{1}{T}\int_{t=0}^{t=T} \exp[j2\pi f_o t]\exp[-j2\pi f t]dt \tag{6}$$

$$= \exp\left[j2\pi(f_o-f)\frac{T}{2}\right] \frac{\sin[\pi(f_o-f)T]}{\pi(f_o-f)T}$$

Since $T = N\lambda_o/V = N/f_o$, A(f) takes the simpler form

$$A(f) = \exp\left[j\pi\frac{(f_o-f)N}{f_o}\right] \frac{\sin\left[N\pi\frac{(f_o-f)}{f_o}\right]}{N\pi\frac{(f_o-f)}{f_o}} \tag{7}$$

A(f) is the amplitude response of the idt and is complex, with the phase given by the exponential factor. The relative power (or gain) is given by the square of the magnitude:

$$A(f) = \frac{\sin^2(x)}{x^2}, \quad x = N\pi(f_o - f)/fo \qquad (8)$$

This is the celebrated sin (x)/x dependence of a SAW idt of uniform electrode aperture, i.e., unweighted. Figure 4 shows the frequency response predicted for a succession of transducers with increasing numbers of finger pairs.

Several features of this set of curves should be appreciated. First, whenever the argument x, as defined in equation (8), is an integer multiple of π, but not equal to zero, a null in the response occurs. The first null occurs at $f = f_o(1 \pm 1/N)$. Second, whenever x is nearly equal to an odd half-integer multiple of π, a local peak (sidelobe) occurs. The exact value of x can be found by taking the first derivative of equations (7) or (8) with respect to frequency, setting them equal to zero and solving for the value of f at which this occurs. This locates the true maxima. Using the approximation, however, is quite satisfactory. The result is that the first sidelobe is found to occur at –13.45 dB relative to the main signal. Any SAW filter consists of two transducers. The power versus frequency response is the product of the individual idt power curves:

$$P(f) \sim |A1(f)|^2 \cdot |A2(f)|^2 \qquad (9)$$

For two identical transducers, the first sidelobe is then found at –27 dB.

The third feature is the bandwidth. The change in frequency from the band center to the first null is f_o/N. This is the number usually quoted as the 3 dB bandwidth, but is not correct, strictly speaking. For a single transducer, the frequency band centered around f_o, of extent f_o/N falls to –3.9 dB at the band edge. For transmission between two transducers, the roll-off is –7.8 dB.

These three factors — the lack of monotonic roll-off in filter response away from the central response, the limiting of the first sidelobe to –27 dB and the lack of flatness in the response within any reasonably defined bandwidth — are the basic motivations for developing design techniques that may be applied to improve the filtering capability of SAW devices.

The Fourier transform of the unweighted (rectangular) transducer is a sin(x)/x. Since the inverse transform will return the rectangular time domain (impulse) response, the Fourier transform of a time domain excitation function weighted as sin(x)/x will produce a frequency response that has a rectangular appearance, i.e., flat within a given frequency band, dropping off sharply outside of it. (In this context, x does not refer to any spatial position. It is only the argument — in radians — of the trigonometric sine function.)

Once we accept this mathematical symmetry, a second feature must be attended to. The finite impulse response results in a frequency domain which extends to all values of frequency, albeit with decreasing strength. So a transducer that has a truly finite and rectangular frequency response — constant in some bandwidth, zero elsewhere — must be infinitely long.

This defines the fundamental art and skill of SAW transducer design: How to achieve sufficient bandwidth limited filtering with good sidelobe suppression and sharp transition skirts beyond the band edge, all within a device structure of manageable size.

When we simply weight a SAW idt with a sin(x)/x function and truncate the device to a finite length, something undesireable happens. Refer to the series of examples illustrated in Figure 5.

Column 1 of Figure 5 is a schematic of the actual SAW transducer for each specified transducer length (i.e., number of electrode finger pairs or, equivalently, number of wavelengths). Column 2 is the frequency response of the power transmission efficiency between two such identical transducers. In column 1 the horizontal scale is reduced by 2x between Figures 5c-1 and 5d-1 to accommodate the entire image as it grows longer. In column 2 the vertical scale is in decibels, with tick marks indicated every 10 dB. The filter response is measured relative to the response at band center (100 MHz), which is 0 dB. The scale has an upper limit of +10 dB to allow for an in-band response that may ripple above 0 dB. The horizontal scale shown spans 40 MHz about the center frequency and has tick marks every 10 MHz. The nominal bandwidth specified for this filter is 10 MHz.

Just how is the desired bandwidth specified mathematically so that the transducer apodization is correctly generated? The most straightforward approach is to go back and use a method parallel to that shown above for the frequency response of a rectangular (unweighted) idt time domain. This time, the frequency domain is specified as rectangular, with the bandwidth B and the center frequency f_o as the only important parameters. Following the development above, we can obtain a function which specifies the relative overlap between adjacent electrodes spaced every half wavelength (at center frequency):

$$A(n) = \frac{\sin[(n-N)\pi B/2f_o]}{[n-N)\pi B/2f_o]} \exp[j\pi n] \tag{10}$$

$n = 0, 1, \ldots 2N$

The function changes sign every electrode with the term $(-1)^n = \exp[j\pi n]$ to account for the 180°phase reversal every half wavelength. The entire function has the sin(x)/x behavior. The product results in a main lobe with a set of monotonically decreasing lobes that string out until arbitrarily truncated at some value N1 to limit the extent of the idt. A phase reveral occurs when the sine function goes through zero. This can be seen in Figure 5c-1, where two adjacent electrodes suddenly appear to emerge from the same pad. This is because two sign reversals take place simultaneously between two consecutive electrode positions — one from the term in $(-1)^n$ and one from the change in sign of the sine term (no play on words intended).

Now let's look at what happens as we let the idt get longer. Compare Figure 5a to Figure 4b. Both idts have 10 finger pairs, but now the sin(x)/x function is weighting the apodization. Both look pretty much the same, except that now the first set of sidelobes are lower by about 4 dB. By tapering off the excitation strength of the electrodes at each end of the idt, we have made some improvement in lowering their ability to generate a signal in the frequency domain beyond the first null. However, notice a small trade-off: the first pair of frequency nulls in 5a-2 have spread slightly compared to 4b. Apparently the idt is behaving as if, in this respect, it had slightly fewer electrodes.

In Figure 5b-1 the idt extends out to the first spatial nulls, or phase reversal points. Now, clearly, because there are more electrodes (i.e., finger pairs) the frequency response has narrowed considerably, both at the null points and at the 3 dB level. Even more remarkable, the first sidelobes have dropped below −50 dB, in continuation of the process noted in the last paragraph.

Extending the idt another 10 wavelengths, as shown in Figure 5c-1 results in interesting new behavior. Now that a phase reversal has occurred and there are several electrodes generating waves out of phase with those in the main lobe, in-band the transducer tends to act as if it had fewer electrodes. Indeed, the 3 dB bandwidth has broadened and the positions of the first nulls have spread out. Unfortunately, the sidelobe level has jumped

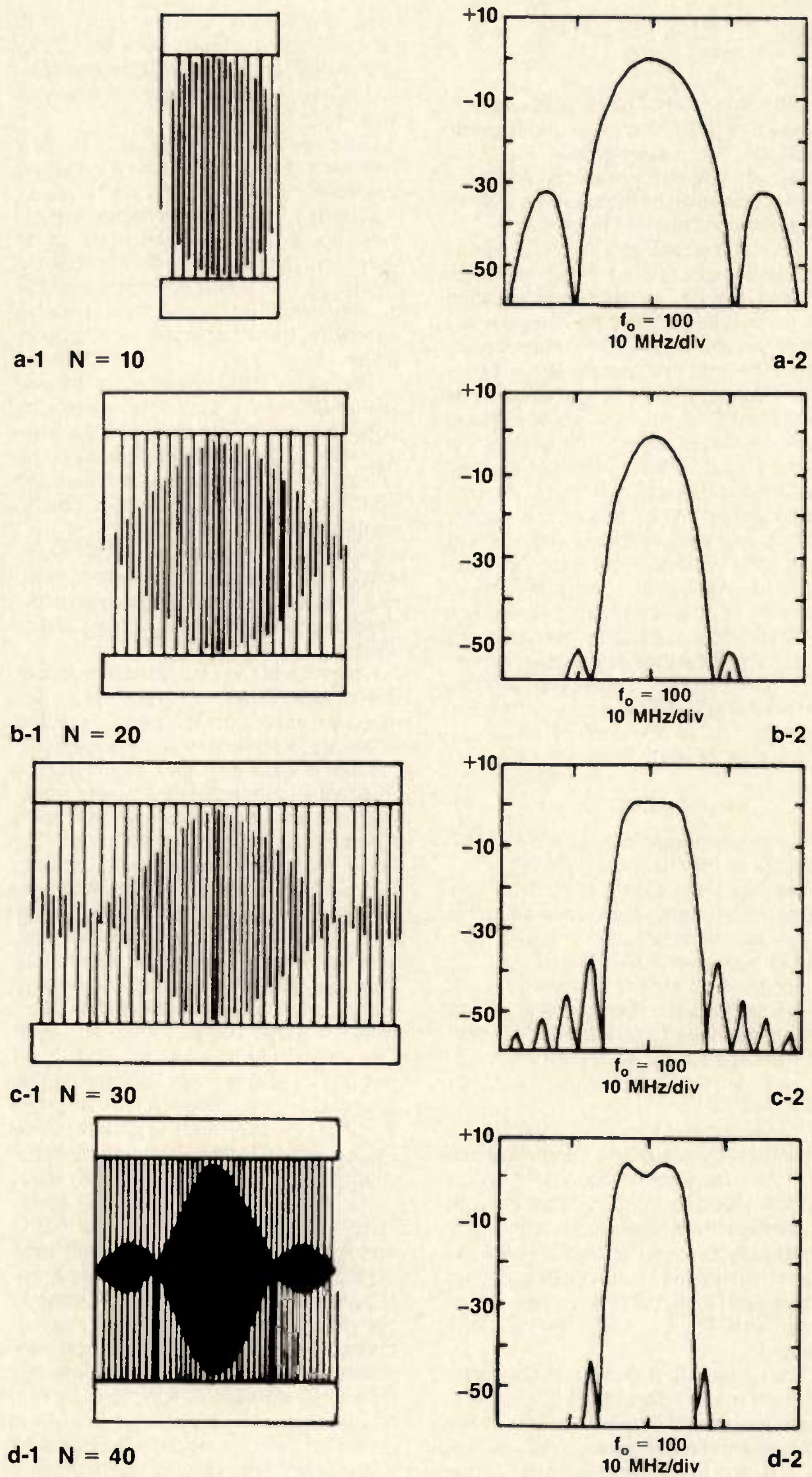
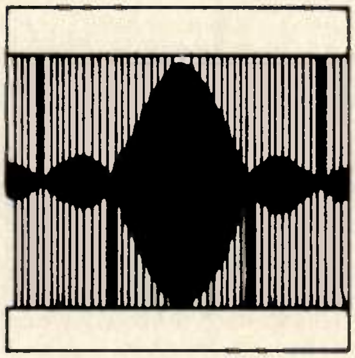
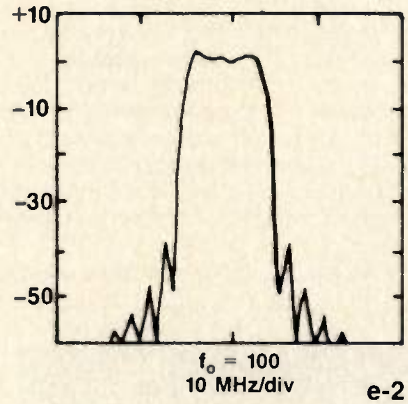
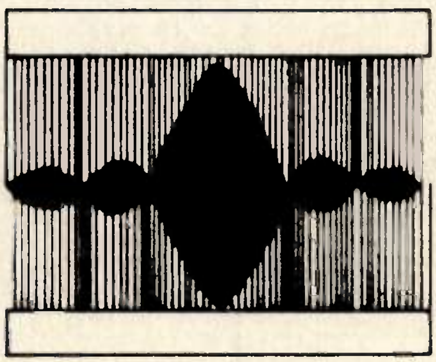


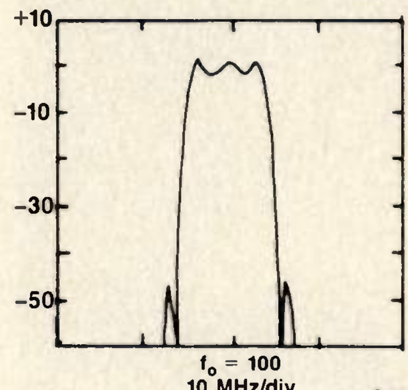
Figure 5. Progressive filtering characteristics of pairs of IDTs apodized with a sin(x)/x weighting as the number of electrodes increases from N = 10 to N = 70.



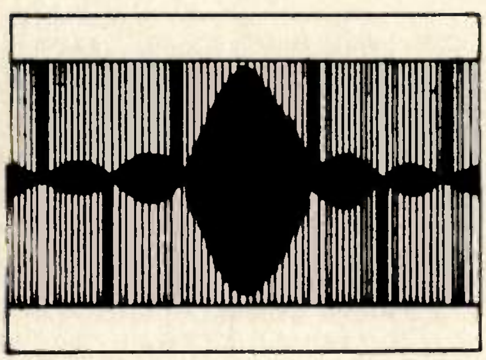


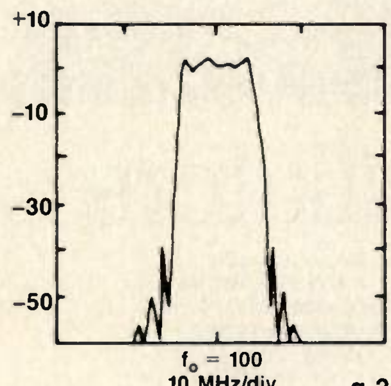
e-1 N = 50 e-2





f-1 N = 60 f-2





g-1 N = 70 g-2

Figure 5 (continued).

back up, as if the outer electrodes, with their corresponding phase reversal, are suitably positioned to generate more acoustic energy out-of-band.

The most impressive things to happen, however, are the flattening of the response in-band and the somewhat precipitous drop-off in response outside the central frequency domain. These are features that we like, although they have occurred at the expense of undesireably degraded sidelobe levels out of band.

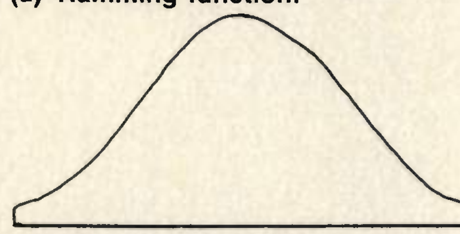
When the first pair of idt sidelobes are completed, a new phenomenon occurs. The sidelobe level again subsides, as in 5b-2 when the main lobe was complete, but rather noticeable ripple is introduced in the main response. What we had accomplished in the last figure has clearly been overdone here.

As we proceed through the remaining cases in Figure 5, it is evident that when the idt lobes are complete, the frequency sidelobes are lower, but the in-band ripple is large. When the outer idt lobes are half of a full lobe length, the in-band response is much flatter but frequency sidelobes rise. Throughout the progression, however, the transition skirts — the frequency bands on either side of the main response between the inband and out of band regions — become increasingly steep, which is one of the features we want most.

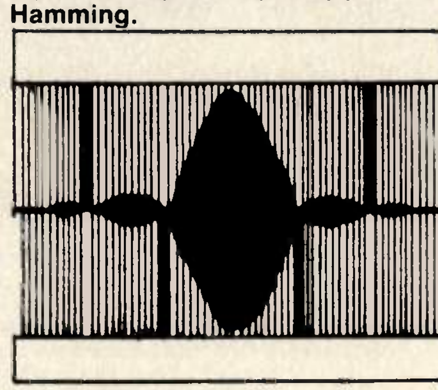
It would seem that, in principal, if we could simply let the transducer continue on to infinity, the sidelobes should drop off altogether, the passband should go flat and the transition skirts should become vertical. This will never happen. Instead, the sidelobes stay with us, the in-band ripple gets more bothersome (Gibbs phenomena) and the filter would have to get unpractically large. Why this happens is related to the discrete sampling nature of the design method. Note that the behavior of the filter is the result of a discretely sampled function, not a continuum.

To close this installment, the reader is given a taste of the technique used to op-

(a) Hamming function.



(b) IDT weighted by sin(x)/x and Hamming.



(c) Filter performance.

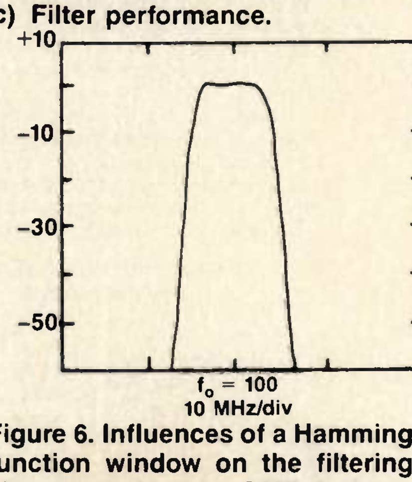


Figure 6. Influences of a Hamming function window on the filtering characteristics of a SAW device.

timize all of the features simultaneously that seem to evade us — low sidelobes, flat in-band response and steep transition skirts, within a device of practical size. Like a set of syncopated bellows, just when one undesireable characteristic appears to deflate another breathes full of life.

The method that has received much attention, and achieved much success, is called windowing. It is a well known technique used in radar to weight the frequency spectrum in pulse compression transceivers to suppress time domain sidelobes and thus improve range accuracy. We use it the opposite way — the time domain waveform is windowed to suppress sidelobes in the frequency domain.

There are many types of window functions, and we will discuss several of them in the next part of this series. Right now, an example is given of one called the Hamming function. It physically applies a scale factor that modifies the sin(x)/x function for each electrode, and is itself dependent on position along the transducer. Figure 6a is a plot of the Hamming function. It has maximum value (set at unity) in the center and tapers off at the ends. In fact, it is a cosine function on a pedestal, with one full cosine wave cycle across the length of the idt.

If we apply this window function to the transducer in Figure 5f-1, which is 60 wavelengths long, we get the transducer in Figure 6b. Notice how the transducer sidelobes are strongly attenuated. The frequency response for a pair of such idts is shown in Figure 6c. The change is dramatic. No sidelobes are observable above –60 dB, and the in-band response is devoid of ripple. We have reached a milestone; a technique is available which allows us to overcome the limitations of the (discrete) digital sampling approach used in designing a SAW transversal filter.

About the Author

Jeff Schoenfeld has been a contributing editor of *R.F. Design* for more than three years. Surface acoustic wave devices and their systems applications has been his principal specialty and interest in the field of RF. Jeff is currently program manager of research for robotic sensor systems at a major Southern California aerospace/electronics company where science gets down to business. Please contact him through *RF Design*, 6530 S. Yosemite St., Englewood, Colorado 80111.

For Further Reading . . .

L.T. Clairborne, G.S. Kino and E. Stern, Special issue on Surface Acoustic Wave Devices and Applications, Vol. 64, No. 5, May 1976.

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R.H. Tancrell and M.G. Holland, "Acoustic surface wave filters," Proc. IEEE, Vol. 59, p.359 (1971).

R.M. Bracewell, The Fourier Transform and its Applications, McGraw-Hill, New York, 1965.

Some Questions You Should Ask Your EMI/RFI Test Equipment Supplier

How long has your company been in the EMI/RFI Testing Equipment business?

The Electro-Mechanics Company has been designing and manufacturing EMI/RFI Test Accessories for over 25 years.

We began with Magnetic Field Instruments and Radio Frequency Antennas for the military. Since the mid-sixties we have been working closely with the military and industry standard setting groups, and EMCO now has one of the broadest lines of Test Antennas and EMI/RFI Test Accessories in the World.

What exactly is your major product line?

EMCO's primary business is Test Antennas for use in Emissions and Immunity (Susceptibility) Testing as required for MIL Standard, FCC, VDE, and CISPR Test Procedures.

Typical Military Antennas for Radiated Immunity (RS) and Emissions (RE) Testing cover the frequency ranges from **30 Hz to 18 GHz,** and are noted in MIL STD 462, Notice 3, Table 1. EMCO currently manufactures **Magnetic Field Loops**, the 41″ **Rod Antenna, Parallel Strip Line**, both

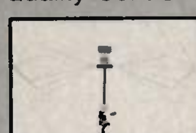
Biconical Antennas, the **Conical Log Spirals** and the **Double Ridged Guide Antennas** shown on this table.

Antennas which are currently acceptable for use in FCC Volume II, Part 15 Emissions Testing include, **Adjustable Element Dipole Sets**, Broadband **Biconical Antennas** and Broadband **Log Periodic Antennas**. EMCO manufactures all of these separately or can include them as part of an FCC "Class A" and "Class B" **Antenna Test System**.

What differentiates your antennas from your competitors?

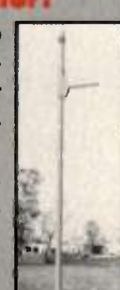
One major difference is Calibration. Each Antenna is calibrated using NBS Traceable Testing Equipment, on our own FCC open field test site. Calibration data includes Antenna Factor, Numeric Power Gain, and dBi Gain for each individual Antenna. For Immunity Testing Antennas we include Field Strength measurements in Volts Per Meter, and Radiation Patterns where applicable.

Another difference is Design and Construction. Each Antenna is designed to be durable and long-lasting, yet functional in varied applications, such as in Anechoic Chambers or Outside Test Sites. Antennas and accessories are machined and constructed "in-house" for Optimum Quality Control.



One last difference and maybe the most important, is EMCO's continual Product improvement thru Research and Development. For example, our **Dipole** and **Biconical Balun** design is much improved from the old DM-105 and military designs . . . and we are continually researching and redesigning to make EMI/RFI Testing simpler and more accurate.

What other Test Equipment and Accessories do you offer?



EMCO adds efficiency to EMI Testing with an **Antenna Positioning Tower** (1-6 meters) and an **Equipment Testing Turntable**. Both are suitable for outside or indoor use, come with a standard Digital Readout Controller and are available with **IEEE-488 Bus** Option.

For Conducted Emissions Testing, EMCO manufactures **Line Impedance Stabilization Networks** to satisfy FCC and VDE requirements. Our unique design allows production of as many as 4 separate lines (three phase) in one unit.

Other Related Equipment include: **Signal Rejection Networks, Acceptance Networks, Magnetic Field Intensity Meters, Magnetometers** and **Helmholtz Coil Systems.**

Why should my company buy your EMI/RFI Test Equipment?

The Electro-Mechanics Company is more than just another manufacturer. We realize that in order to grow and help improve EMI/RFI Testing we must constantly forge ahead . . . not live in the past.

As the FCC moves toward better and more Standardized Test Procedures, EMCO is staying close to ANSI (American National Standards Institute), NBS (National Bureau of Standards) and other standards groups so we can keep improving our equipment. Involvement with current and future industry needs also helps us plan for design of new equipment . . . an ongoing process at EMCO.

EMCO is committed to offering Technical Assistance, as well as Test Accessories, to help solve EMI Testing Problems. Part of that Technical Assistance is advice on purchasing only the equipment needed, not kits or systems with unnecessary items. We can also advise on various manufacturers of other complimentary test equipment.

If you have more questions and are looking for Helpful Answers, Call us at (512) 835-4684.

The Electro-Mechanics Company

P.O. Box 1546/Austin, Texas 78767/Telex 767187

INFO/CARD 42

Designing Unintentional Jammers

By Kenneth J. Grymala
Technical Consultant
GC Technologies, Inc.

Every year it costs our military a lot of money to track down unintentional jamming systems inadvertently designed with passive components. These devices were never meant to radiate. In fact, some of them have been through full EMI/TEMPEST testing and have been proved to be non-radiating. Yet these "non-radiating passive jammers" can very seriously degrade the communications capability of an entire military platform, such as a ship or aircraft.

The circuits are radio receiving front-end components. The worst offenders are the "protection circuits" used for wideband intercept receivers and wideband receiving multicouplers. Most use some type of diode limiting, and some also use light bulbs, fuses, spark gaps, gas fired tubes or a myriad of other non-linear devices. Figures 1A through 1C show typical overload protection circuits that can cause problems.

The protection circuit in Figure 1A may be low capacitance switching diodes that act together as a conventional limiter. It also may be a hot carrier diode that acts as a detector to bias a pin diode into attenuation. In either case, levels sufficient to produce intermodulation products or broadband white noise can occur easily in a typical overload situation.

Figure 1B has a fusible link. These were originally meant to protect signal generators from accidentally being burned out during transceiver testing. However, they have frequently found their way into receiver and multicoupler circuits. They are probably the safest from the re-radiation standpoint, but they are quite nonlinear. As a consequence, these fuses will lower the second and third order intercept points of most equipment they are meant to protect.

The circuit shown in Figure 1C is similar to 1B, except a light bulb is used instead of the fuse. The bulb's increasing resistance as it heats up works against the diode limiter. This allows a higher level of overvoltage protection than can be tolerated by the limiter alone. This circuit is one of the worst offenders. Frequently, the bulb and diode combination are just

Figure 1A. Coaxial diode limiter

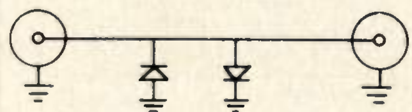


Figure 1B. Coaxial RF fuse

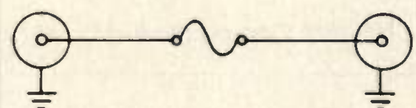


Figure 1C. Coaxial overload protector

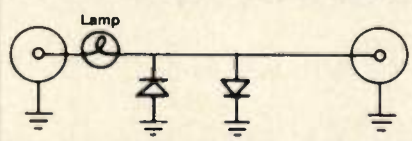


Figure 1. Protection Circuits

right to turn the limiter into a white noise generator. In this case, only one strong signal is needed to activate the circuit and cause serious re-radiation problems.

Problems begin to occur when just a few hundred milliwatts are applied to these devices. In the case of a ship or aircraft, it is common to have watts of transmitter power, from more than one transmitter, coming down a receive antenna line. In a typical military system, such as a ship or aircraft, the separation between MF/HF transmit to receive antennas will be much less than 60 dB. Receive antennas are frequently grouped together and may have as little as 10 dB of isolation from each other. Figure 2 illustrates a typical military system composed of communications and intercept equipment.

If such a protection device is hooked directly to the antenna it normally will provide the needed protection to the equipment it's supposed to protect. However, it will also generate a very strong level of broadband noise or thousands of intermodulation products that go right back out to the antenna. From here, these spurious signals are propagated to other nearby receiving systems where they cause serious interference. Under "ideal" conditions, the generated interference can be 60 to 80 dB higher than signals of interest.

The protection devices often are external to equipment and have been added by a well meaning technician or engineer who wanted to protect sensitive equipment from burnout whenever a nearby high powered transmitter was turned on. The problems often are just brushed off as "bad atmospherics" or excellent propagation ("just listen to all those signals!").

What is really happening is re-radiation of intermodulation products caused by the mixing of two or more high powered transmit signals within the protection device. It's kind of like the old rusty bolt, but it is intentionally designed to be highly efficient. The antennas are well matched and the diodes are of the highest quality. To make matters worse, the culprits are usually impedance matched to the antenna system. They have their most detrimental effect when connected to antennas that are co-located with other receiving antennas whose systems are capable of operating within high power fields. This problem can occur from active antennas, varactor tuned preselectors, pre-amplifiers and receiver first converters.

Solutions and recommendations

In cases where LC filtering is not possible, the devices to be protected must be removed from the antenna line, or the strong transmit signal amplitudes must be attenuated to a point where they no longer cause a problem. As a minimum, a good RF overload protection circuit should have the following characteristics: non EMI-radiating during overload; low insertion loss and low VSWR; protection whether equipment power is on or off; protection against short duration, high power bursts; and protection against long term, high power overload.

Figure 3 illustrates how a typical well designed protection circuit works. When the device to be protected is not in use, a relay at the input is normally opened to protect against an RF overload. When the unit is in operation, the relay is closed. The relay should provide low insertion

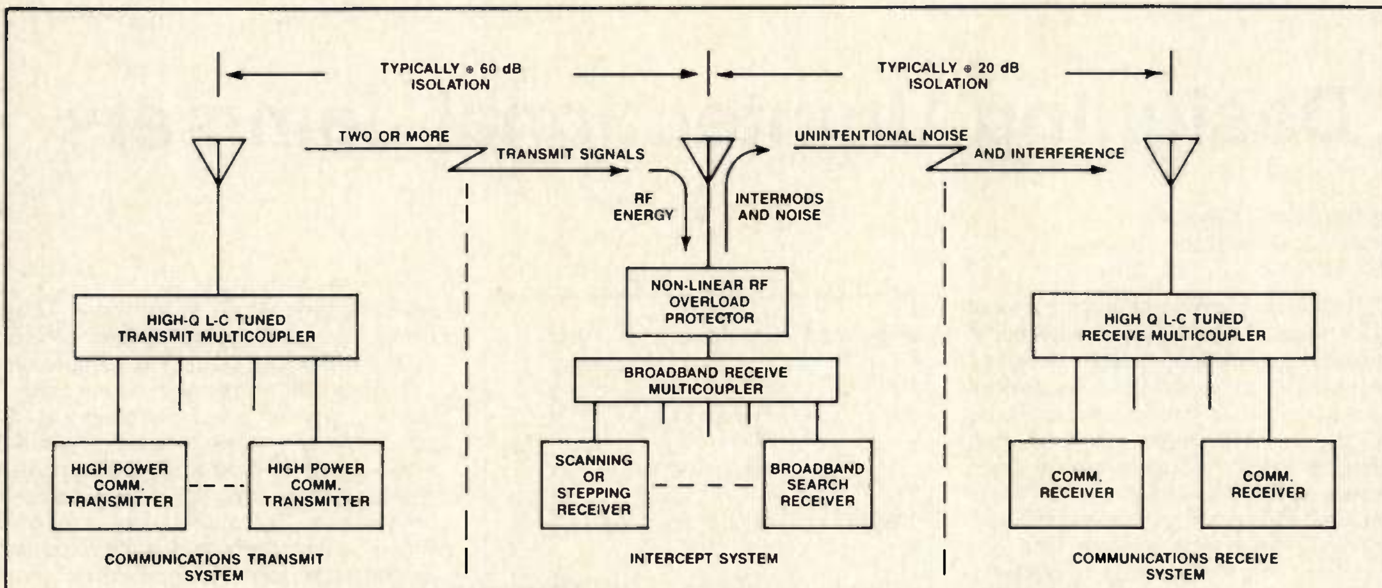


Figure 2. Typical Military Communications and Intercept System.

loss and low VSWR at the frequencies the circuit is designed for. It must also be capable of withstanding the anticipated power levels.

The protection circuit has a very high impedance detector that does not disturb the impedance characteristics of the equipment. Its output feeds a relay driver. Whenever an RF overload is sensed, the relay opens the circuit between the high incoming power and the sensitive circuitry. The relay driver usually contains a release timer circuit of 1 to 10 seconds. This circuit serves two purposes: One is to save the operators' nerves if the overload is from a non-CW signal, such as an SSB voice signal, and to hold the protection circuit on between overload dips and peaks. The other is to reduce chatter if the feedline length between the antenna and the overload protector happens to be an appropriate ¼ wavelength multiple. It is possible that the input to the protector will drop to zero when the circuit opens the line, causing the circuit to deactivate and begin chattering. With the timer circuit in place the relay will still cycle on and off but at a much lower rate. (A second alternative to the chatter problem is the addition of an external high power, matched dummy load).

Most protection circuits also employ limiters behind the relay. The purpose of the limiter is to provide protection to the sensitive circuits during the reaction time of the relay, which is typically 15-25 milliseconds. At low level signal inputs the limiter does not cause any problems, and at high overload levels the limiter is only in the circuit for a very short time.

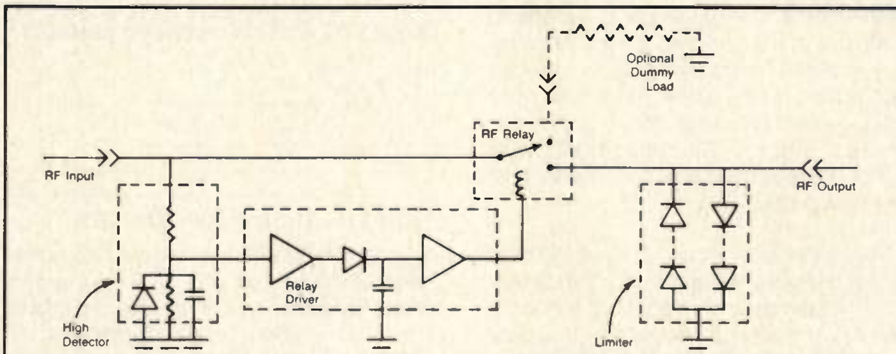


Figure 3. Functional block diagram of RF overload protector.

Numerous other variations can exist. For example, a multiple stage attenuation circuit can be added. With this method the receiving system is not fully disabled except under severe overload. Instead, fixed attenuators are placed in series with the line. In most MF/HF receiving systems, as much as 20 dB can be added without seriously affecting sensitivity. This is because in a well designed MF/HF system the sensitivity should be based on minimum atmospheric and galactic noise levels that are external to the antenna system.

Lightning and EMP protectors also can be designed into the circuit, but if they are used ahead of the relay they must not cause any non-linear action with typical overloads. If a lightning or EMP protection device is used ahead of the relay circuitry it should be thoroughly tested to ensure that it does not cause problems. Since these devices are typically high impedance devices, they should be tested to levels of several hundred volts. This will simulate the effects of the unmatched impedance transformations caused when the conventional overload protection circuit opens the line.

Conclusions

When designing new equipment or systems that are likely to be subjected to multiple high level inputs, adequate attention must be paid to overload protection. The circuits must adequately protect equipment from burnout. They must also provide a high degree of compatibility with other systems. In recent years a few receiver manufacturers and most of the test equipment manufacturers have begun to install very good reverse power protectors in their equipment. The rest of us should build them into our new equipment and systems. rf

Quick Disconnect Pin-and-Socket

"Latch-N-Lok" modular interconnection, a shielded, pin-and-socket quick disconnect interface assembly for computer and other electronic systems, has been introduced by Du Pont Connector Systems. The assembly includes a receptacle and a plug joined to a cord or cable. It features positive plug-to-receptacle latching with an audible click, EMI/ESD shielding, quick disconnect and attractive appearance. In addition. "Latch-N-Lok" assemblies cost less than the round DIN-type interconnections.

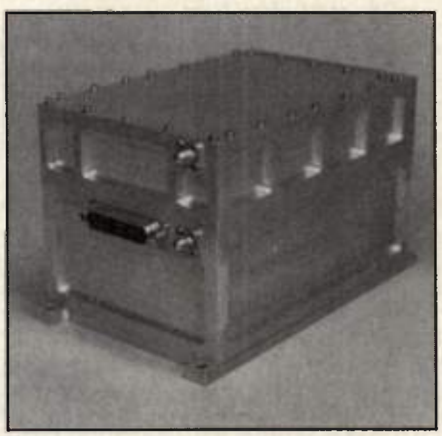
Based on the patented "PV" receptacle, and "BergStik" header, the new interconnection assembly has up to 20 I/O positions. Both plugs and receptacles come with straight, right-angle or combination configurations. **Du Pont Connector Systems, Wilmington, Del., please circle INFO/CARD #176.**

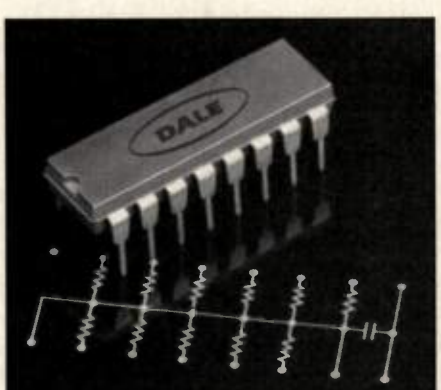
Computer-Controlled VHF Frequency Synthesizer

The AT-FS2574 frequency synthesizer provides 1000 discrete frequencies in 10 kHz steps by computer-control with TTL logic level signals. An internal switching power conditioner assures reliable operation over varying DC input voltages. Specifications include: Frequency range, 248 to 258 MHz, output power, 0 dBm ± 1 dB over temperature and frequency; operating temperature (baseplate), −20°C to +60°C; settling time, 1 ms; spurious signals, −60 dBc typ; harmonic, −30 dBc min.; SSB phase noise, −65 dBc/Hz at 1 KHz from carrier, −90 dBc/Hz at 10 KHz from carrier; external reference, 10 MHz, 1 V P-P into 50 ohms. **AD-TECH Microwave, Inc., Scottsdale, Ariz., please circle INFO/CARD #175.**

DIP Style Resistor/Capacitor Networks

Resistor/capacitor networks for ECL and Thevenin equivalent termination are now available from Dale Electronics. Designated as Model MDRC, the molded DIP networks have a .190" maximum seated height and are compatible with automatic insertion equipment. Currently, three models are available in the following configurations: **Model MDRC-1641** — for 2.0 V ECL termination, contains 11 resistors of equal value and a .01 μF decoupling capacitor for bypassing transients between supply voltages, **Model MDRC-1642** — for ECL pulldown to a 5.2 V buss, contains 12 resistors plus a 0.1 μF capacitor for bypassing transients on the voltage bus. **Model MDRC-1643** — for Thevenin equivalent termination, contains four series pairs of resistors; a divider between the pairs provides a Thevenin equivalent voltage of 2.0 V and a .01 μF decoupling capacitor bypasses the VEE buss. **Dale Electronics, Inc., El Paso, Tex., please circle INFO/CARD #174.**





150 MHz Oscilloscope

A quad input, dual independent time base 150 MHz oscilloscope featuring ±2% vertical accuracy, 500 μV/div vertical sensitivity and 20 kV accelerating potential has been introduced by B&K-Precision, Industrial Electronic Products Group of Dynascan Corporation. Designated Model 1596, the instrument's low profile

design and light weight (16.28 lbs.) fill field service as well as "on the bench" R&D applications. Model 1596 features 500 μV/div sensitivity to 70 MHz (cascade channel 1 to channel 2), 1 mV/div sensitivity to 100 MHz and 5 m/div sensitivity to 150 MHz. Waveforms are viewed on a 8 div x 10 div (1 div = 1 cm) rectangular CRT with internal graticule, scale illumination and 20 kV accelerating voltage. Model 1596 features A Only, ALT, A-INT-B, B DLY'D and DUAL mode sweep operation. **B&K Precision/Dynascan Corporation, Chicago, Ill., INFO/CARD #173.**

Compact 150-watt RF Amplifiers for NMR Research

Considerably smaller and lighter than other RF amplifiers in their power range, the new Models 150LB and 150LC from Amplifier Research are rated at 130 watts minimum, 150 watts nominal power, through 120-210 MHz and 200-290 MHz respectively. They will continue to operate

regardless of magnitude or phase of source and load impedance without oscillation, shutdown or damage. Their selected bandwidths provide a comfortable range of frequencies for varied clinical and research purposes, particularly in NMR. The new amplifiers combine solid-state low power stages with a vacuum-tube final amplifier, providing instantaneous bandwidth (full power at any frequency in their operating spectrum, without need for tuning or bandswitching), and exceptional pulse and blanking characteristics for NMR experiments. A typical RF envelope exhibits pulse droop of less than 1%. **Amplifier Research, Souderton, Penn., INFO/CARD #172.**

Wide Range Dual Rotary Attenuator

JFW Industries, Inc. introduces their model 50DR-001, a 50 ohm dual rotary attenuator. This low cost unit has an attenuation range of 0-110 dB. It is dual concentric with 0-100 dB in 10 dB steps added to 0-10 dB in 1 dB steps and can be mounted using limited panel space. The 50DR-001 has a frequency range of DC-1000 MHz. It is available with RF connectors that include BNC, N, SMA and TNC. **JFW Industries, Inc., Indianapolis, Ind., INFO/CARD #171.**

RF Patch Cords

A new line of RF patch cords in a wide range of connector styles, including mini-hook grippers, dual stacking banana plugs, alligator clips and BNC connectors, has been introduced by E.F. Johnson Company Components Division. Johnson RF patch cords are available with more than a dozen termination configurations, with three cable types, and cable lengths from 12 inches to five feet. Molded breakouts with twisted pair cables that convert coaxial connections to twin test leads are available with male or female BNC connector to dual grippers. Patch cord assemblies are available in dual banana plug-to-dual banana plug configurations with either RG-58 coaxial cable or twisted pair cable. Banana plug-to-alligator clip configurations are available with RG-58 or twisted pair cable, and dual banana plug-to-grippers or BNC connector are available with RG-58 cable. BNC-to-BNC patch cords are available with either RG-58 or RG-59 cable in male-to-male and male-to-female configurations. A BNC-to-grippers patch cord assembly with RG-58 cable also is available. **E.F. Johnson Company Components Division, Waseca, Minn., INFO/CARD #159.**

RF Interseries Adapter Kit

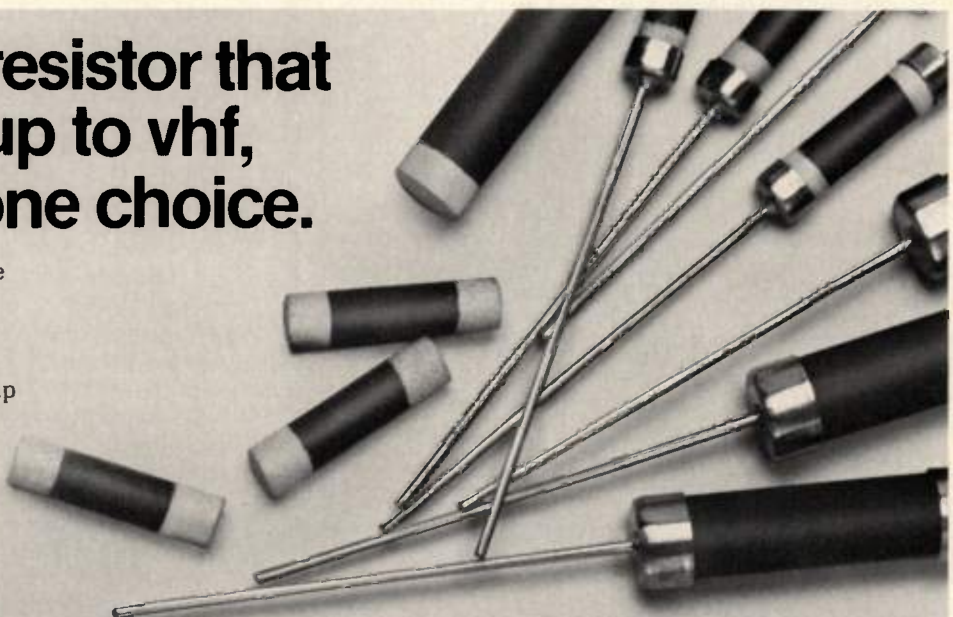
With this kit it is easy to assemble compact, precision 50-ohm adapters for 30 different matching requirements between four popular coaxial RF connector series. The four series included in this kit are N, UHF, BNC and TNC connectors, one male and one female each — except there are two male N and two female N. Also included are five couplers, so that five complete adapters can be assembled at any one time. This permits 28 combinations between series or with male/female of the same series. The two additional N connectors also permit assembling adapters with male N/male N and female N/female N functions. **Bird Electronic Corp., Cleveland (Solon), Ohio, INFO/CARD #170.**

Audio Analyzers for Broadcast and Transceiver Testing

Two new products for audio analysis from Hewlett-Packard Company, the HP 8903B audio analyzer and HP 8903E distortion analyzer, enhance measurement capabilities in the broadcast and transceiver-test marketplace. Like their predecessor, the HP 8903A, but at a lower price, these programmable offerings combine many instruments into one. Included in both analyzers are the same functions available from high-performance AC voltmeters, fully automatic distortion analyzers, DC voltmeters, SINAD meters and audio-frequency counters. Not only an analyzer, the HP 8903B also has an audio source capable of swept measurements down to −90 dB. The analyzer can measure swept-frequency-response deviations as small as 0.01 dB. The more economical HP 8903E, with only audio-measurement functions, has been developed for customers who already possess an audio source but are in need of sensitive test capabilities. **Hewlett-Packard Company, Palo Alto, Calif., please circle INFO/CARD #168.**

Electronic Gaskets

Electronic gaskets that protect against noise, dust, moisture and chemical contaminants, in addition to shielding RFI/EMI, were announced by Instrument Specialties Company, Inc. Two basic models are available: straight and flexible. The new Sticky Fingers® straight electronic gaskets, designated as Series 97-842, -841, -821 and -815, combine beryllium copper finger strips with a neoprene rubber seal to provide environmental protection as well as superior RFI/EMI shielding for applications where control of noise, dust, moisture and chemical contaminants is also required. **Instrument Specialties Company, Inc., Delaware Water Gap, Penn., please circle INFO/CARD #167.**



rf literature

RF Coaxial Connector Catalog

Ava Electronics announces the availability of the new 85-3 catalog which concentrates on BNC, TNC, N (the newest addition to the line), and Twinax connectors, adapters, and cable assemblies. The catalog includes information on features, materials and electrical characteristics of the products. UG type connectors are cross-referenced where applicable. Standard cable assemblies are provided in 3, 6, and 12 foot lengths. Shown on the back cover of the catalog are crimp tools and a representative sampling of custom connectors and cable assemblies. **Ava Electronics Corp., Drexel Hill, Penn., please circle INFO/CARD #140.**

Switches

Midland-Ross Corporation, Electronic Connector Division, announces a new 22-page switch catalog that describes its line of thumbwheel, DIP and Strip-Pak™ rotary PCB switches. Also included are a complete line of shorting jacks with .100 or .200 inch spacing between the contacts. Complete specifications for the AttenuSmart™ digital attenuator are given. The catalog has complete truth tables for thumbwheel switches and the Strip-Pak™ rotary printed circuit board switches. **Midland-Ross Corp., Cambridge, Mass., INFO/CARD #139.**

Keene Laminates

Keene Laminates' 16-page, four-color brochure covers its product offerings for industrial, electrical and electronics markets. The literature highlights three main standard product areas: flexible products, Di-Clad® PTFE/FEP microwave circuitboard products and silicone products. It also details their capabilities to supply custom laminated, coated and treated materials for applications ranging from printed wiring to sailcloth. Each product section itemizes typical applications, key product features, and the technical support team behind them. Full color photos show applications in flexible circuitry, electrical insulations, computer memory core substrates, laminating presspads, and high-performance sailcloth. **Keene Laminates, East Providence, R.I., INFO/CARD #138.**

Precision Instruments

Esterline Angus Instrument Corporation announces the availability of the A1000SF short form catalog. This catalog outlines Esterline Angus's full range of products, including, Miniservo® strip chart recorders, power survey demand recorders, direct writing recorders, the MRL multipoint recorder/logger, plotter/printer, hand-held multimeters, charts, accessories and more. The catalog concisely identifies, defines and explains each product. Available options are noted in each description. **Esterline Angus Instrument Corp., Indianapolis, Ind., INFO/CARD #137.**

Microminiature Connectors

ELCO Corporation has just made available a new 12-page catalog dedicated to microminiature connectors with size 24 contacts on .050" centers to MIL-C-83513. The catalog, covering all ELCO MICROCON microminiature connectors, includes rectangular "D" connectors with and without metal shells and jackscrews, printed circuit mountable connectors, strip connectors to any length and circular connectors. All feature proprietary one-piece springpin contacts. MICROCON microminiature connectors offer intermatable but lower cost, lighter weight and lower insertion/withdrawal force alternatives in high density computer and medical equipment applications. **ELCO Corporation, Cupertino, Calif., INFO/CARD #136.**

rf literature *Continued*

Microwave Components and Subsystems

A 36-page catalog from American Microwave Corporation describes the company's RF products. Data sheets and drawings describe the company's wideband power dividers, directional couplers, diode switches, PIN diode attenuators and impedance transformers. **American Microwave Corp., Frederick, Md., INFO/CARD #135.**

New LID Brochure

The Slatersville Division of Amperex Electronic Corporation has released a new six-page brochure containing the latest information on its extensive line of leadless inverted devices (LIDs) for surface mount applications. The brochure lists 59 LID products, including general purpose and voltage reference diodes, general purpose, amplifier/switching, switching, and high-frequency transistors and linear and digital CMOS integrated circuits. The brochure lists part types in the readily recognized "1N" and "2N" numbering system. **Amperex Electronic Corporation, Slatersville, R.I., INFO/CARD #134.**

Mixers, Power Dividers and Transformers

This 48 page catalog from the Electrowave Product Division of Triangle Microwave offers a complete array of mixers, power dividers, couplers, transformers, modulators, attenuator/switches and frequency doublers with detailed specifications, charts, outlines and selection guides provided. **Triangle Microwave, Inc., Electrowave Products Division, East Hanover, N.J., please circle INFO/CARD #133.**

Microwave Components

Norsal Industries has just published a complete catalog of microwave components covering the .5-18 GHz frequency range. Products include passive components (directional couplers, hybrids and power dividers), frequency translation devices (mixers, single sideband modulators and QIFMs), and amplitude control devices (diode switches and attenuators). All products have been designed for use in military airborne environments and many have been qualified to applicable MIL-STD-202 requirements. **Norsal Industries, Central Islip, N.Y., please circle INFO/CARD #132.**

Flexible Circuit Interconnects

The newest Interconics brochure entitled "Flexible Circuit Interconnects" contains information on flexible and rigid/flex printed circuits and assemblies. A full range of products and services from design evaluation through testing. **Interconics, St. Paul, Minn., INFO/CARD #131.**

Tucker Electronics Test Equipment

Tucker Electronics Company announces publication of a free 64-page catalog featuring reconditioned and factory new electronic test equipment. A special video section lists new and preowned NTSC video generators, vectorscopes, and other video test equipment. Also includes over thirty special spring values — reduced prices on popular test equipment (signal generators, oscilloscopes, standards) from popular manufacturers (H-P, Leader, Tektronix). All items are ready for immediate sale and many are also available for rental. **Tucker Electronics Company, Garland, Tex., INFO/CARD #130.**

D.A.T.A.Books Military Electronic Devices Guide

D.A.T.A., Inc. has introduced a new cross reference guide for engineering, purchasing, receiving and other personnel using military qualified microcircuits (MIL-M-38510) and semiconductors (MIL-S-19500) in military, aerospace and related applications. D.A.T.A.'s new *Military Electronic Devices Guide,* compiled for use by U.S. government agencies and contractors, contains two major sections: Microcircuits and Semiconductors. These two sections are further broken out into type designation, cross indices, a component selection section, manufacturers' listing, definitions of government electronics terminology and the D.A.T.A. component locator. An important feature of the new Guide is the extensive cross referencing of specific military component numbers by government designation, generic/industry number and national stock number (NSN). **D.A.T.A., Inc., San Diego, Calif., INFO/CARD #129.**

EEsof's Guide to CAE with Touchstone

Touchstone, EEsof's RF/microwave computer-aided engineering program, is described and displayed in a six-page full-color brochure. The brochure illustrates Touchstone's power. A balanced amplifier is taken through a design scenario, through analysis and optimization, with clearly detailed text and reproductions of the graphics screens that show the circuit as it develops. A circuit file is created with Touchstone's full-screen editor using idealized transmission line elements for the example. Also in the brochure example, gain measurements are made and other measurements quickly added with the sweep key. All measurements are then optimized. The brochure reproduces screens showing four different optimization trials in different colors. The final screen shows all four OUT block measurements at once, and the optimized balance amplifier completed. **EEsof, Westlake Village, Calif., INFO/CARD #128.**

Kathi Walsh
Classified Advertising Manager

rf design

A Cardiff Publication

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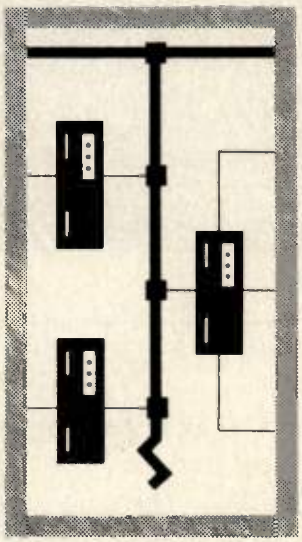

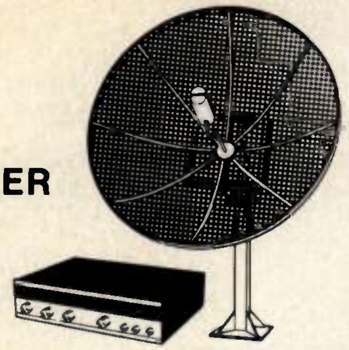

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The State-Of-The-Art In Solid State Power For RF/Microwave Applications

RF/Microwave products for telecommunications, defense electronics, laboratory instrumentation and test — frequencies from less than 1 MHz up to 20 GHz — power outputs from 1 watt up to several kilowatts — all solid state — that's the world of M/A-COM MPD. It's a world that's getting wider every day, with a constantly growing spectrum of commercial, industrial and military applications:

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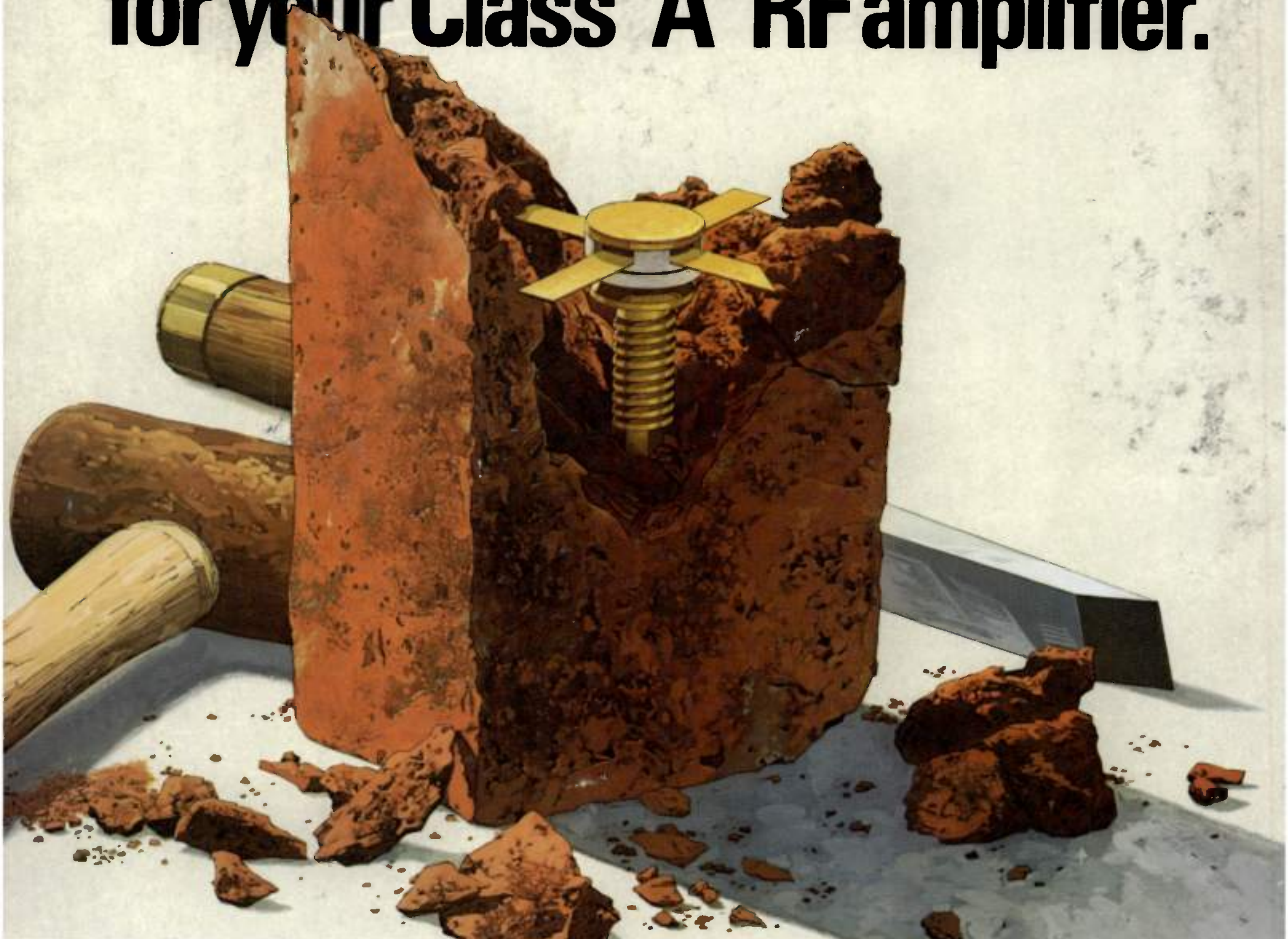
INFO/CARD 56

A rugged transistor for your Class "A" RF amplifier.



RF amplifier designers can now have a high-power transistor that's as tough as a brick! TRW RF Devices Division has introduced two new high-power Class "A" linear transistors that are rugged enough to hold up under the harshest operating conditions; the MRA1000-14L and MRA0500-19L.

These two single-ended devices operate Class "A" linear with ∞:1 VSWR and high-power input overdrive capability. The MRA1000-14L is usable up to 1GHz with 14W output @ 1dB compression point. The MRA0500-19L delivers 19 Watts of power up to 500MHz @ 1dB compression point. Both transistors have excellent gain, thermal performance and are input matched.

In addition to being rugged, they are also cost-effective. TRW utilizes a compact, gold-metallized, .380 SOE STUD package for both transistors which makes the price very affordable — $83.60 for the MRA1000-14L, $63 for the MRA0500-19L (U.S. dollars in 100s). You could pay up to $220 for a high-power Class "A" linear transistor, but with less capability.

Use these Class "A" devices for your RF amplifier applications in electronic warfare, communications and instrumentation. Call today and ask for the high-power RF transistor that's tough, but whose cost won't hit you like a ton of bricks.

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DEVICE	FREQ (MHz)	P1dB (W)	SSG (dB)	Psat min (W)	LOAD VSWR @P1dB	INPUT OVERDRIVE (W)	θ jc @ T_F = 70°C	BIAS POINT
MRA0500-19L	500	19	8	30	∞:1	10W	1.5° C/W	$19V_{DC}$ @ 3.5A
MRA1000-14L	1000	14	8	20	∞:1	7W	2.1° C/W	$19V_{DC}$ @ 2.45A

INFO/CARD 57

TRW

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