rf design
ideas for engineers
February 1987

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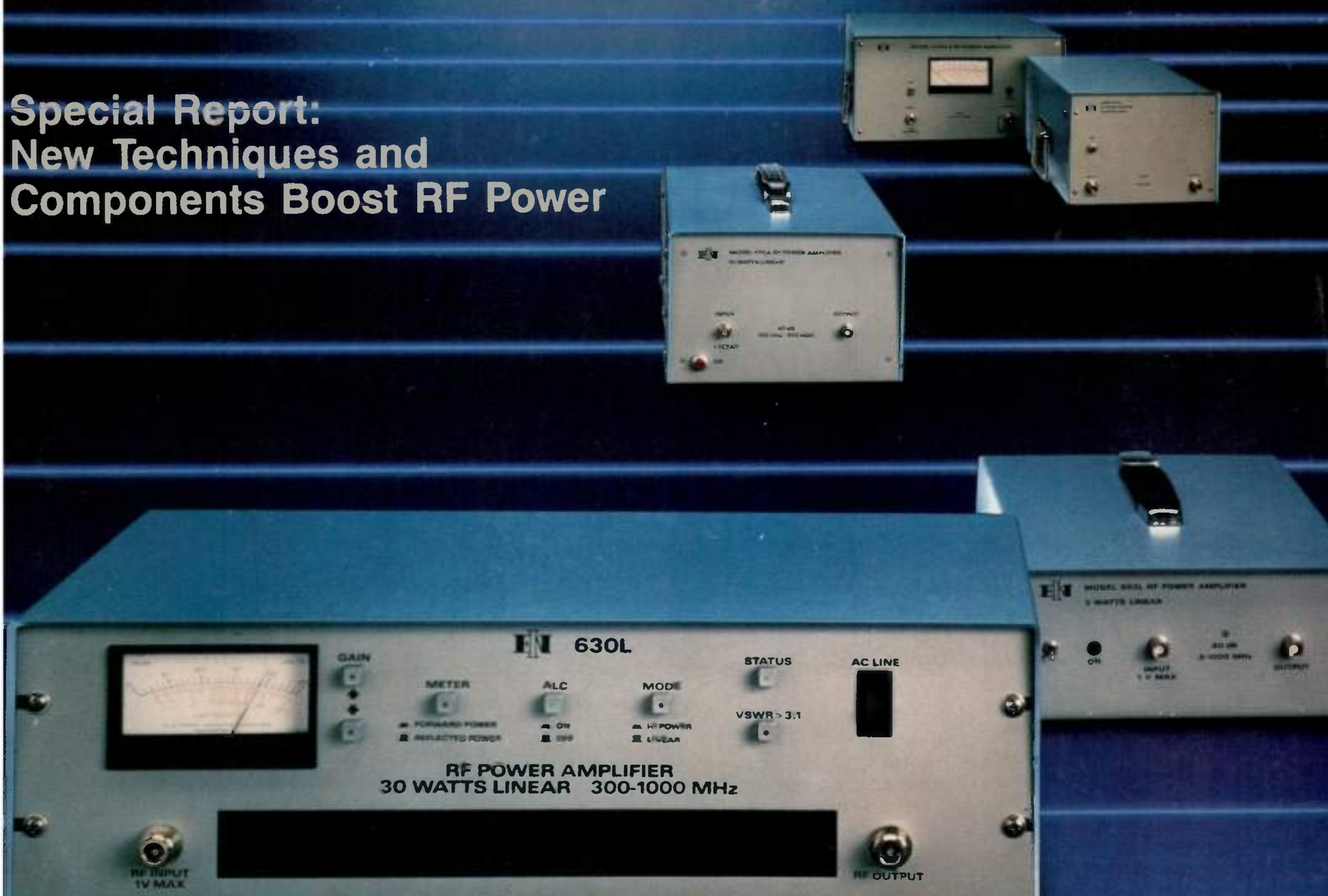
New Techniques and Components Boost RF Power



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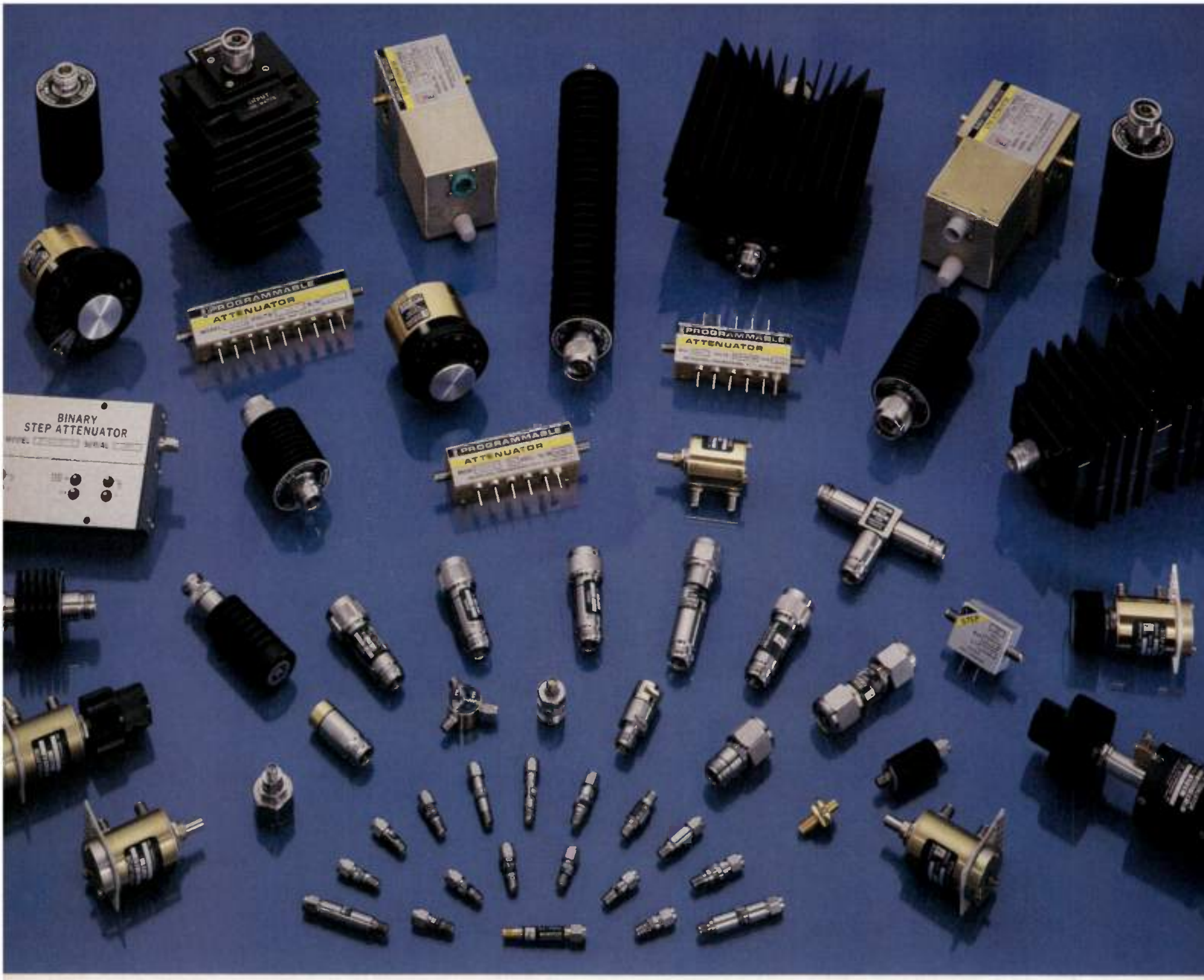

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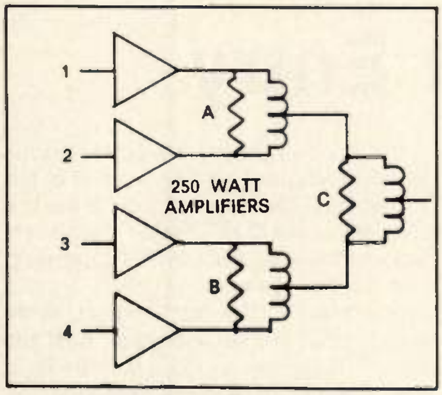
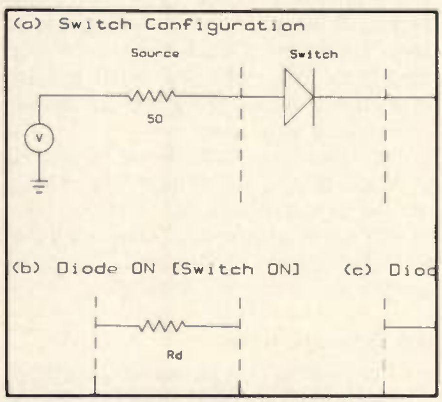
INFO/CARD 3

rf design

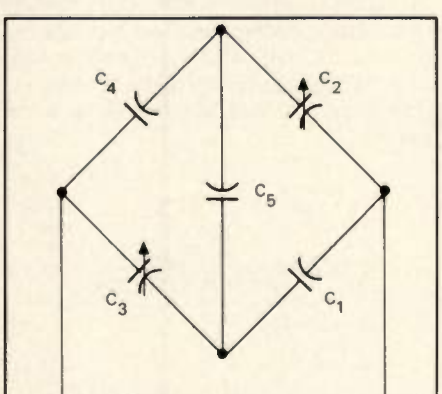
February 1987



Page 36 — Special Report



Page 89 — Designer's Notebook



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rf editorial

Wanted: Your Contest Entry

By Gary A. Breed
Editor

"Shoot! I could've done that!" — unidentified RF engineer, commenting on the winner of the First Annual RF Design Awards Contest.

Maybe that engineer could have been a winner, but he never got the chance. . . *he didn't enter.* Why didn't *you* enter? Did you think your ideas weren't important? (Why not leave that evaluation up to the judges.) Did you think the competition would be too stiff? (Our entrants weren't Nobel laureates, just working engineers like you.)

Maybe you just didn't know what to think of our design contest. I'll accept that argument for our first contest, but now you know what kind of recognition the winners will receive, and you know that the prizes offered are the best you've ever seen for such a contest; you have no excuse not to enter your unique engineering contribution in the Second Annual RF Design Awards Contest!

Still not convinced? We published the 1986 winning design and several of the contenders. Take another look at the last several months of *RF Design.* Those contest entries vary from digital to analog; from several ICs and transistors to just a couple diodes. We don't expect earth-shaking discoveries, just your "neat litle circuit" that does its job a little better, a little cheaper, or a little differently.

The rules and judging criteria for the contest are designed to favor small, relatively simple circuits. They also place plenty of weight on your willingness to take a little extra time to present it as clearly as you can. We aren't judging grammar or handwriting; we just want to understand your idea.

Dan Baker, our 1986 winner, joins Andy Przedpelski and me on the panel of judges. We all appreciate the pride you have in your work, and in that "little" idea that will be your entry. Please make our job as judges as difficult as possible!

An Introduction

Mark Gomez has joined *RF Design* as Assistant Editor. Mark comes to us via Malaysia, England and the University of Wyoming. With a BSEE and experience in test and instrumentation, Mark has the right analog background and the right enthusiasm for RF that is needed to help keep *RF Design* on top of the techniques and products that you need to know about.

Gary A. Breed

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INFO/CARD 5

Getting Your Hands on the RF Devices You Need

By Keith Aldrich
Publisher

In this issue you will find not one but two articles on a subject which as an engineering magazine we have never covered before: the distribution of RF components.

Until recently, the electronics parts distributor, so familiar to most OEMs, has not played much of a role in the selling or purchasing of RF devices. RF circuits have been too customized, or produced in too small a quantity for their components to become "commodity" items, the main staple of distributor sales. Partially as a result, distributors have taken little interest in RF requirements, technology or parlance and have been poor representatives of RF manufacturers.

This situation has been inconvenient to the RF engineer looking for quick samples or small quantities of particular devices to try out in the development of a new design. In other industries, it is the distributor who typically fills such demands. Likewise, the distributor for other industries has stocked component inventories for some customers, sparing them the necessity of doing it themselves. No such luxury has been available for OEMs who make RF equipment.

The two articles in this issue deal with recent changes in this situation. An article from Avantek on page 91 describes a number of distributor firms now emerging (without naming any) which handle complementary lines of RF components as their main specialization. Avantek's interest in the subject stems at least in part from the MMIC amplifiers it is marketing for $1.80 in 10,000-piece quantities. This kind of marketing is a radical departure, obviously, from that which has been used by the company in such markets as electronic countermeasures. The low-cost MMICs come close to being commodity items, used in application "From Test to Toys," as supporting ads proclaim. The Avantek product is respresentative of many others now coming out, and the emergence of RF distributors is a sign of such times.

A second article, the lead news item on page 16, describes a specific "master distributor" of RF power devices: RF Gain, a Richardson Electronics company with a massive distribution center in LaFox, Ill., which ships product on the same day an order is received in 90 percent of cases, no matter how small or obscure the order. The company also maintains stock in a number of regional offices, so that it can handle inventory of particular RF parts for regular customers in that area.

Both these stories signal a new era in the RF industry. While some may lament the passing of the good old days, we personally hail the dawning of a mature market with all the modern conveniences. That is why we have published these articles, even though they do not deal with engineering techniques. The advantages they speak of are for the convenience of RF engineers, to help them hasten their designs onto the marketplace. And we're for that.

Keith Aldrich

rf design

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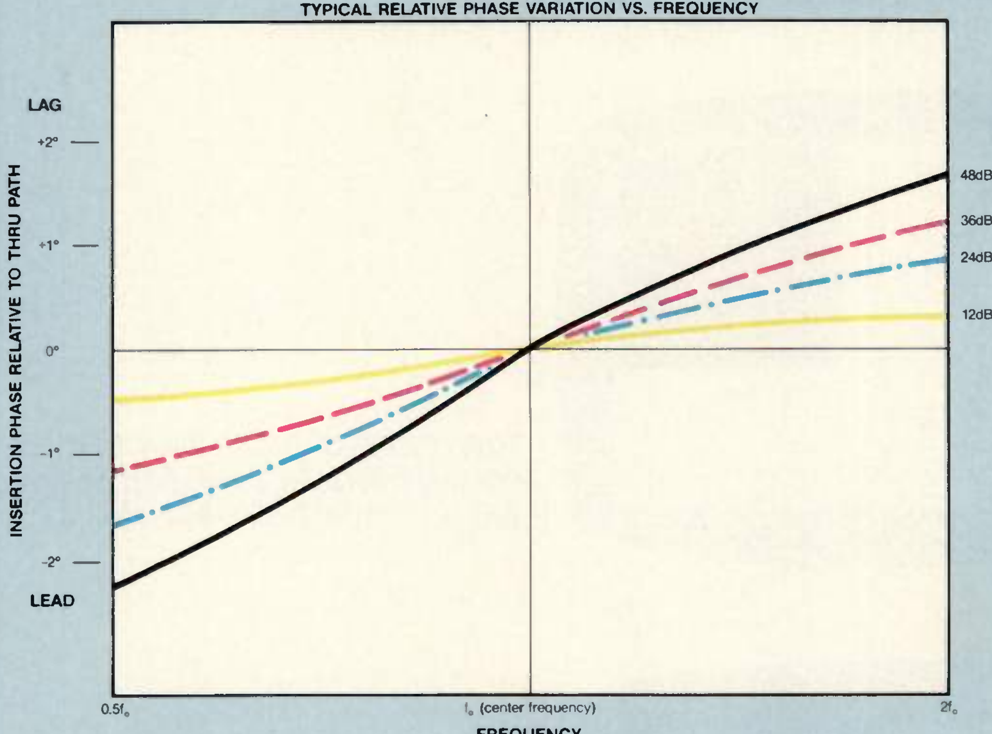

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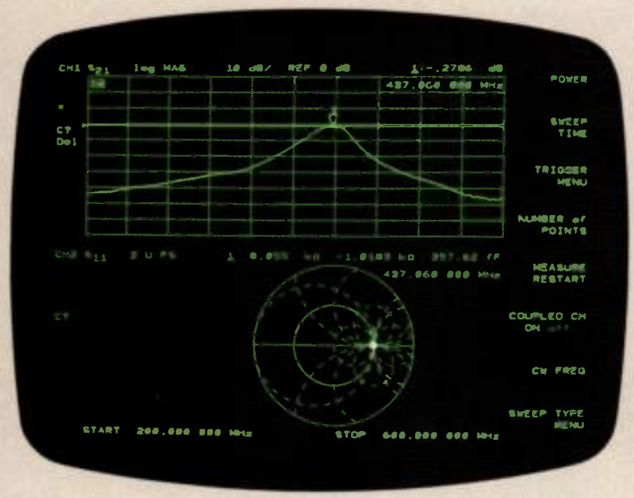

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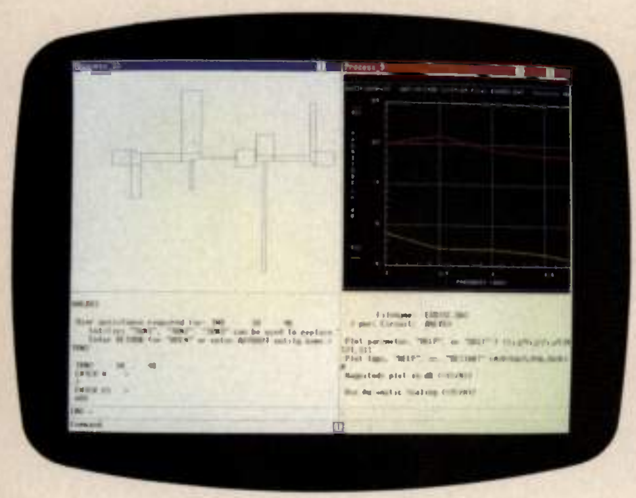

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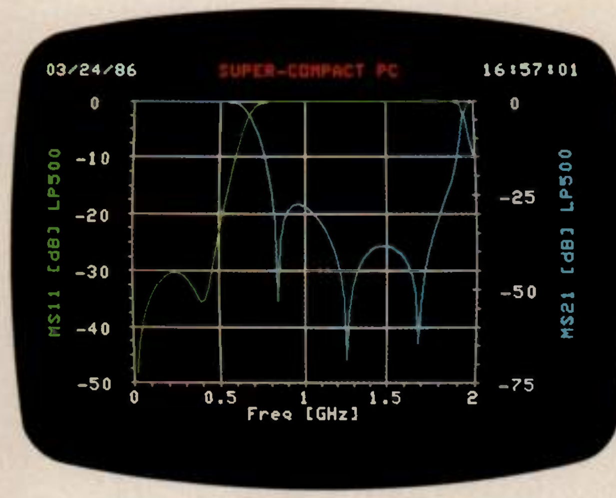

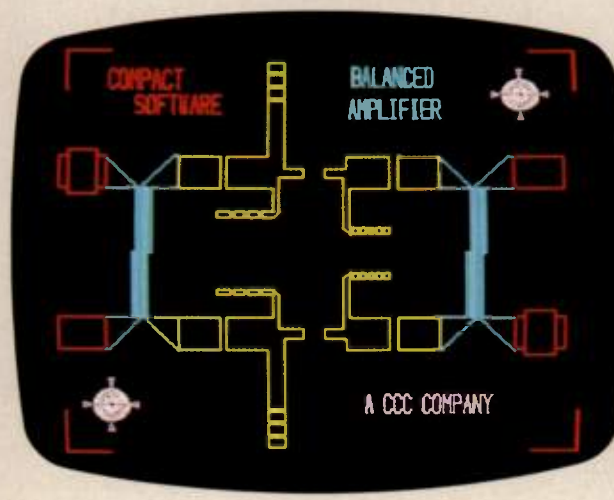

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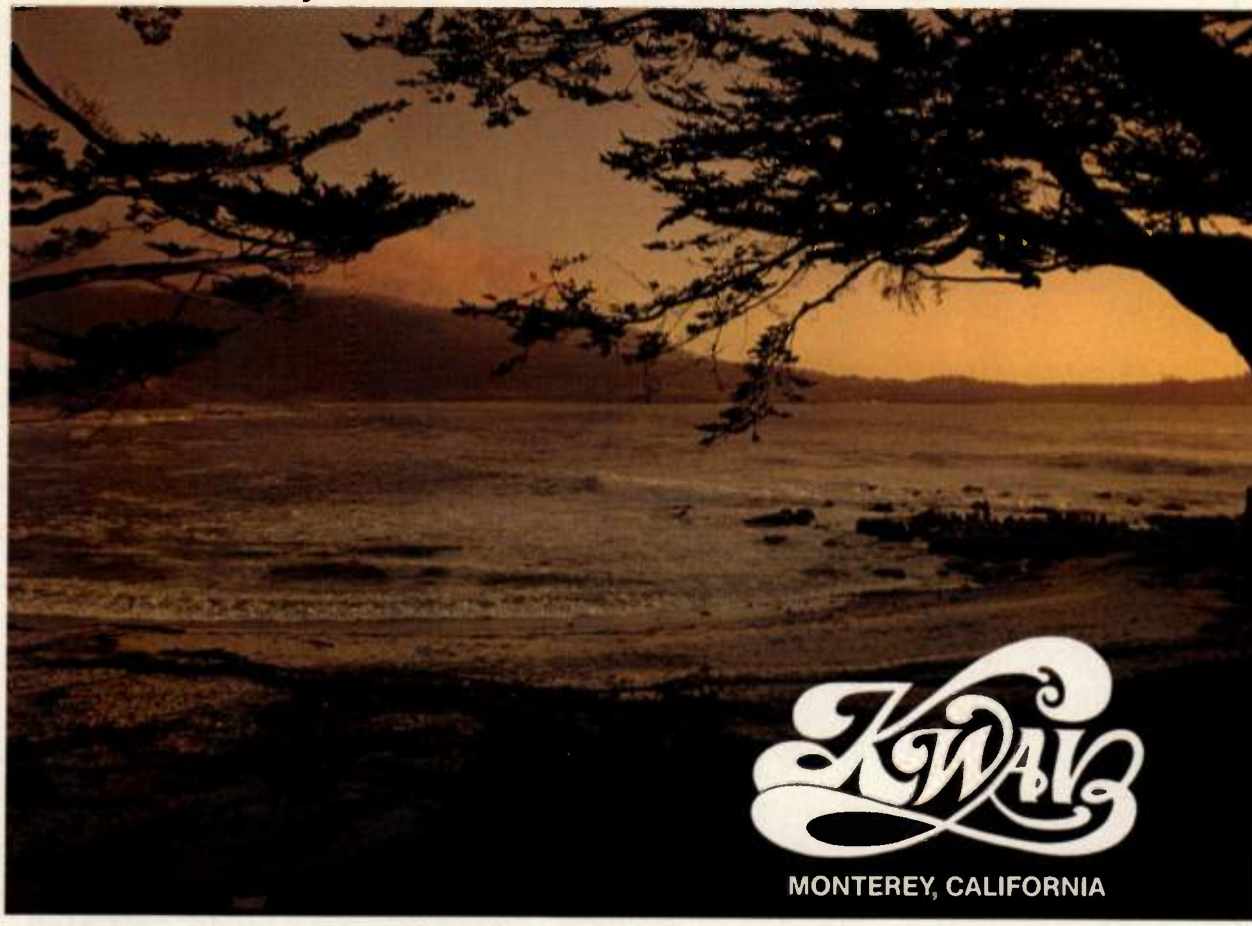

Ken Warren, Chief Engineer at KWAV reports that their 10 kW FM transmitter went on the air in November, 1972, equipped with EIMAC power tubes. The original tubes are still in operation after over 13 years of continuous duty!

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INFO/CARD 8

rf letters

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

More Ladder Analysis Program Notes

Editor:

Thanks to a number of readers with sharp eyes (and compilers)! The following is a complete list of corrections to date for my Ladder Network Analysis program as described in the November 1986 issue of *RF Design* magazine (p. 68). There have been four separate revisions of this program as sent to those requesting either listings or the program disk. Some of the versions already include some of all of the corrections. At this point, it would be easiest to simply compare the noted line numbers against the version you have and make the required corections (if any). For those of you with C64 versions, use the line numbers under the column "C64" and those with IBM-PC versions, use the column "IBM."

Load your version of BASIC. Load the NETWORK program. List the affected line numbrs and edit the line as shown below. Be sure to press the RETURN key when finished with each individual line, so the changes will be entered in the computer's memory. Finally, save the corrected version of the program to the disk. If anyone has trouble with these corrections, please return your master disk and I will send you the latest version. I apologize for any inconvenience this may have caused.

C64	IBM	
140	140	Change the version to 4.03 and the date to Dec. 15, 1986.
160	160	Change the ST(MS) to ET(MS).
—	180	(IBM only) Change the version number to 4.03PC.
570	580	Add a right parentheses following the first "+1." The line should read: EF=((C(N)+1)/2)+. . .(the rest is OK).
575	585	Add the following new line: C(N)=INT(EF*100+0.5)/100
585	605	Add the following new line: C(N)=INT(EF*100+0.5)/100
—	590	(IBM only) Change the GOTO 760 to GOTO 690.
620	630	Remove the R(N)=M from the end of the line. It is not needed.
660	670	The square root of C(N) and the factor CM should be added. Change the line to read: L(N)=(DE*3E10)/(SQR(C(N))*CM*FO*FR*360):. .(the rest is OK).
800	—	(C64 only) Change the GOTO 850 to read GOTO 860.
850	850	Remove this line by typing 850 and then the RETURN key. It is a remnant from past versions and is not needed.
—	1220	(IBM only) Some versions read: PRINT J TAB(T1) OUTPUT$. Change this to read: PRINT J TAB(4) OUTPUT$.
1590	1480	Add a right parentheses following the first "+1." The line should read: EF=((C(E)+1)/2)+. . .(the rest is OK).
1680	1570	The square root of C(E) and the factor CM should be added. Change the line to read: L(E)=(DE*3E10)/(SQR(C(E))*CM*FO*FR*360):. .(the rest is OK).
—	2370	(IBM only) Change to read: Q2=160−((P1(I)−Y1)*E1).
—	2372	(IBM only) Delete this line, if present.
—	2375	(IBM only) Delete this line, if present.
—	2690	(IBM only) Change the version number to 4.03PC.

Kenneth Wyatt
Woodland Park, Colorado

Pros and Cons on Military Projects

Editor:

Your viewpoint in the Nov. 1986 magazine shows how far afield from reality some of us have managed to drift since World War II. You don't remember Neville Chamberlain, who carried his umbrella to Munich in 1938, and you don't realize how the communists have learned to stabilize tyranny based on our Constitutional separation of powers — a triad of the Communist Party, the KGB, and the GRU, instead of an executive branch, a legislative branch, and a judicial branch.

Our national safety is at issue here. Neither the LLL X-ray expert nor the media snoops appreciate that. Much of our technological advancements of the last fifty years, computers, navigation systems, supersonic flight, satellite systems, medical advances, microcircuits, even color TV, have resulted from programs directed toward our national safety as much as anything else.

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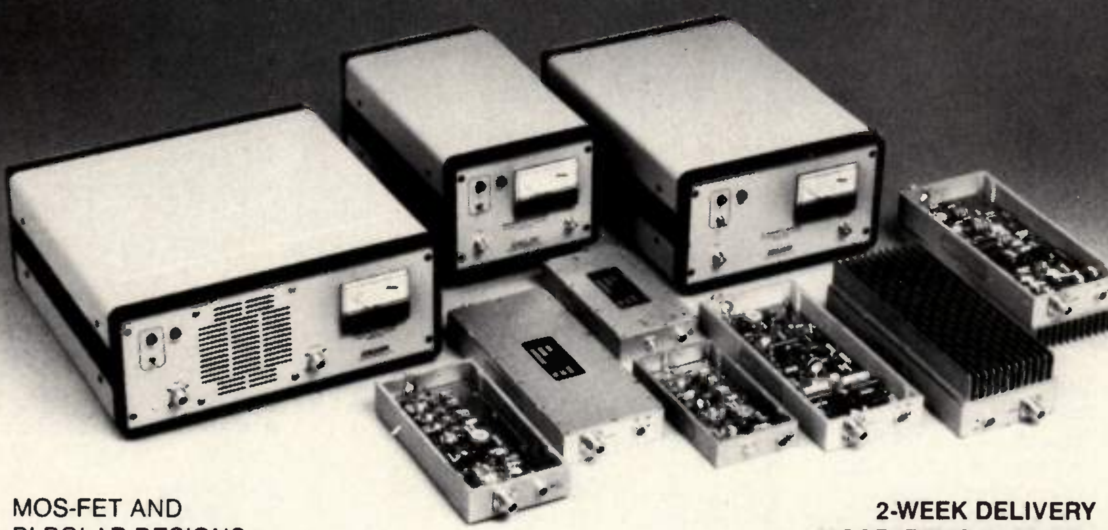

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We *have* to keep our powder dry as long as there is as much as one tyranny in the world. Their goal is to help us to bury ourselves. And as long as our people do not accept the small amount of responsibility for helping to protect their neighbors and descendents from our own Gulag, we will end up in one.

Keats A. Pullen, Jr.
Kingsville, Maryland

Editor:

I appreciated very much your mention in "RF Viewpoint" of the young man who left his job rather than work on "star wars" projects.

I am a project enginer, 33; my conscience also will not permit me to work on military equipment. To this end I decline any work requiring a security clearance. This stand has brought criticism, even ridicule, from my colleagues.

I know that there is comparatively little non-military work available. Nonetheless, engineering search firms have told me that some 20 percent of engineering graduates are refusing war-related projects. If true, that figure would counter an impression garned from the media that the coming generation of professionals is only "out for bucks."

Thank you for helping to make these new engineers aware that others share their choice.

Tom M. Padwa
Baltimore, Maryland

Errata

"Low Noise Preamplifier Design for NMR," January 1987, page 39, omitted a few important words. The second paragraph of the second column on page 39 should begin:

"The noise figure F defined as the ratio of the total amplifier output noise power *to the output noise* due to the source resistor only is given by Equation 1."

RF Gain/Richardson Services Small Thomson-Mostek Orders Fast

December 31, 1986 marked the end of the first full year in which Thomson Components-Mostek, Montgomeryville, Pa., employed RF Gain, a Richardson Electronics Company, as the "fully-franchised master distributed" of its RF power transistors and other products. The relationship has proved "very successful," according to Don Kupinewicz, Marketing Manager of the Thomson-Mostek company, accounting for a substantial number of orders of less than $5,000 each, some as small as $25.

"The main advantage of Richardson is that is is specifically geared to the RF market area that our product goes into," said John Walsh, Thomson's military products marketing manager. "They know RF products, RF engineering, RF buzzwords, and carry everything in RF power from megawatt transmitters to small signal RF devices and everything in between.

"Also," said Walsh, "they have extremely responsive service. If an engineer gets an order in by two or three o'clock, Richardson will get that order out the same day, for delivery the next day."

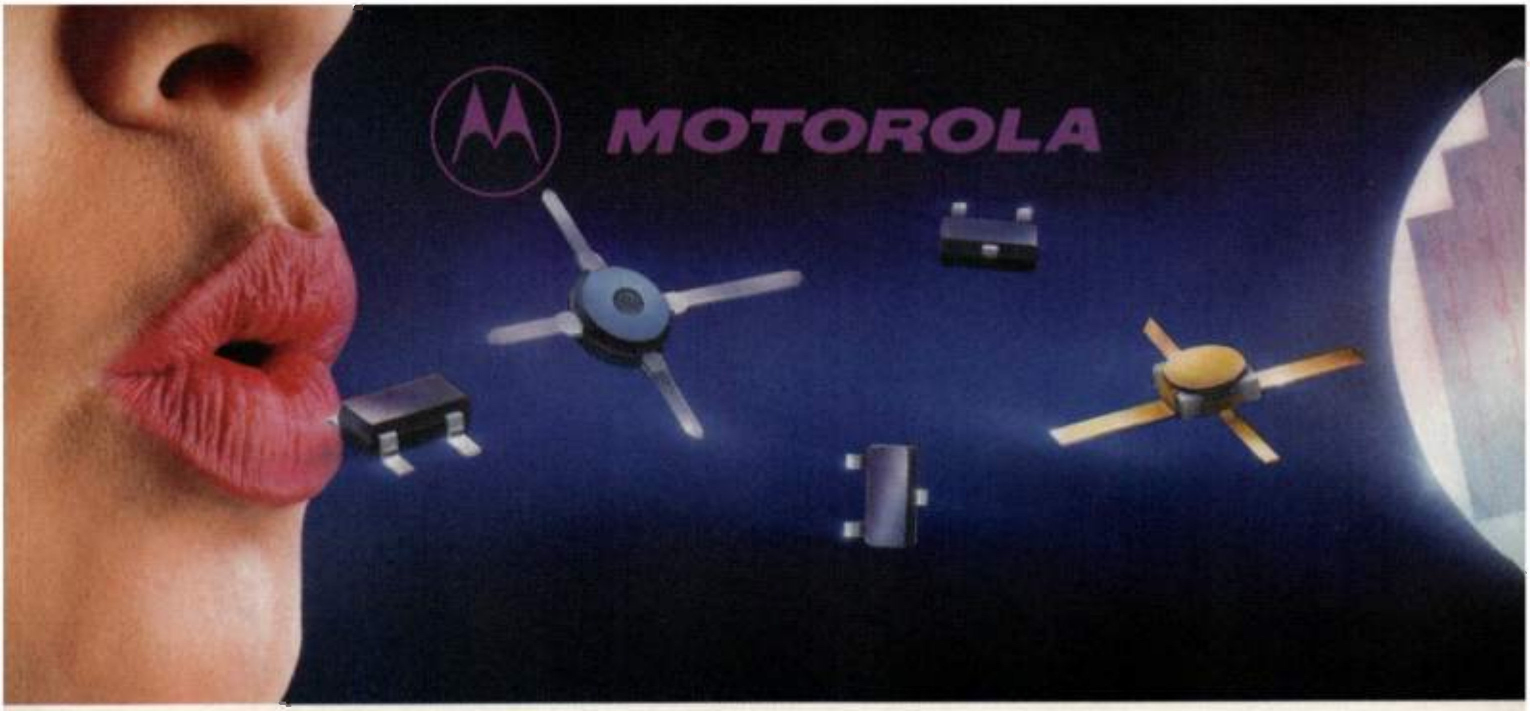
Bill Henderson, Thomson's regional product marketing manager for the Northeast, elaborated on these advantages: "To most big distributors, the RF market is too small and too customized for them to take much interest. The words "drop-in" and "or-equal" don't apply as much. You can't just trade off one manufacturer's part with another's nearly as often. The Richardson people maintain extensive cross-reference files, and know just when you can trade off and when you can't. Plus, they carry most of them in stock and can ship one or the other just as fast. This is a big help to an engineer, especially when he needs samples or small quantities on short notice for some job he's working on."

Most of the RF Gain/Richardson inventory is housed in a massive distribution center at Richardson's new corporate headquarters plan in LaFox, Ill., but inventories are also maintained according to customer demand in several regional offices in the United States and overseas.

Thomson-Mostek may be the company's largest supplier in terms of volume, but is only one of many whose products are stocked by Richardson: others include Philips, Amperex, RCA, and Motorola. RF Gain was acquired by Richardson three years ago, and was founded only eight years ago in Long Island as the brain-child of David Gilden and Joel Levine. Levine is now manager of the Richardson Division that includes the RF Gain operation. Just months ago the division added Randy Conaway, formerly of Thomson-Mostek, as Product Manager for RF power transistors.

Both Levine and Conaway are bullish about the future for Richardson Electronics, which has jumped from an annual sales volume of $12 million in 1979 to about $75 million last year, with prospects for 20 percent growth in 1987. No other company, says Conaway, specializes in the niche of "trailing edge" technology, a term coined to suggest the availability of products broadly in use, whether or not they represent the latest technology. (Richardson is the world's major supplier of power tubes, for example.) RF power transistors represent new additions to this technology ("leading edge" of the "trailing edge?!") Says Levine: "Our objective is to become not so much the master distributor for a select group of manufacturers as the master distributor for the entire RF industry, when it comes to RF power."

New distribution center in LaFox, Ill., stocks $30 million inventory.



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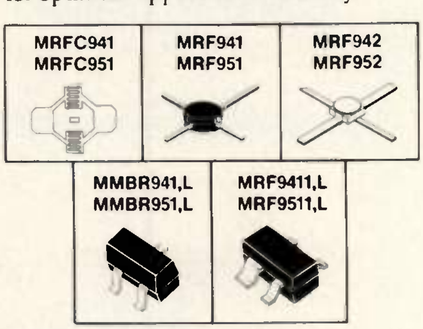

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We even plan to offer the ceramics in Hi-Rel versions.

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The 1.2 micron die geometries are all of gold top-metal construction with fully-implanted base and emitter structures with silicon nitride passivation for optimum reliability.

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CMOS PLLs with the greatest flexibility and lowest power drain for frequency synthesizer applications to over 1 GHz.

It's no secret. Motorola offers the industry's broadest line of CMOS Phase-Locked Loop Frequency Synthesizers, and a great variety of bipolar single and dual modulus prescalers to match, for designs to over 1 GHz.

These Motorola ICs permit you to do cost-effective, reliable and flexible low current-drain synthesizer designs. Applications embrace mobile, marine and amateur two-way radios, cellular radiotelephones, avionics and instrumentation equipment, TV/CATV tuners, scanners, sonobuoys and federal/military radios.

A multitude of frequencies.

Motorola PLLs can generate a multitude of frequencies from a single reference source, providing a means of tuning either by switch closure or in concert with a microprocessor. They allow you to produce and control an almost infinite number of frequencies with just one crystal.

When these CMOS PLL Frequency Synthesizers are combined with a loop filter and VCO, they provide direct synthesis up to their specific frequency limits. For higher VCO frequencies, down mixers or one of Motorola's single or dual modulus prescalers, as appropriate, are used between the VCO and PLL.

Other facets of flexibility.

All of Motorola's general purpose CMOS PLL frequency synthesizers give you the choice of on- or off-chip reference oscillator operation. Many are CMOS MPU/MCU-compatible.

With the exception of the MC145159, which has a high gain sample and hold (analog) phase detector, they all provide digital phase/frequency detectors with single-ended three-state or double-ended outputs.

You have your choice of reference divider integer values, and versatile programmable dividers also are provided.

See us at RF Technology Expo, Booths #423, 425, 427, 324, 326 & 328.

The blessings of CMOS.

Our CMOS wide operating supply range of 3 to 9 volts and wide operating temperature range of –40 to +85 degrees C, with the inherent high noise immunity and low power operation, make your design job a lot easier.

Selected Motorola CMOS PLL Frequency Synthesizers

Prescale Modulus	Interface	Typical System Examples	Part Number
Single	Serial	60 MHz w ÷ 4 prescaler Loop resolution = 4 kHz	MC145155 MC145157
	4-bit bus		MC145145
	Parallel		MC145151
		16 MHz w ÷ 4 prescaler Loop resolution = 40 kHz	MC145106
Dual	Serial	1 GHz w ÷ 128/129 prescaler Loop resolution = 12.5 kHz	MC145156 MC145158 MC145159
	4-bit bus		MC145146
	Parallel		MC145152

Selected Motorola Bipolar Prescalers

Modulus	Frequency	IC (mA) typ.	Part Number
÷32/÷33	225 MHz	6	MC12015
÷40/÷41	225 MHz	6	MC12016
÷64/÷65	225 MHz	6	MC12017
÷128/÷129	520 MHz	8	MC12018
÷20/÷21	225 MHz	6	MC12019
÷128/÷129	1 GHz	7.5	MC12022*
÷64	225 MHz	3.5	MC12023
÷64	1.1 GHz	23	MC12073
÷256	1.1 GHz	23	MC12074

*Available Q1, 1987. Pin and functionally compatible with Fujitsu MB501L

Keeping pace.

The Motorola frequency synthesizer line is regularly revised and upgraded to reflect advancing technology and keep pace with industry needs.

We recently introduced enhanced versions of nine MC14514X and MC14515X series devices with improved ac characteristics.

Additional product developments now in progress ensure that you can count on continued line enhancement, higher levels of integration and much higher frequencies with low dynamic power consumption.

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If a phone call can't answer your needs, we'll have one of our local specialists contact you.

For more detailed information on CMOS PLL frequency synthesizers, prescalers and electronic tuning components, complete and send in the coupon or write to Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036.

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Priced as low as $1.30 each, Avantek's silicon MMIC amplifiers and frequency converters provide outstanding gain-bandwidth per dollar.

Design engineers can simplify circuit designs, improve performance and lower overall system costs, as MODAMP™ MSA-series amplifiers and MSF-series frequency converters provide improved gain and bandwidth over hybrid components . . . for less. These Monolithic Microwave Integrated Circuit (MMIC) components are designed for use in applications that listen, watch or talk . . . from satellites, G.P.S. navigation receivers and fiber optic systems . . . to police radar detectors, medical equipment and . . . even toys.

A Growing Family of MMICs to Meet System Designer's Needs

Since 1982, Avantek's silicon MMIC product family has grown to include more than 50 different models covering the frequency spectrum from DC to 8 GHz, with gains as high as 33 dB, noise figures as low as 2.5 dB and power outputs as high as 20 dBm (@ 100 MHz). The MSA- and MSF-series of products are available in a range of packages, from low-cost plastic to high-rel metal/ceramic.

Selected MSA & MSF Components
(Performance @ 1.0 GHz)

Model-	Max. Useable Frequency (GHz)	Gain (dB, typ.)	Noise Figure (db.typ.)	P_{1dB} (dBm. typ.)	Package Type	1000 Piece Price $$$
MSA-0170	4.5	17.0	5.5	1.5	A	12.35
MSA-0204	4.0	11.0	6.5	4.0	B	1.90
MSA-0370	4.5	12.5	5.5	10.0	A	16.10
MSA-0420	3.5	8.5	7.0	15.0	C	18.45
MSA-0685	4.0	16.5	3.0	1.5	D	1.30
MSA-0835	6.0	23.5	3.0	12.5	E	7.80
MSF-8835	8.0	20.0	N/A	9.0	E	12.40

A) 70 mil stripline B) 145 mil plastic C) 200 mil BEO
D) 85 mil plastic E) 100 mil ceram

Avantek is a recognized leader in advanced, high-performance microwave semiconductors and MMICs for space and military applications. And, we deliver in quantity . . . last year Avantek shipped more than 1,000,000 MMICs and built over 800,000 complex microwave components for more than 3,000 customers. So, when you need high performance low-cost MMICs — whether your system listens, watches or talks — you know Avantek can deliver . . . *in volume*. Contact your nearest Avantek Distributor for additional information.

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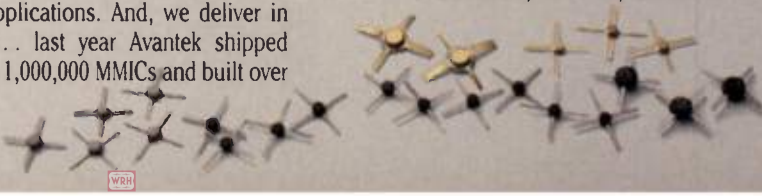
TMA/RF, Teterboro, NJ (201) 393-9330

Central
Penstock Midwest, Palatine, IL (312) 934-3700
Thorson Distributing Co., Dallas, TX (214) 233-5744

West
Penstock, Inc., Los Altos, CA (415) 948-6552
Sertek, Inc., Westlake Village, CA (818) 707-2872

AVANTEK
3175 Bowers Ave, Santa Clara, CA 95054-3292



INFO/CARD 13

See us at RF Technology Expo, Booths #329, 331 & 333.

NBS Issues Three Reports on EMC Measurements, Susceptibility and Shielding

The National Bureau of Standards has recently issued three reports in the area of electromagnetic compatibility (EMC). The first covers susceptibility to interference of electroexplosive devices, such as automotive airbag initiators, aerospace explosive bolts, mining and construction apparatus. Another is a study concerning measurement of shielding material effectiveness. This study addresses the need for measurement techniques for the less predictable shielding performance of plastic and composite shielding materials. The third report includes the text material for a short course in EMC/EMI measurements presented by NBS, including TEM cells, anechoic chambers, open fields and reverberant chambers.

All three may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. *A Statistical Characterization of Electroexplosive Devices Relevant to Electromagnetic Compatibility Assessment* (TN 1094) is $2.75, stock no. 003-003-02744-8. *A Study of Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials* (TN 1095) is $3.50, stock no. 003-003-02735-9. *Electromagnetic Compatibility and Interference Metrology* (TN 1099) is $8.50, stock no. 003-003-02760-0.

Swedish Defense Forces to get Frequency-Hopping Radios

The Materiel Administration of the Swedish Armed Forces (FMV) has announced a contract for a state-of-the-art Combat Net Radio system for the Swedish Army and Navy.

The contract, placed with Ericsson Radio Systems AB, Stockholm (Sweden), involves a new type of Combat Net Radio system using frequency hopping for both voice and data. Delivery will take place in the beginning of 1989 and is scheduled to be completed in 1993. Marconi Defence Systems Ltd., a subsidiary of GEC, England, is the main subcontractor to Ericsson for the order. Marconi will be responsible for supplying major parts of the transceiver.

The new Combat Net Radio system, designated StarCom (TR 8000 in Sweden), was developed in close cooperation between Ericsson, Marconi and the Materiel Administration of the Swedish Armed Forces. It is protected against jamming and interception, since radio traffic "hops" over the entire frequency band many times per second and is simultaneously encrypted. It is one of the first systems capable of utilizing this technology and to be produced in large quantity anywhere in the world. The Swedish Defence Forces, as well as the armed forces in other countries, have for several years conducted practical field trials of the system and achieved very good results.

The Ericsson StarCom frequency hopping radio system has been selected for tactical communications by the Swedish Armed Forces.

HP Calculator Capable of Symbolic Mathematics

Hewlett-Packard company introduces the HP-28C, believed to be the first calculator capable of doing symbolic mathematics. Algebra and calculus operations that could not be performed with a calculator can now be performed on the HP-28C. The display is a four-line by 23 character LCD. Complex numbers, matrices, vectors, lists, algebraic expressions and other data types can be viewed, edited and

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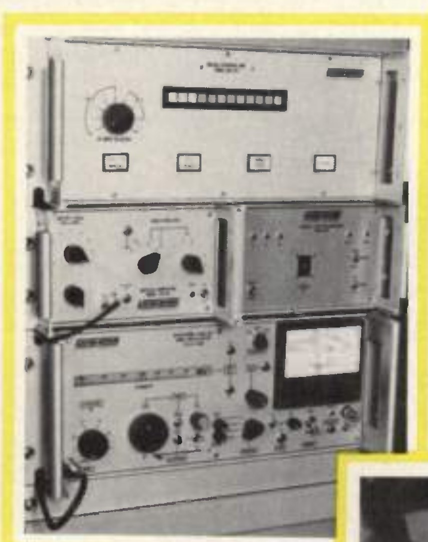
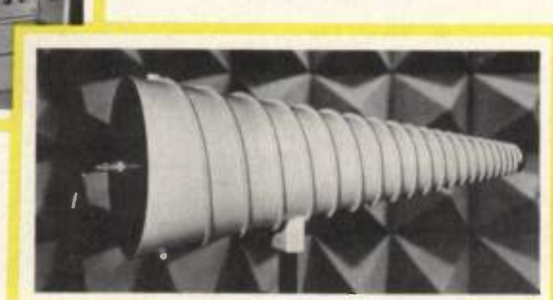


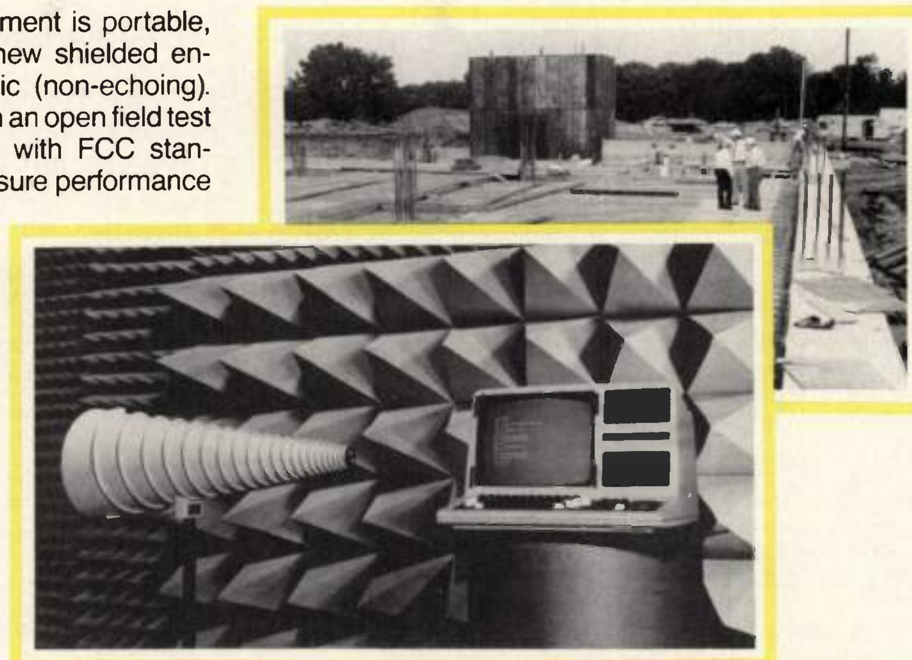
Tests are computer-controlled, to provide customized testing with precise results, repeatability, and hard-copy documentation to be included in your test reports. In addition to those tests mentioned above, shielding can be tested to MIL-STD-285, IEEE 188, NSA, etc. RF gaskets are tested using the SAE ARP-1705 transfer impedence method, to 140 dB. Computers and proved software, plotters, signal sources, oscilloscopes, meters, receivers, amplifiers and antennas are employed in a quantity and degree of sophistication not available even to most manufacturers of Class A and B devices. In fact, few, if any, other test facilities in the U.S. have a comparable array of equipment, calibrated and traceable to the National Bureau of Standards!



Interference Control?

Where do we test?

Your place or ours! If your equipment is portable, we'll conduct your tests in our new shielded enclosures, including semi-anechoic (non-echoing). Commercial tests are confirmed in an open field test site, itself tested in accordance with FCC standards. Originally developed to ensure performance of our own EMC shielding strips, these superb facilities are available to you on a daily basis. Engineering help is also available on request. On the other hand, when on-site testing is required, we'll gladly come to you with our portable laboratory instruments.



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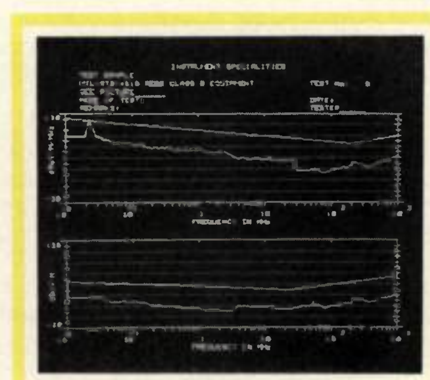
We've been told our Test Reports are the best in the industry. More detailed, and much clearer, since you get a continuous sweep of frequency spectrum—not just a few hand-plotted points. You get computer print-outs and documented data which meet both FCC and military audit requirements. And, if desired, we can supply you with engineering consultation leading to specific recommendations and verification. Finally, our strict non-disclosure policy assures that only you or your designees receive this valuable data.



For more information on rates and schedule availability, or to discuss your specific needs, phone and ask for EMC Customer Service. Or, write us at Dept. RFD-29.

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rf calendar

February 24-26, 1987
NEPCON West 87
Convention Center, Anaheim, California
Information: Show Manager, NEPCON West 87, Cahners Exposition Group, 1350 East Touhy Ave., P.O. 5060, Des Plaines, Illinois 60017-5060; Tel: (312) 299-9311

February 25-27, 1987
Industry-University Advanced Materials Conference
Colorado School of Mines, Golden, Colorado
Information: Dr. Jerome G. Morse, Advanced Materials Institute, Colorado School of Mines, Golden, CO 80401; Tel: (303) 273-3852

March 24-26, 1987
Southcon/87
Georgia World Congress Center, Atlanta, Georgia
Information: (800) 421-6816 (outside California); (800) 262-4208 inside California; or (213) 772-2965

April 1-8, 1987
Electronics and Electrical Engineering '87
Hannover Fairgrounds, Hannover, West Germany
Information: Hannover Fairs USA, Inc., 103 Carnegie Center, P.O. Box 7066, Princeton, NJ 08540; Tel: (609) 987-1202

April 21-23, 1987
Electrical Overstress Exposition
San Jose Convention Center, San Jose, California
Information: Jim Russell, EOE, 2504 N. Tamiami Trail, Nokomis, FL 33555; Tel: (813) 966-9521

April 27-29, 1987
IEEE Instrumentation and Measurement Technology Conference
Sheraton-Boston Hotel, Boston, Massachusetts
Information: Robert Myers, Myers/Smith, Inc., 1700 Westwood Blvd., Los Angeles, CA 90024; Tel: (213) 475-4571.

May 11-13, 1987
37th Electronics Components Conference
Boston Park Plaza Hotel and Towers, Boston, Massachusetts
Information: Tom Pilcher, Electronic Industries Association 2001 Eye St. N.W., Washington, DC 20006; Tel: (317) 261-1306

May 27-29, 1987
41st Annual Frequency Control Symposium
Dunfey City Line Hotel, Philadelphia, Pennsylvania
Information: Dr. R.L. Filler, U.S. Army Electronics Technology and Devices Laboratory, SLCET-EQ, Fort Monmouth, N.J. 07703-5000; Tel: (201) 544-2467.

June 9-11, 1987
IEEE MTT-S International Microwave Symposium
Bally's Grand Hotel, Las Vegas, Nevada
Information: Robert A. Weck, U.S. Army, LABCOM, ETD Lab, SLCET-MH-W, Fort Monmouth, NJ 07703-5000; Tel: (201) 544-4489

June 22-26, 1987
Laser 87 Optoelectronics Microwaves
Munich Trade Fair Center, Munich, West Germany
Information: Münchener Messe-und Ausstellungsgesellschaft mbH, Messegelände, Postfach 121009, D8000 München 12, West Germany; Tel: (89) 5107-0

rf courses

Georgia Institute of Technology

Elements of Phased-Array Radar System Design
March 10-13, 1987, Atlanta, Georgia

Millimeter Wave Systems and Technology
April 6-9, 1987, Atlanta, Georgia

Information: Deidre Mercer, Department of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332; Tel: (404) 894-2547.

The George Washington University

Defense Electronics Executive Overview
March 2-6, 1987, Washington, DC

Spread Spectrum Communication Systems
March 9-13, 1987, Washington, DC

Principles of Air Defense and Air Penetration
April 6-9, 1987, Washington, DC

Synchronization in Spread Spectrum Systems
April 6-10, 1987, Washington, DC

Wind Shear Radar
April 20-22, 1987, Washington, DC

Information: Ken Tebo, Director, Off Campus Programs, Continuing Engineering Education Program, George Washington University, Washington, DC 20052

Southeastern Center for Electrical Engineering Education

Antennas: Principles, Design, and Measurements
March 24-27, 1987, St. Cloud, Florida

Information: Ann Beekman, SCEEE, 1101, Massachusetts Ave., St. Cloud, FL 32769; Tel: (305) 892-6146

R&B Enterprises

EMP Design and Pulse
February 19-20, 1987, Philadelphia, Pennsylvania

Grounding, Bonding and Shielding
March 12-13, 1987, Philadelphia, Pennsylvania

Information: Greg Gore, R&B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428-2721; Tel: (215) 825-1960

Interference Control Technologies, Inc.

Practical EMI Fixes
March 17-20, 1987, San Antonio, Texas

TEMPEST Facilities
April 7-10, 1987, Atlanta, Georgia

Grounding and Shielding
March 10-13, 1987, Orlando, Florida
April 7-10, 1987, Phoenix, Arizona

Design and Measurement
April 20-24, 1987, San Jose, California

Intro to EMI/RFI/EMC
May 18-20, 1987, San Diego, California

Information: Interference Control Technologies, Inc., P.O. Box D, Gainesville, VA 22065; Tel: (703) 347-0300

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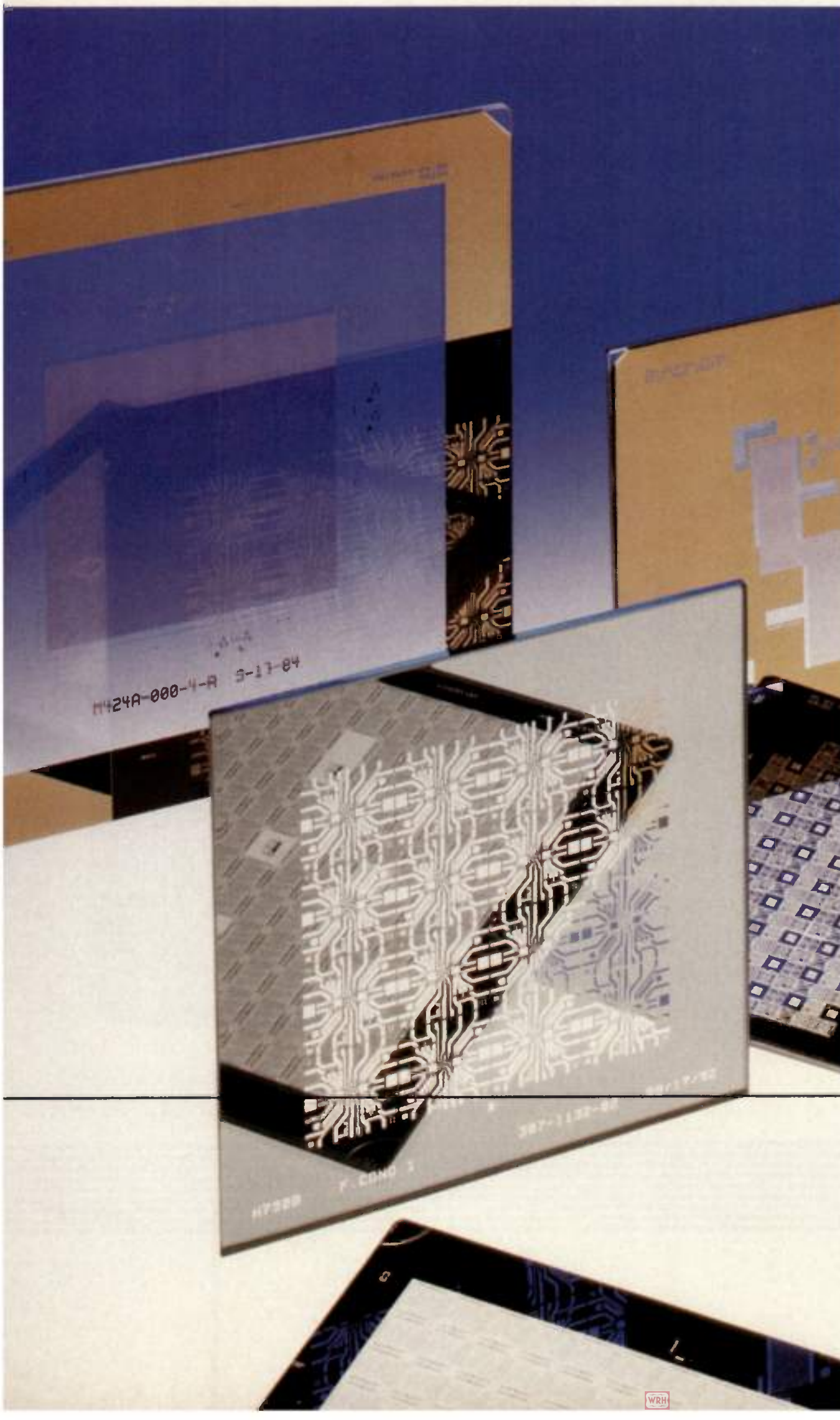

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INFO/CARD 15

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Since Touchstone was already the microwave industry's standard of computer-aided engineering, there seemed little room for really dramatic improvement. But this new release makes Touchstone significantly more powerful.

Start with elements. Touchstone 1.5 adds twenty elements, to total over 120. That means even quicker, better design results. And MMIC foundry element libraries are now a Touchstone option.

More optimizers

We've added six optimizers, including minimax, least p^{th}, and quasi-Newton. We've also added a minimax option to our gradient and random optimizers. And the random optimizer now lets you *maximize*—as well as minimize—error function! The additional optimizers give you choices that help your designs converge more rapidly to the results you want. In fact, no other program comes close.

Larger Circuits

Same with analysis. Touchstone 1.5 boosts circuit file size by a factor of four, increases the length of lines to 225 characters. This quantum improvement lets you analyze much larger circuits—and makes Touchstone 1.5 your only logical choice for complex projects like sophisticated MMIC designs.

Advanced graphics

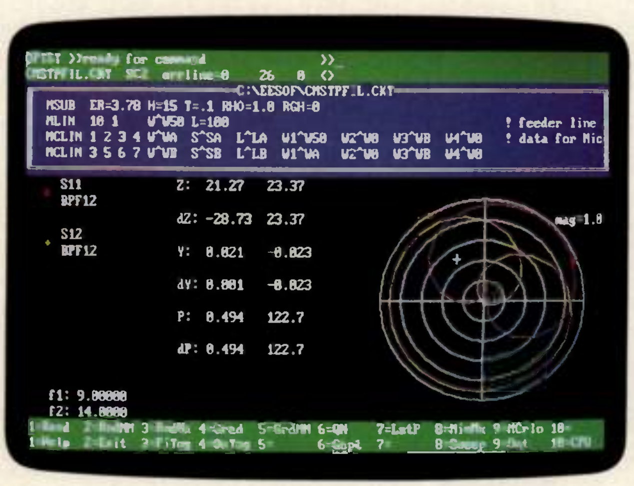
Touchstone 1.5 brings you many new features such as polar displays, Smith charts that display admittance and impedance, and an interactive graphics cursor (with the mouse, for instance, you can read numerical Smith chart coordinates directly from the graphics screen). What's more we've improved the graphics speed.

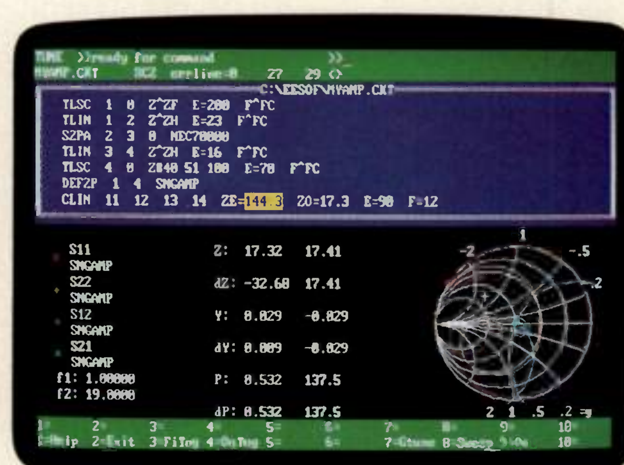
We've also developed advanced windowing. Pop-up windows offer help. Others display numerical output in color. The screen now splits between graphics and text to let you organize your data better. Actually, we've improved the windowing environment so much that you'll probably only *want* a single monitor.

What next?

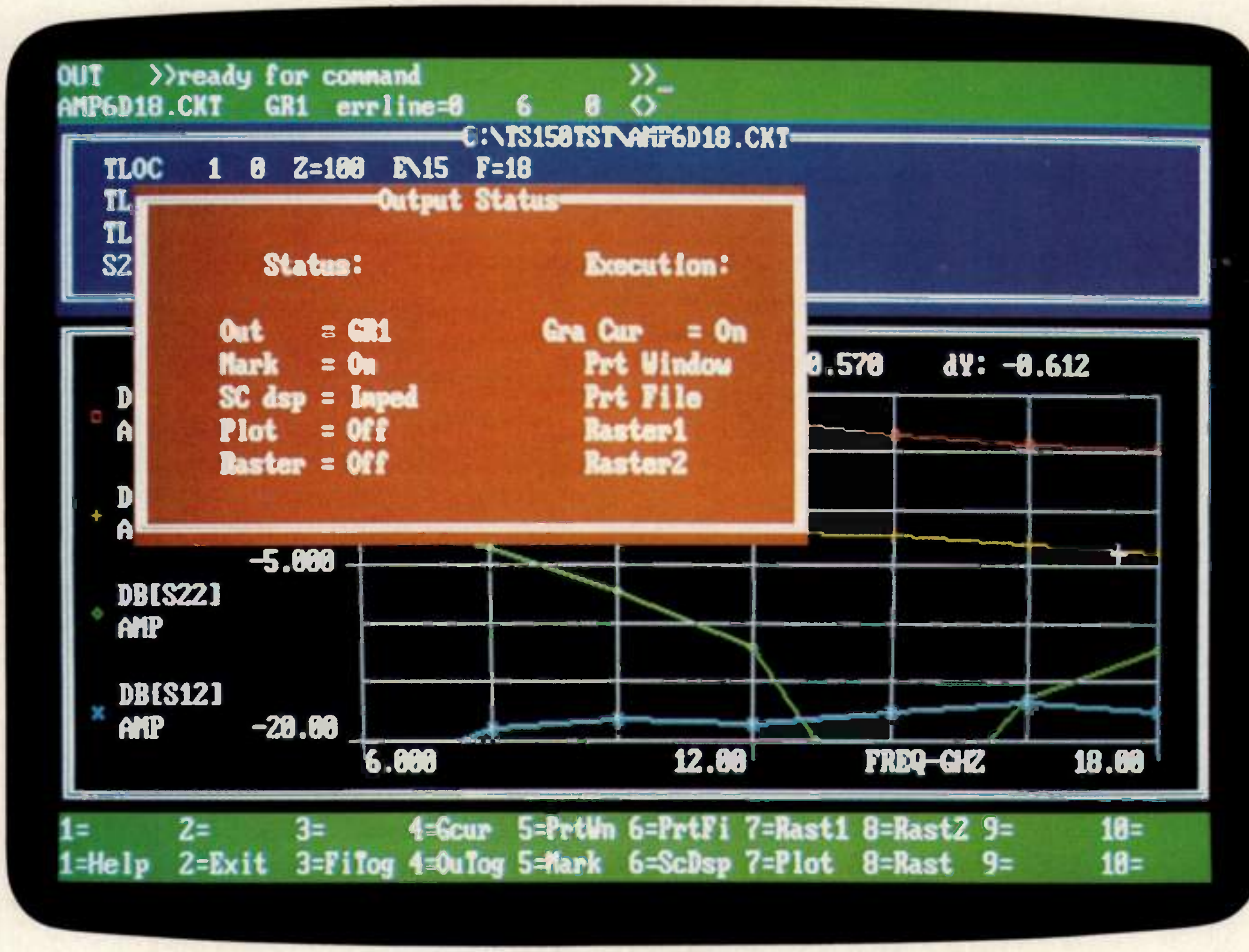
These are just the major new features. There's more. And in all, they plainly make Touchstone 1.5 the industry's CAE tool of unapproached value.

What's next? We're hard at work. And Touchstone owners will get new releases—as they get 1.5—as part of their regular extended support contracts. To join them, call or write EEsof now.





The microwave/RF industry's optimal CAE tool —has just been optimized!



You see above how Touchstone's graphics output gives you control of the interactive cursor. And you get an idea of the many advanced kinds of plots that 1.5 lets you generate — with hard copies of everything you see on the screen.

Also note the windowing, another feature of Touchstone 1.5. This one displays the output status, and you invoke it at the touch of a single function key.

Opposite page (Left): Polar display with optimization activated: (Right): Admittance chart with tune mode activated.

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Capacitance Cj (pF) MAX	.03	.06	.02	.07
Lifetime TL (ns) TYP	50	50	150	150
Switching Time TS (ns) TYP	5	5	15	15

*Mesa **Planar
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used in calculations as easily as ordinary numbers. For example, a matrix can be multiplied by a complex number by pressing the "×" (times) key. The operating system allows the user to mix direct entry of algebraic expressions with RPN (reverse polish notation) logic operations. Equations can be entered and stored in the user's own terms with the equation solver capability. A variable, anywhere in the equation can be solved by this machine. The menus and soft keys incorporated provide high level problem solving without the need for programming.

The HP-28C can also graphically depict any single valued function and plot statistical data. Once an expression is plotted in the display, the user can locate an approximate root, press a key to record the coordinates, then use the equation solver to calculate the root with 12-digit accuracy. Contained is a unit conversion system for converting values between unit systems. The values of 120 units are built in; the user can have unlimited combinations. The memory for the calculator is composed of 128K ROM and 2K RAM.

The calculator has separate alpha and numeric keyboards. It measures 7.5" × 6.25" × 0.5" when open and weighs 8 ounces. The supply comes from three N-cell alkaline batteries. The options for the HP-28C include a battery powered thermal HP printer which communicates via an infrared beam.

RF Business Briefs

TRW to Sell VHSIC Devices Commercially

TRW will begin sales of its advanced Very High Speed Integrated Circuit (VHSIC) devices through its commercial electronic components operation. Devices available through the sales force of TRW's Electronic Components Group are those created by TRW's Electronic Systems Group for Phase 1 of the Department of Defense's tri-service VHSIC program. Sales will be made only to United States defense contractors qualified to receive and safeguard International Traffic in Arms Regulation (ITAR) materials. The government agency that qualifies defense contractors to purchase such material is the Defense Logistics Service Center, Battle Creek, Mich.

AEL Sells Israel Subsidiary

AEL Industries, Inc. has completed the sale of its 59 percent interest in Elisra Electronic Systems Ltd. to Tadiran Ltd., Israel's largest electronics company, in exchange for six percent of Tadiran's capital stock. The transaction is valued at $20 million. According to the agreement of sale, AEL can request redemption of all or a part of its share holdings at any time during the 1990/1991 timeframe if Tadiran does not offer to include AEL's holdings in a public offering during the next three years.

TRW Sells Transformer Division to OPT Industries

TRW Inc. and OPT Industries, Inc. announced that OPT has purchased TRW's Transformer & Coil Products operation for an undisclosed price. The business will operate as United Transformer Corporation, a wholly-owned subsidiary of OPT Industries, with headquarters in New York

City. Product lines acquired from TRW include transformers and inductors, magnetic amplifiers, electronic wave filters, and coils, primarily for military customers.

EPSCO, Inc. Acquires Neico Microwave Company

EPSCO, Inc. announces the acquisition of the assets and business of Neico Microwave Company and subsidiaries, a privately owned company located in Hopkinton, Mass., for $4.8 million in cash and approximately 110,000 shares of EPSCO common stock. Neico Microwave is a manufacturer of microwave transmitter and antenna components with net sales of approximately $9.1 million for the calendar year 1986.

GigaBit Logic Announces Cray Order

GigaBit Logic announces that Cray Research Inc. has placed a one-year order with GigaBit in excess of $3 million. Cray, the acknowledged world leader in supercomputers, will use the logic and memory devices procured under this order to enter the next phase of development of a GaAs-based parallel processor supercomputer. Seymour Cray, the project leader and principal designer of the Cray-3, has worked closely with GigaBit Logic and his own GaAs team to perfect the ICs for the Cray-3 system. In support of the project, GigaBit has achieved yields approaching 40 percent on VLSI ICs with densities of 30,000 components per device.

National Semiconductor and Westinghouse in VHSIC Pact

National Semiconductor Corporation has entered into an agreement with Westinghouse Corporation for fabrication of VHSIC (Very High-Speed Integrated Circuit) 10k gate arrays. The foundry service utilizes National's 1.25-micron VHSIC facility in Santa Clara, which is fully certified under MIL-M-38510. Westinghouse's gate arrays will go into the F16 VHSIC programmable signal processor (vpsp) and the multi-role surveillance radar (mrsr) program. The contract begins immediately and is scheduled to run through calendar year 1987.

Scientific-Atlanta Receives Order for Radar Measurement System

Scientific-Atlanta, Inc. has received an $8.8 million order from the Department of the Air Force for an integrated radar measurement system. Under the terms of the contract, Scientific-Atlanta will design, fabricate and install a state-of-the-art integrated radar measurement system and support equipment for the 6585 Test Group, Holloman Air Force Base, New Mexico, Radar Target Scatter Site (RATSCAT). The U.S. Air Force and its prime contractors will use the system for radar cross section measurements of designated targets such as airplanes and missiles.

TRAK Receives Amplifier Contract

TRAK Microwave Corporation has received a contract valued at approximately $1 million from the U.S. Navy. The contract is for gain and phase-matched GaAs FET amplifiers with built-in filter for an airborne phased array telemetry system.

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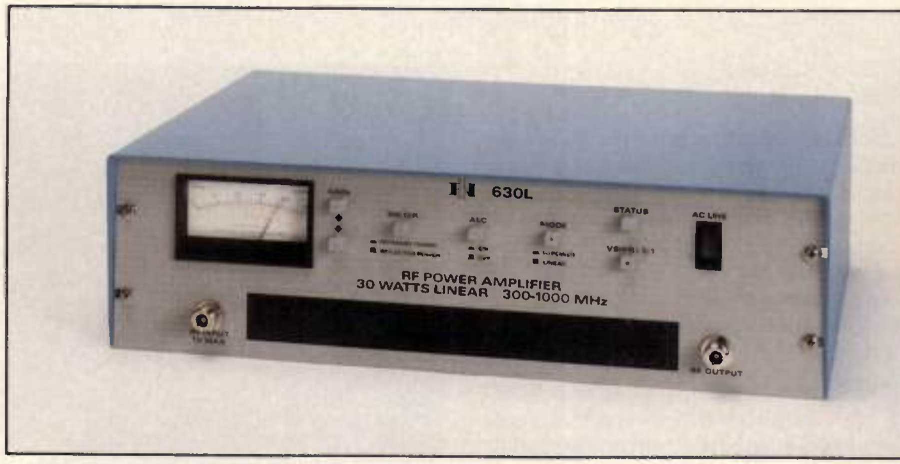
*Patent No. #3,735,269

New Amplifier Employs Latest RF Power Techniques

By Yogendra Chawla
ENI, Inc.

The 630L RF Power Amplifier is a new solid state broadband power amplifier from ENI, providing a linear low distortion output of up to 30 Watts over the 300 to 1000 MHz frequency range. The 630L is a self contained amplifier with a gain of 45 dB and gain variation of ±1.5 dB in an open loop application or ±0.5 dB when used in closed loop operation. The wide bandwidth is achieved without band switching, so the amplifier may be driven by any standard signal or sweep generator to provide amplified CW, AM, FM, SSB, TV pulse and other complex modulated RF signals.



The ENI 630L is recommended for applications requiring high gain linear amplification without band switching and tuning. It may be used as a standard gain block or as a computer controlled subsystem with TTL or IEEE 488 bus interface capability.

The unit is designed with an optimal mix of broadband solid state RF amplifier design techniques including lumped elements, ferrite loaded coaxial, microstrip and stripline for the desired performance. The overall design is modular in concept for ease of manufacturing and maintenance. The RF power transistors are quadrature combined for low interface VSWRs and graceful degradation in the event of a transistor failulre. The RF chain has built-in gain gain and output power margins for best reliability. The individual RF transistor stages are optimally designed for maximum stable gain and efficiency. High power S-parameter measurement techniques have been used to maximize design confidence.

The quality and reliability of an ENI amplifier is designed in using extensive built-in operation protection to prevent damage from excessive voltage, current and temperature. A fault condition is displayed by the "status" lamp on the front. The load VSWR is continuously monitored and a greater than 3:1 VSWR condition is indicated on the front panel. The amplifier maintains power regulation in closed loop operation up to a 3:1 VSWR, when the output power is limited without shutting off the amplifier. The thermal design is optimized for overall reliability using forced air cooling with a front to rear air flow, so the unit may be easily rack mounted.

A large meter is mounted on the front panel for indication of forward and reflected power. The amplifier gain is controllable from front panel "up/down" push buttons, or via the remote TTL or IEEE 488 interface. When additional power is needed, the amplifier may be switched from the linear Class A mode of operation to a higher Class AB mode by selecting a front panel "Mode" control push button. Internal or external Automatic Level Control of the unit is available when the front panel "ALC" button is selected. With the ALC off, the amplifier provides the nominal 45 dB of gain over the 300 to 1000 MHz frequency range.

ENI, Inc., Rochester, N.Y. For more information, circle INFO/CARD #170.

ENI 630L Performance Summary

Typical Applications

EMI/RFI susceptibility testing	Equipment calibration
RF components and subsystem testing	General laboratory instrumentation
Antenna testing	

Some of the Features

Digital gain control	System status for fault location
Open loop operation	Load VSWR indication when greater than 3:1
Internal and external closed loop operation	Built-in test equipment (BITE) for maintenance
Linear and high power mode	Full remote control capability via a computer
Optional signal on-off gating	Optional IEEE-488 bus interface
Forward and reflected power measurement	

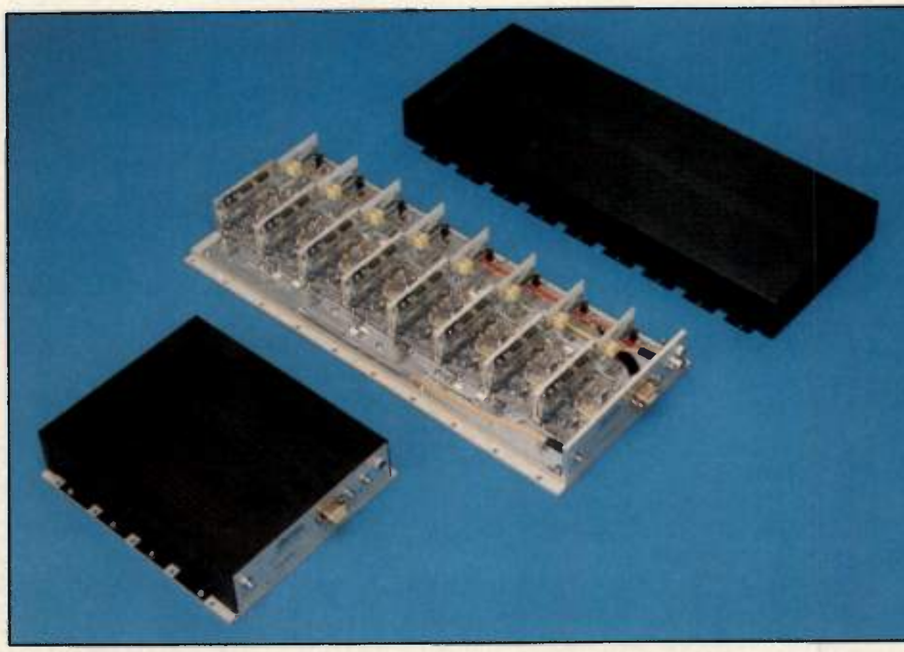
Brief Performance Specifications

Bandwidth	300-1000 MHz
Power	30 Watts CW
Gain	45 dB nominal
Gain variation	±1.5 dB for open loop ±0.5 dB for closed loop
Harmonic Distortion	Better than 20 dB
Third Order IM Distortion	Better than 25 dB
Noise Figure	10 dB
Cooling	Forced air

New Techniques and Components Boost RF Power

By Gary A. Breed
Editor

More power, better efficiency, broader bandwidth, higher frequency and more reliability: These are the many areas of development in solid-state RF power technology. This Special Report takes a quick look at some of the latest design innovations and product developments that make RF power one of the most active areas in the electronics industry.



RF power components and techniques come together in Acrian class A linear amplifiers for UHF television transmitters.

There are two general areas to explore: components and techniques. Transistors are the biggest story in components, with support from chip capacitors and resistors, plus ferrite and iron powder materials for inductors and transformers. Design and construction techniques of note are combining methods, thermal management, feedback networks and protection circuitry. These developments are in response to the demand for RF power in communications, military, broadcasting, medical and scientific applications.

RF Power Transistors

Bipolar RF transistors continue to be a major part of RF power applications, particularly in lower voltage and lower cost applications. Devices are available providing up to 600 watts power at HF and low-VHF (Motorola MRF430). Similarly rated devices are available from Thomson-Mostek. In the UHF range, where 225-400 MHz military equipment provides the demand, TRW has push-pull devices which provide 100 watts at 500 MHz, and others up to 50 watts at 1000 MHz. Amperex and Acrian are also active in RF power bipolars.

Power FET devices are the transistors "in the news" with rapid development in power capability, frequency range, and fabrication techniques. The whole alphabet is represented in the world of power FETs, with T-, V- and D-MOS and POLY-, HEX-, PSI-, ISO- and MOSFETs. Along with the multitude of trade names for devices are as many variations on the fabrication processes. The gate structure of an FET is the critical portion of its design, and different manufacturers have developed their own methods to meet their own performance objectives.

The performance of power FETs is impressive. Motorola's TMOS™ devices include the MRF154 with 600 watts power up to 90 MHz or more. M/A-Com PHI has VMOS devices in the 150 watt range for applications up to 175 MHz, and DMOS FETs in the UHF range with watt power output. Acrian and Polycore are other active participants in the UHF power FET market. As fabrication techniques improve, FET technology will command an even greater share of new designs.

Another class of FET is the static induction transistor (SIT), a new development that has yet another gate configuration. The SIT shows great promise in pulsed power applications in the HF/VHF/UHF range, and is fabricated in a highly reproduceable manner. Prototype units have demonstrated power at the 200 watt level (CW) at 225 MHz, and promise even higher power at lower frequencies and in pulsed mode. SITs are already in use at audio and ultrasonic frequencies, and applications at RF are being developed right now.

Passive Components

Higher power requires coupling capacitors with greater current handling capacity, terminating resistors of higher wattage and low reactance, and magnetic materials with lowest temperature rise and highest electrical stability. Capacitor manufacturers have made great improvements in large chip capacitors for RF applications, responding to the need for power handling, as well as the higher voltages utilized by some FETs. Resistors and terminations are available with higher power in smaller spaces. New ceramic materials allow a greater resistance stability with temperature rise, making smaller attenuators and terminations possible.

Magnetic materials are in demand, too. Transformers and inductors are integral to all power amplifier designs, and at least at HF and VHF frequencies they are the primary means of coupling and combining transistors and amplifiers. Ferrites and iron powders are by nature lossy and the challenge continues to provide electrical stability at high power levels.

Combining Techniques

At higher frequencies, above about 100 MHz, transmission-line combining networks remain the primary means of summing the power of transistors and amplifier modules. While the basic techniques have not changed for some time, some of the recent component developments (terminations, substrates, coaxial cables) have made it possible to reduce losses and improve the accuracy of these combiners. A major application requiring maximum precision and stability of transmission-line couplers and combiners is phased-array radar.

Another type of radar is pushing forward the state-of-the-art at HF: over-the-horizon-radar (OTHR). One company in the middle of OTHR system development is Werlatone Inc. This firm has developed combiners to go from individual 600-watt modules to 25 kW combined outputs over a frequency range of 1-200 MHz. The SITs noted earlier are being developed to cover this wide bandwidth required for OTHR. To monitor this high power phased-array system, Werlatone has also developed a high power precision directional coupler to provide continuous power monitoring calibration.

At the 25 kW level, the low distortion required for the OTHR system ruled out the use of ferrite loaded combiners. An air-core design was developed using hardline transmission line and high power external terminations. Werlatone's unique (and proprietary) development is the use of all standard 50 ohm loads rather than the usual 2R or R/2 terminations. Over the 5-28 MHz range, the final design will handle 40 kW with an insertion loss of about 0.2 dB and port-to-port isolation of 20 dB. Although a specific application developed by Werlatone, this combiner represents the type of applications RF power engineers are being asked to develop.

Amplifier Design

Implementing an amplifier design using some of these new devices and system techniques requires a combination of analytical and creative engineering. Selecting the right device for an application is certainly not an obvious matter. Options include internal matching, different gain characteristics, biasing and operating voltages, single or multi-chip configuration, plus all the subtle (and not so subtle) variations found among the power FET fabrication methods.

One goal the engineers strive toward is maximum efficiency. Of course, the matching networks can be optimized and operating parameters can be chosen for most efficient operation, but the real progress has been in the switch-mode classes of amplification. Class D, E and higher modes offer greater efficiency than Class A, B or C, but at the cost of linearity. CW and certain pulse applications have no need of linearity, nor does FM. For these applications, operating a transistor as a switch is the most efficient means of amplification. Shaping the driving pulse can improve a specific device's efficiency by compensating for its input capacitance and its F_T limitations.

So far, this is an application for lower VHF and HF, since the square wave of a switching amplifier contains the fundamental frequency and harmonics (some applications limit the driving waveform to the fundamental, 3rd and 5th harmonics). The 80 percent efficiency figures achieved are very attractive in high power communications and industrial uses, where a considerable savings in electrical power can be realized.

Linear applications such as AM and SSB require modulation of a switched amplifier. AM modulation of Class D and E amplifiers has been used for over ten years in mediumwave and shortwave broadcast transmitters. Less widespread is the use of SSB with switching amplifiers. SSB requires the stripping of the amplitude components from the modulating waveform, then restoring them by amplitude modulating the final amplifier. The varying frequency components are unchanged by the amplifier chain. In this method, the time delays of the RF signal and the amplitude envelope must be equal for proper recombination at the output.

Wider bandwidths and higher frequencies present RF engineers with design challenges, too. Input and output matching has to be efficient over the desired bandwidth, and also must include whatever compensation is needed for the variations in device characteristics. Higher frequencies require accurate and consistent mechanical construction. The larger devices and their higher powers force designers to include voltage, current and thermal considerations for all parts of the circuit, from the conductors on a substrate laminate to the decoupling chokes and capacitors.

System Considerations

Perhaps the item at the top of the list of performance requirements is *reliability.* Commercial and military needs both involve reliability for safety, effectiveness and economic reasons. Since power transistors are inherently less forgiving of their operating environment than the tubes that preceded them, protection and isolation circuitry has to be designed into an amplifier system. One technique used by Microwave Modules and Devices and by ENI involves the use of 90° couplers to combine the outputs of several transistors. The primary advantage of this method is that it reduces VSWR sensitivity of the system, both at the input and output. Another advantage over the more common push-pull operation is better suppression of odd-order harmonics.

Soft failure is another aspect of reliability in a combined-amplifier system. If one module fails, it is important that the entire system not be shut down. The 90° combining scheme noted above provides isolation between amplifiers, limiting the effect a failed module has on a system. Hybrid combiners are designed to dump any power due to a system unbalance into a resistive load. Standard design results in a system of four modules being able to operate at one-fourth rated power if one module fails. The unbalance caused by a failure results in dissipation of a substantial amount of power in the loads, but allows continued operation of the system.

The additional protections usually included in solid-state RF power amplifier systems are: overvoltage, overcurrent, high VSWR, low or high drive power and temperature. While these are straightforward requirements, it should be noted that the protection circuits themselves have to be highly reliable.

Summary

This report has only pointed out some highlights of current work in RF power. There are a lot more ideas being worked on in the component manufacturers' labs, and on the workbenches of design engineers in all parts of the RF industry. rf

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Iron Powder Cores for RF Power Applications

By Jim Cox
Micrometals, Inc.

As RF engineers strive for higher power, they need to have the right components, capable of handling that power. The purpose of this article is to present new information which will allow the RF design engineer to select the proper iron powder core for inductors and transformers handling power in the 250 kHz to 5 MHz frequency range. Much of the data presented can be used for applications throughout the HF range.

Iron powder cores are commonly used to produce high Q inductors and transformers for selective circuits. Iron powder cores used in RF applications are composed of extremely small particles of highly pure carbonyl iron. the distributed airgap of iron powder cores contributes to their rather low permeability and very good stability. In applications involving low level signals, the choice of core size, material and winding is normally based on required Q and/or packaging requirements. A listing of the general magnetic properties of carbonyl iron powders is shown in Figure 1.

Low level broadband transformers and RF chokes are commonly built on high permeability ferrite cores. Ferrites are a non-metallic, ceramic ferromagnetic compound with a spinel crystalline structure. Ferrite cores have higher permeability than iron powder cores, but are less stable. While much of the information presented here will be applicable to ferrite cores, the data presented is primarily intended for iron powder cores.

Inductor and transformer applications involving higher power signals require additional considerations. A common misconception is that core saturation is the primary limiting factor in selecting a core for RF power applications. While it needs to be determined how much voltage drop or current flow a given inductor or transformer can support before a limit is reached, this limit will be either magnetic saturation *or* excessive temperature rise resulting from both winding (copper) and core material losses.

General Magnetic Properties

Mix #	Basic Iron Powder	Material Permeability (μo)	Temperature Stability (+)	Resonant Circuit Frequency Range[1] (MHz)	Color Code
1	Carbonyl C	20	280 ppm/°C	.15-2.0	Blue
2	Carbonyl E	10	95	.25-10.	Red
3	Carbonyl HP	35	370	.02-1.0	Gray
6	Carbonyl SF	8.5	35	2.0-30.	Yellow
7	Carbonyl TH	9.0	30	1.0-20.	White
8	Carbonyl GQ4	35	255	.02-1.0	Orange
10	Carbonyl W	6.0	150	10-100	Black
12	Synthetic Oxide	4.0	170*	20-200	Green/White
15	Carbonyl GS6	25	190	.10-3.0	Red/White
17	Carbonyl	4.0	50	20-200	Blue/Yellow
22	Synthetic Oxide	4.0	410*	20-200	Green/Orange
0	Phenolic	1	0	50-250	Tan

[1]Frequency range indicated is for maximum Q. For wide-band applications where high Q is not required, the useful frequency range will typically extend 10 to 100 times higher.
*Non-linear

Figure 1. Table of iron powder core materials.

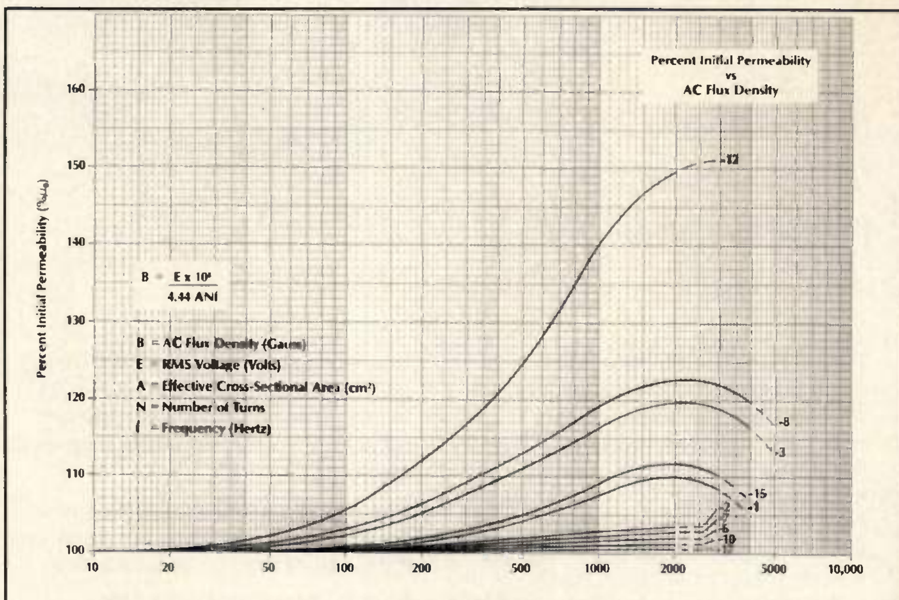

Figure 2. Core saturation determination.

Magnetic saturation is the point at which an increase in magnetization force does not result in any further increase in flux density. This implies that there will be a loss of permeability. An inductor will show a decrease in inductance and a transformer will show both a decrease in impedance and will not transform the additional signal. Carbonyl iron powders typically reach their maximum permeability at about 3,000 gauss and then begin to saturate. They reach full saturation at ap-

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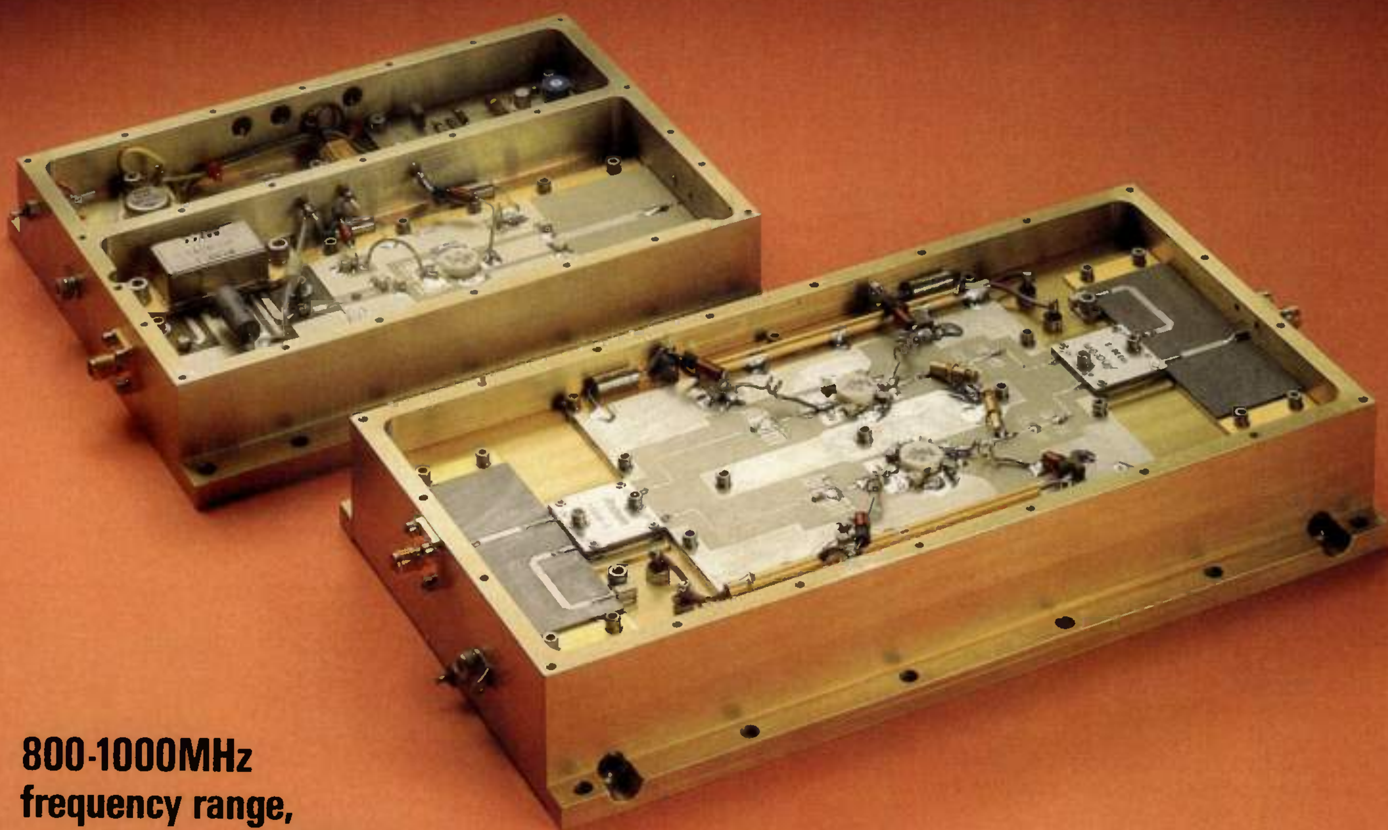

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PAM-810-7-25L	800-1000	30	8	11	10	+55	<2.1	24/4.8

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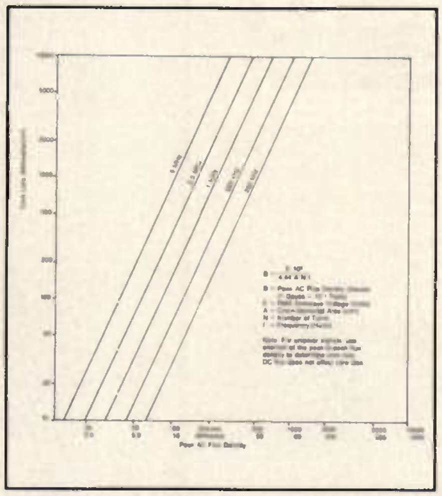

Figure 3. Core loss vs. AC flux density for −6 material (u = 8.5).

proximately 10,000 gauss. This characteristic is illustrated in Figure 2.

With continuous sinewave signals, iron powder cores are limited by temperature rise resulting from losses rather than magnetic saturation. Temperature rise results from losses in both the winding and the core material. The fundamental winding losses are equal to I^2R where I is the RMS current flowing in amperes and R is the effective AC resistance. At high frequency the current carried by a conductor tends to be concentrated near the surface (skin effect). The skin depth of the AC cur-

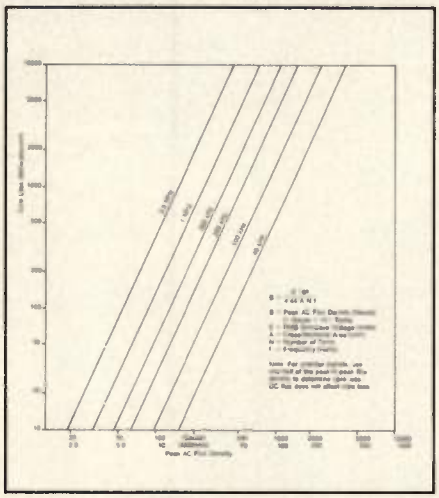

Figure 4. Core loss vs. AC flux density for −2 material (u = 10).

rent in a copper conductor at room temperature is described by:

$$\text{Skin Depth (cm)} = \frac{6.62}{\sqrt{f}}$$

where f is frequency in hertz.

Wire size should be chosen for a skin depth equal to the conductor radius. For example, at 1 MHz a wire larger than #35 AWG will not be fully utilized and will thus show an increased AC resistance. Due to this, the use of a large number of strands of fine wire that are insulated from each other and interwoven can be useful in reducing the AC resistance of conductors at high frequency. Such a conductor is known as litz wire. Practical litz conductors are very effective at frequencies below 500 kHz, but begin to lose effect above 3 MHz.

Core Losses

Figures 3 and 4 show core loss graphs for two iron powder core materials (Micrometals, Inc. materials 6 and 2) with permeabilities of 8.5 and 10. The losses generated by the core materials were determined experimentally. The total loss of a wound coil was measured and the losses due to the test set-up, the winding, and the core material were separated. The information presented is for the core material alone.

	Power dissipation (mW/cm^3)		
Core	**10 C**	**25 C**	**40 C**
T30	400	1148	2026
T37	412	1170	2065
T44	310	884	1556
T50	307	874	1535
T68	234	664	1167
T80	212	602	1056
T94	160	454	802
T106	114	322	566
T130	117	331	582
T157	94	266	468
T200	87	260	436
T300	62	186	327
T400	43	130	228

Figure 5. Chart of power dissipation for various core sizes.

als were determined experimentally. The total loss of a wound coil was measured and the losses due to the test set-up, the winding, and the core material were separated. The information presented is for the core material alone.

The core loss is expressed in milliwatts per cubic centimeter as a function of peak AC flux density (DC flux does not generate core loss) for a number of frequencies from 40 kHz to 5.0 MHz. This power dissipated by a core will generate temperature rise. The formula used which describes this relationship is:

$$\text{Temp. Rise (°C)} = \left[\frac{\text{Power Dissipation (Milliwatts)}}{\text{Surface Area (cm}^2\text{)}}\right]^{.833}$$

This formula provides a reasonable approximation for the temperature rise of a core in free air. In other environments, such as moving air or an enclosed case,

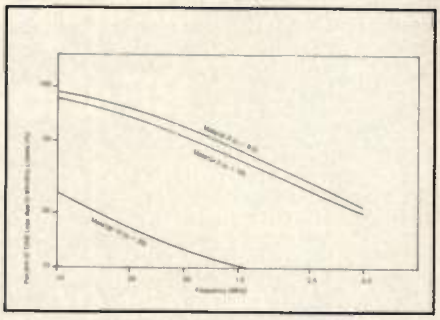

Figure 6. Percent winding loss for single-layer coils.

other relationships will need to be used. With constant power dissipation, it typically takes a core about 2 hours to reach its final temperature. Applications involving low-duty or intermittent operation can time average the losses.

It is important to limit the operating temperature of inductors and transformers using iron powder cores. Long term operation of iron powder cores above 100°C can cause a permanent reduction in both Q and inductance.

A listing of the power dissipation in milliwatts per cubic centimeter for temperature rises of 10, 25 and 40 degrees C for most of the common iron powder core sizes is shown in Figure 5. For those not familiar with the part numbering system: A T30 is a toroidal core with an outside diameter of about .30 inches, while a T400 is a 4.00 inch outside diameter toroid. It can be seen that the physically small parts can dissipate more power per unit volume than the physically large parts.

The peak AC flux density (Figures 3 and 4) for sinewaves is described by Faraday's Law:

$$B = \frac{E\ 10^8}{4.44\ A\ N\ f}$$

Where:
B = Peak AC Flux Density (Gauss) (1 Gauss = 10^{-4} Tesla)
E = RMS Sinewave Voltage (Volts)
A = Core Cross-Sectional Area (cm^2)
N = Number of Turns
f = Frequency (Hertz)

This form of Faraday's Law is generally more useful for transformer applications where the applied voltage is normally known. For an inductor,

$$E = 2\pi f L I$$

Where:
E = RMS Sinewave Voltage (Volts)
f = Frequency (Hertz)
L = Inductance (Henries)
I = RMS Current (Amperes)

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Comparing the core loss characteristics of the three materials shown in Figures 4, 5 and 6 at a particular frequency does not indicate a significant difference in the power dissipated in milliwatts per cubic centimeter at a given AC flux density. However, with further investigation it becomes evident that for a given inductance and voltage, the lower permeability materials generate less AC flux density and, thus, lower core loss, than the higher permeability materials.

Coils wound on lower permeability materials, however, require more turns than higher permeability materials to produce the same inductance, and will, therefore, produce greater winding loss. In general, the best compromise in performance will occur when the winding and core losses are approximately equal.

While the distribution of total loss between the core and winding for any given frequency is dependent on the winding details, as well as the physical size of the coil, it is useful to have a rough approximation of this distribution. Figure 6 illustrates this distribution for three iron powder core materials over the frequency range of 250 kHz to 5.0 MHz with a typical single layer winding. This graph shows that at a frequency of 1 MHz, of the total loss generated in a typical coil wound on material 2, about 40 percent of that loss is due to the winding. In the higher permeability material 15, at 1 MHz, about 10 percent of the total loss generated is due to the winding. With this guideline, it is then possible to estimate how much core loss can be tolerated without exceeding reasonable temperature rise limits.

In an effort to take the basic core loss data, which is expressed in magnetic terms and present it in more common engineering terms, application curves have been generated by Micrometals, Inc. The set of curves shown in Figure 7 shows the maximum voltage as a function of inductance (and inductive reactance) for various core sizes in Micrometals material 2 at a frequency of 1 MHz for a temperature rise of 25°C due to core loss. These curves are based on continuous sinewave signals. A similar set of curves in terms of current as a function of inductance appears in Figure 8. Similar graphs are available for other frequencies and core materials from Micrometals, Inc.

The use of these curves can be illustrated with the following examples:

1) If an inductor application at 1 MHz requires 10 uH (microhenries) and the AC RMS current level is 1 ampere, Figure 10 shows that a T68 size core will be required (Part number T68-2). It can also be seen in Figure 9 that this condition corresponds to a voltage drop across this coil of about 70 volts.

2) To select a core for a transformer requiring 100 ohms of primary inductive reactance and capable of supporting 200 volts RMS, Figure 9 should be used. This shows that 100 ohms of reactance is equal to 15.9 uH and that a T157 size core will be required to support the 200 volts RMS.

Inductance ratings in microhenries for 100 turns are commonly provided by iron powder core manufacturers. The number of turns required to produce a desired inductance for a core with a known inductance rating is given by:

$$\text{Required Turns} = 100 \left[\frac{\text{desired L (uH)}}{\text{L rating uH/100 turns}} \right]^{1/2}$$

In example (1) the T68-2 has an inductance rating of 57 uH for 100 turns and will thus require 42 turns for 10 uH. The T157-2 in example (2) has an inductance rating of 140 uH for 100 turns. The 15.9 uH will require 34 turns. In general, for inductors, the largest wire which will fit in a full single layer will produce the best results. A winding table with this information is available.

It is further possible to define a "power rating" for the various core sizes. This "power rating" will be defined to be the product of the current flowing through a coil times the voltage being dropped across that coil. For a given temperature rise due to core loss, this product is independent of the number of turns wound on the core. Figure 9 shows this information for material 2 at 1 MHz.

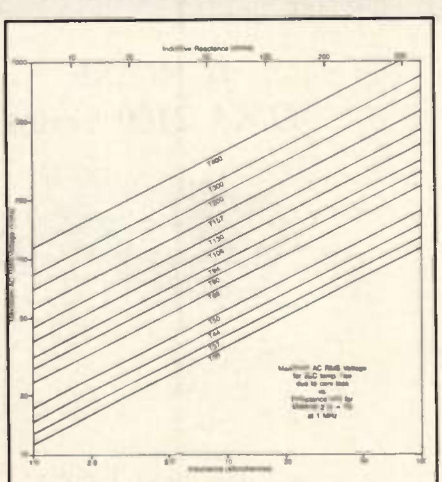

Figure 7. Maximum AC RMS voltage characteristic.

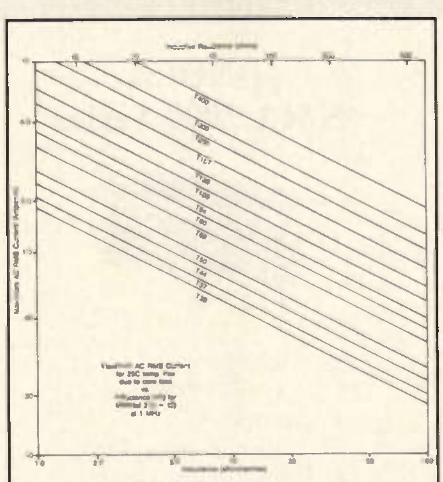

Figure 8. Maximum AC RMS current characteristic.

Material 2 — 1 MHz

Core	Watts
T30	21
T37	26
T44	37
T50	49
T68	88
T80	125
T94	160
T106	236
T130	331
T157	515
T200	794
T300	1127
T400	2108

Figure 9. "Power Rating" for 25C temperature rise due to core loss.

Summary

The selection of the core size and material for RF power inductors and transformers has typically relied on the "cut and try" method. New data and application information is now available which allows the design engineer to more easily and accurately select the optimum iron powder core size and material for these applications. rf

About the Author

Jim Cox is the Chief Applications Engineer at Micrometals, Inc., 1190 North Hawk Circle, Anaheim, CA 92807-1788. He received his BSEE from the University of California at Irvine and has been with Micrometals for 13 years. Jim can be reached at (714) 630-7420.

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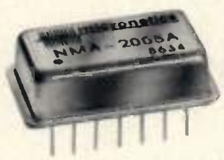

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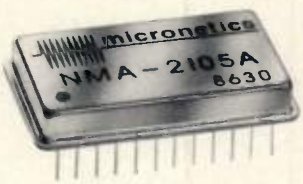

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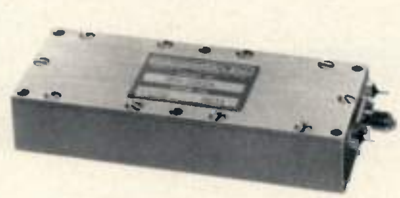

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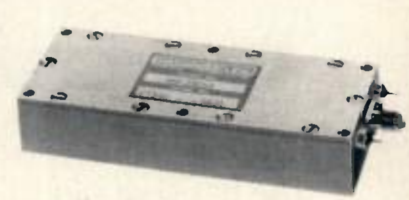

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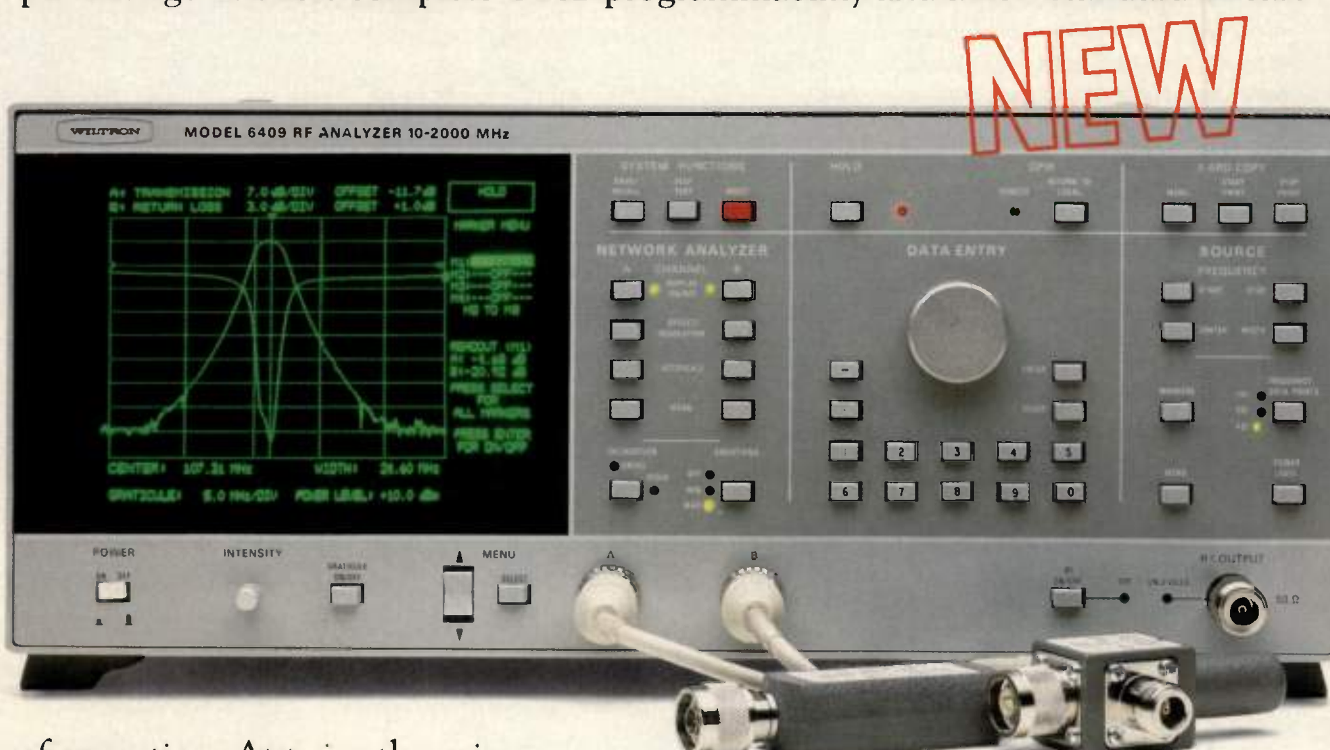

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INFO/CARD 34

Metalized Mica Improves EMI Shielding

By Mark H. Gomez
Assistant Editor

EMI shielding often proves to be an expensive, troublesome affair. This article discusses a cost effective alternative developed by Wilson Fiberfill International. Conventional methods include a properly selected metal alloy placed around or adjacent to a circuit component to suppress radiated magnetic fields interfering with other nearby components or vice versa. The new method utilizes nickel-coated mica compounds to achieve the same results.

There seems to be a crying need for a cost effective method of electromagnetic interference (EMI) shielding. The factors that should be considered for effective shielding should include magnetic properties, physical properties, technological properties, and of course the economic standpoint. Permeability of a material determines the magnetic conductivity. The saturation flux density is important in the shielding of strong magnetic fields. The electrical conductivity, thermal expansion, corrosion behavior, workability, price, design and production aspects are of definite importance. This can be achieved satisfactorily utilizing a polypropylene resin base with a 45 percent loading of nickel coated mica filler which provides up to 40 dB of signal attenuation.

The need for secondary coatings such as conductive paints and zinc sprays is eliminated with this process. Mica is a low cost substitute for fiberglass but it essentially provides the same stiffness and dimensional stability. Solving warpage problems are inherent in the conductive mica filler. Conductive mica filler also processes well since it is easily molded. It provides long-life shielding without flaking or chipping. Another advantage is that mica utilizes existing mold tooling built for amorphous thermo plastics such as acrylontrile-butadienestnyene (ABS). Even at high loading, the nickel coated mica compounds can be processed virtually the same as any mineral filled polypropylene. Nickel coated mica could provide greated conductivity without the sloughing that's associated with carbon blacks now being used in blow molding conductive containers.

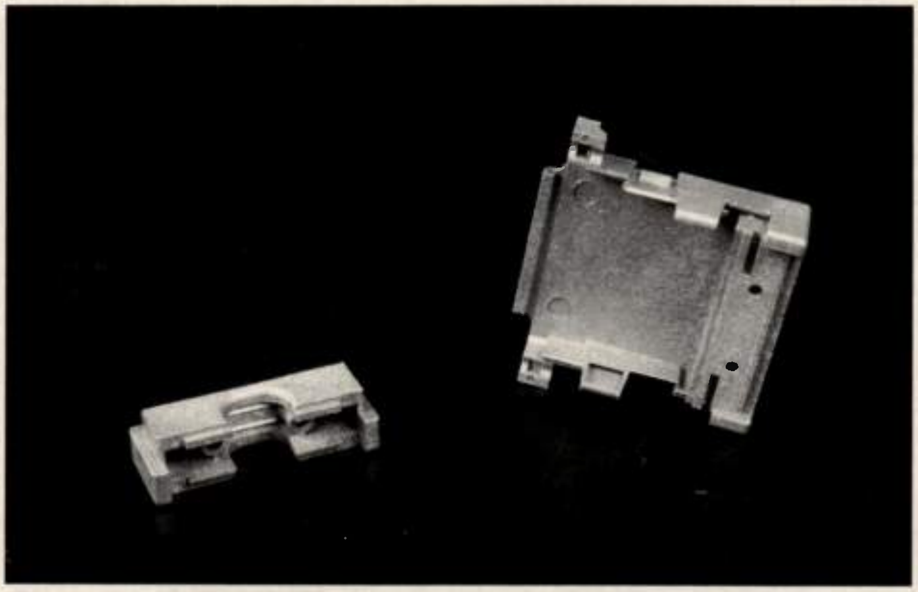

Figure 1. An initial application — a snap fit connector hood.

The nickel coated mica is based on a micro-flake. Mica is used because it has an aspect ratio of 50:1; nickel is used for its excellent electrical properties. Nickel is easily dispersed in the compound as compared to long metal fibers resulting in a uniform homogenous nickel coated mica throughout the part and hence uniform shielding is achieved. The nickel coated mica is a small particle filler which molds easily. Due to its size, the nickel mica flows through small gatings easily when compared to metal fibers which either break or foul at the gate. When compared to aluminum flake, the nickel flake gave better properties as far as dispersion and electrical properties were concerned.

To achieve conductivity, high loadings of compound mica are needed because of the relative low aspect ratio of the filler. Due to their low surface resistivity, the compounds can be used where prevention of electrostatic discharge (ESD) is essential, for example in the direction of microprocessor circuitry.

The cost of using nickel coated mica compounds is about one half that of using nickel coated carbon fiber compounds per cubic inch. The overall picture here is that the cost of providing EMI shielding can be reduced by utilizing the nickel coated mica compounds due to its low initial and manufacturing costs while delivering the same or improved characteristics. Other nickel coated mica materials are in development stages, including polycarbonate, nylon and polybutylene terephthalate (PBT).

For more information from Wilson Fiberfill International, please circle INFO/CARD #131. rf

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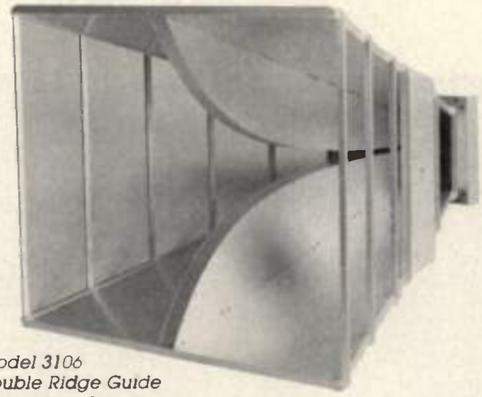

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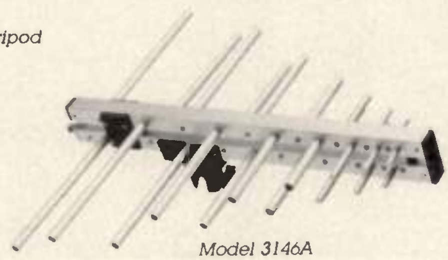

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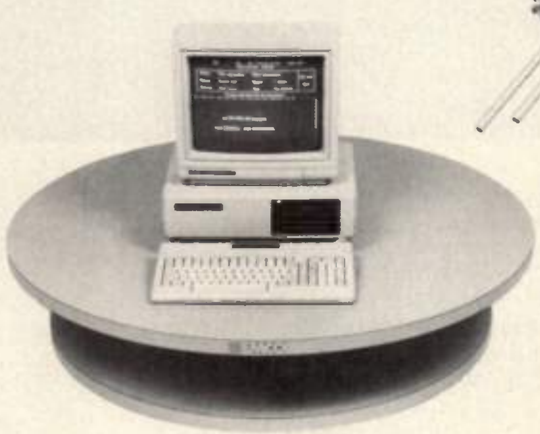

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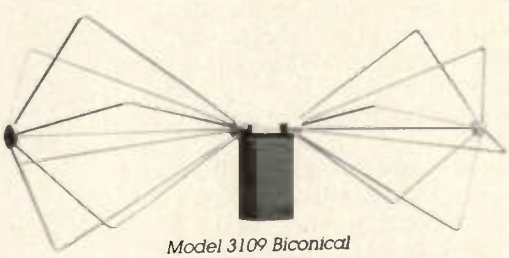

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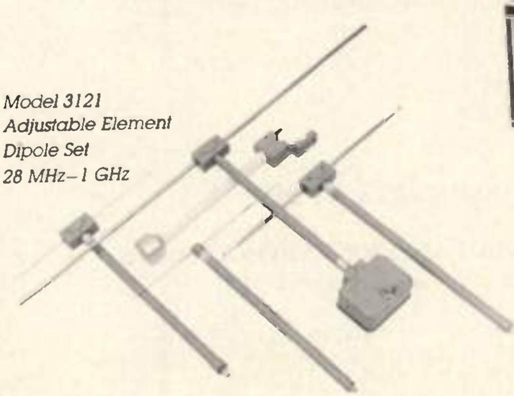

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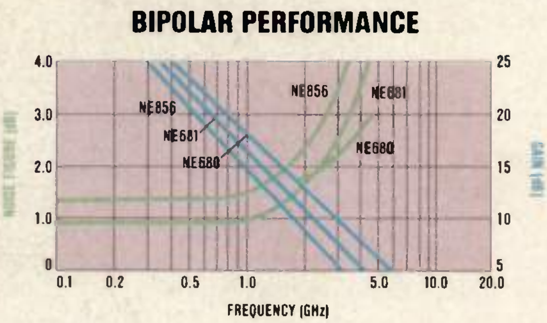

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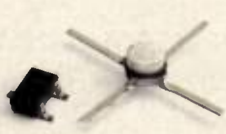

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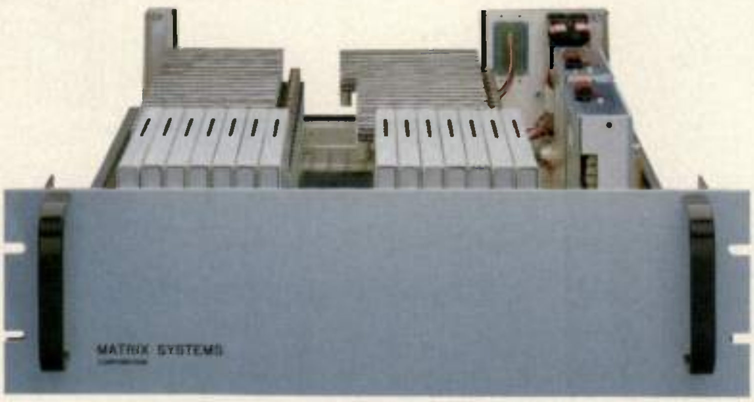

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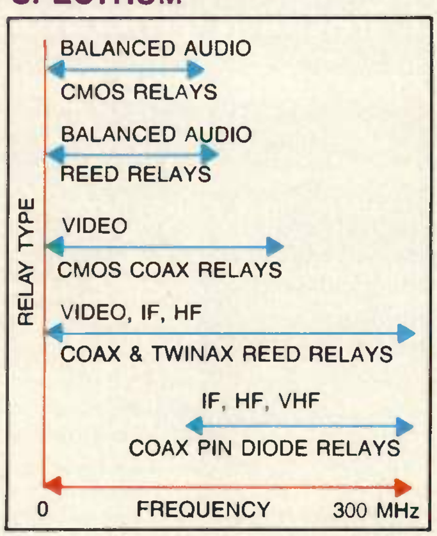

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PIN Diode Switches — Part II

By Andrzej B. Przedpelski
A.R.F. Products, Inc.

The series type PIN diode switch is another widely used RF SPST switch configuration. Instead of short-circuiting the RF path in the OFF condition, as in the shunt configuration, it provides an open circuit. Ideally, all RF power is reflected back to the source and absorbed there. In the ON condition, its effect on the circuit should be minimal.

In the series switch configuration, shown in Figure 1, the most important diode characteristic in the diode nonconducting condition (switch OFF) is its capacity, C_d (Figure 2).

Putting diodes in series increases the isolation by reducing the total effective series capacity. This effect decreases as the number of diodes increases, unless transmission lines are used between the diodes to transform the diode reactances (Figure 3). In this case, however, the optimum line length is not exactly 90 degrees, but depends on the diode capacity. This effect is shown in Figure 4.

Series Switch — 'On' Condition

The diode resistance, R_d, in the conducting condition, determines the insertion loss, as shown in Figure 5 The equivalent circuit of Figure 1 (a) is used, which causes the ideal insertion loss to

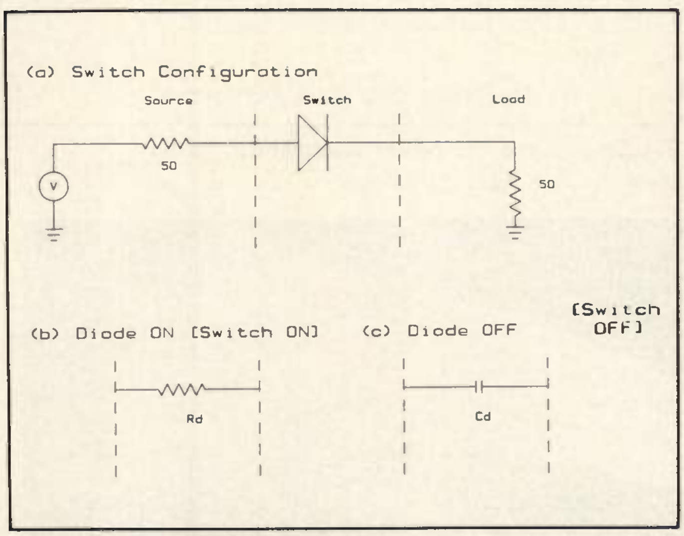


Figure 1. Series PIN diode switch.

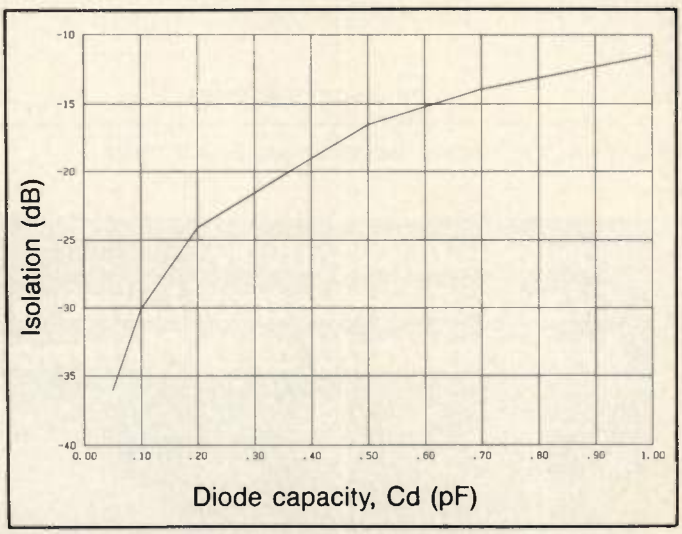


Figure 2. Isolation vs. diode capacity.

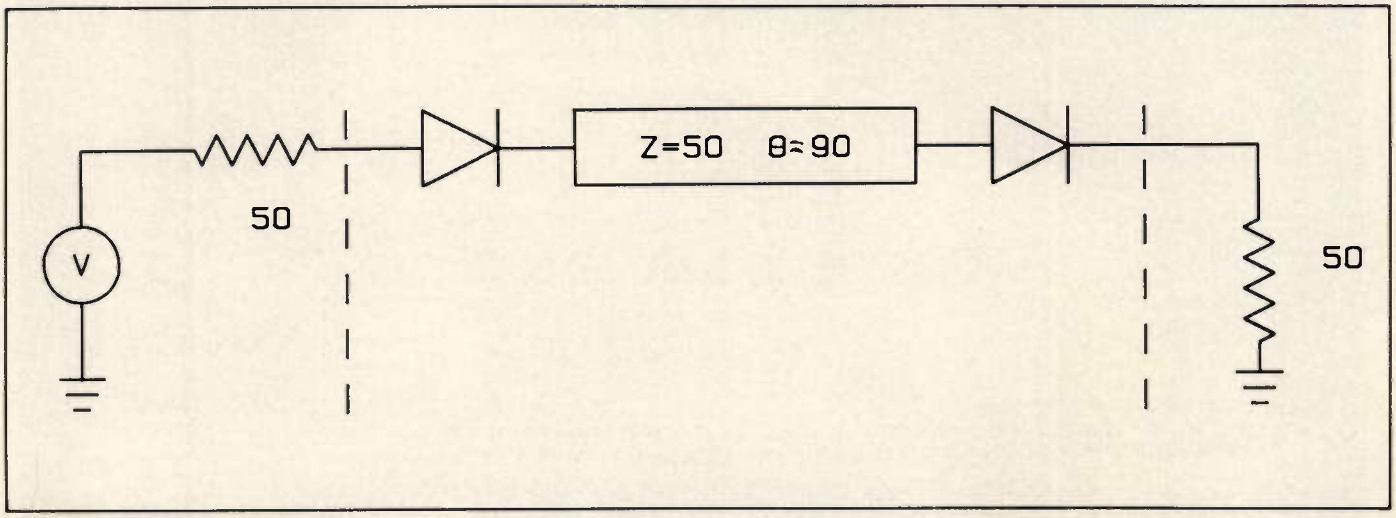


Figure 3. 2-PIN diode switch.

be 6.02 dB.

The above analyses neglect diode lead inductances. In most cases these reactances can be neglected. However, in very critical high frequency applications, they can be taken into account using one of the many available network solving programs.

When the number of diode sections increases, so does the total maximum isolation in the OFF condition. The usual precautions have to be taken to prevent direct signal leakage across the switch.

Part III of these PIN diode notes will deal with T/R switches. Look for it in an upcoming issue. rf

About the Author

Adrzej B. Przedpelski is vice president, development of A.R.F. Products, Inc., 2559 75th St., Boulder, Colo. 80301. He serves as consulting editor to *RF Design*.

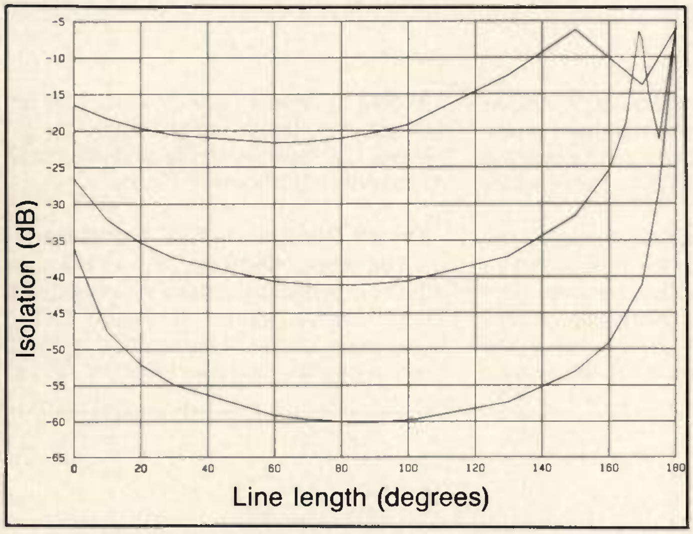


Figure 4. Two diode isolation vs. line length.

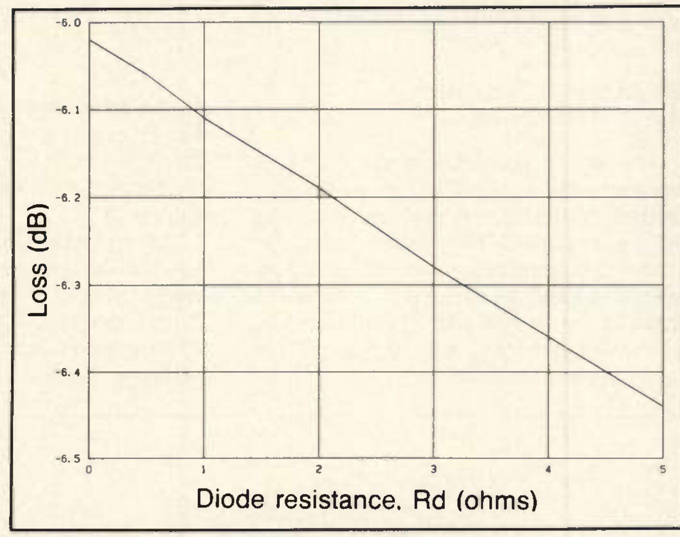


Figure 5. Loss vs. diode resistance.

Where Are the RF and Microwave Component Distributors?

Ready Access to Components Saves Time and Money

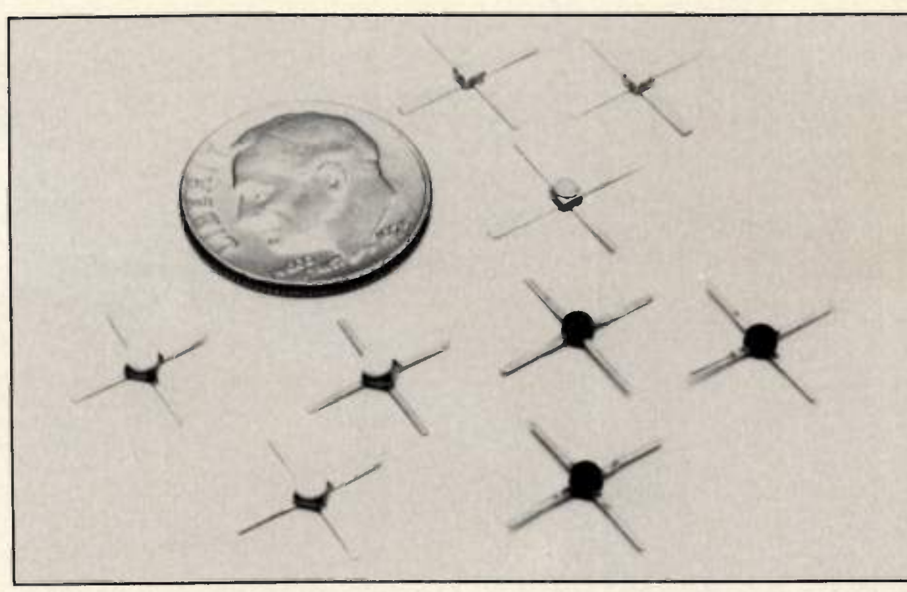
By John F. Locke
and Northe K. Osbrink
Avantek, Inc.

For most areas of the electronics industry it is standard procedure to purchases "commodity" electronic components through a stocking distributor rather than directly from the manufacturer. The distributor is usually the supplier of choice for the engineering laboratory and pilot production line, where the need for components is variable and immediate. All of the advantages of dealing with a distributor apply to the RF/microwave field as well as to the general electronics world.

The distributor maintains a stock of components, with most items available for immediate delivery. Generally, the components carried by a distributor are available for delivery from stock in a week to 30 days; the same components from the manufacturer will often take 90 days or more for delivery in similar quantities. The delivery of "specials" can take even longer, of course.

The distributor is organized for and interested in serving the small-to-medium quantity purchaser — with minimum order levels as low as $25.00 — as well as the OEM, and able to process orders profitably for a few components. By contrast, many manufacturers have substantial minimum requirements for direct-from-factory orders due to their order-processing costs.

A distributor generally offers several complementary lines of components, which can greatly reduce the amount of "shopping" needed to complete a project. Many distributors also offer value-added assembly, technical and testing services. The distributor maintains a stock of data sheets and literature, and can provide helpful consultation to the engineer selecting a particular component. During the project design phase, a distributor can act as a "friend in the industry" who can arrange contact with the manufacturer's engineering staff if required. The distributor already has the firm relationship of a major customer with the manufacturer.



Avantek's distributors carry their complete product line, including the popular MMIC amplifiers.

During the production cycle, the distributor can be a valuable asset again. Emergency requirements for additional components can generally be met immediately. Most distributors are happy to arrange contracted "just-in-time" delivery or to maintain a buffer stock to assure that production requirements are met. they can, in effect, serve as a warehouse for

Table 1: Microwave Components in Distribution

Component	Manufacturer	Frequency
MIXERS	MCL	(3 GHz)
	WJ	(18 GHz)
	AVANTEK	(18 GHz)
AMPLIFIERS	COMLINEAR	(0.1 GHz)
	TRW	(0.9 GHz)
	WJ	(2.5 GHz)
	MCL	(2.3 GHz)
	AVANTEK	(18 GHz)
TRANSISTORS	TRW	(4 GHz)
	MOTOROLA	(0.9 GHz)
	PLESSEY	(1.5 GHz)
	HP	(4 GHz)
	AVANTEK	(18 GHz)
	M/A	(4 GHz)
SWITCHES/ LIMITERS	AVANTEK	(18 GHz)
OSCILLATORS	AVANTEK	(18 GHz)

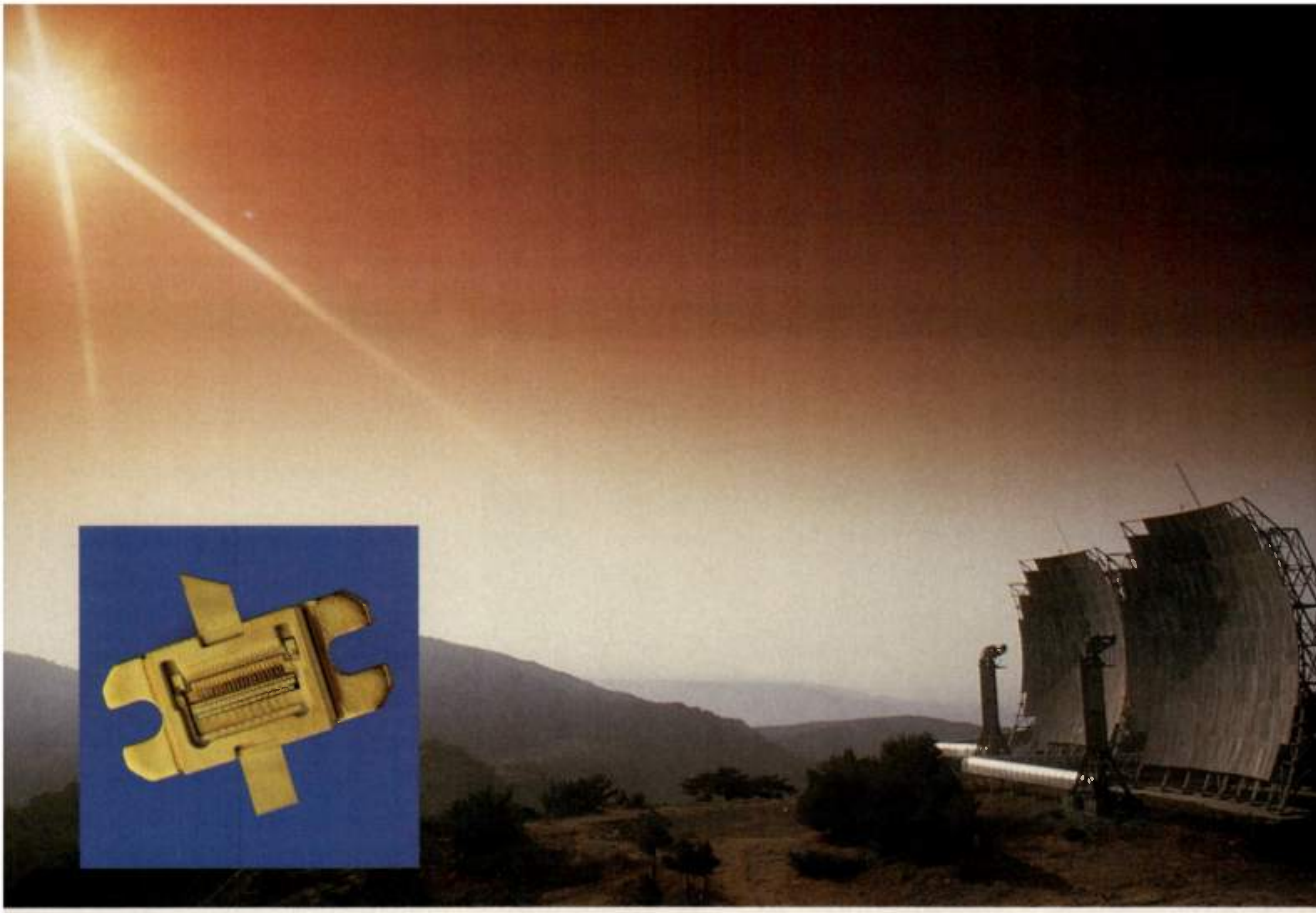
FREQUENCY: 1 MHZ, 10, 100, 1 GHz, 10, 18

production components with no overhead cost to the manufacturer, which can significantly reduce the amount of cash tied up in production inventory. Most distributors will special-order components or stock special components if prior arrangements are made. In fact, the distributor's stock is built around what it sees as its customers' needs.

Finally, once a customer's credit is established, a distributor is often willing to arrange flexible financial terms and other special arrangements such as "future-ship" and "pack-and-hold."

Remarkably, such services of the distributor generally come at no additional cost to the customer. For most products, the pricing is structured so that the cost of a component purchased through a distributor is identical to that of the same component in the same quantity purchased directly. In fact, sometimes additional order processing charges imposed by a manufacturer make the part less expensive from the distributor.

In order to take advantage of these conveniences, of course, it is necessary first to *find* a distributor of RF and microwave components. For the designer requiring



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AM 2729-110	2.7-2.9	125	7.0	40	40	65
AM 2931-110	2.9-3.1	120	7.2	38	42	65

Pulse = 50 μ/4% T_F = 30°C

L-Band/175W

Type No.	Freq. (GHz)	P_O (W)	P_G (dB)	E_{FF} (%)	V_{CC} (V)	ΔT_{JF} (°C)
AM 0814-175	0.85-1.4	175	7.7	52	35	75
AM 1214-175	1.2-1.4	180	8.0	55	40	75

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silicon transistors operating up to one or two GHz, most of the components may be available from the well-known stocking distributors. Unfortunately for the microwave designer using GaAs FETs, or needing such components as microwave mixers, varactor-tuned oscillators or hybrid or monolithic gain modules, the distribution is not nearly so universal or as well-developed.

Why is this? Traditionally, the RF component market is not a "commodity" market. Each project has tended to require special component specifications or custom configurations. Too, many RF component manufacturers are relatively small companies with limited production runs, making it difficult for a distributor to maintain suitable stocking levels. Finally, RF components may not represent a significant enough percentage of its overall sales to justify a full line distributors carrying them; and the distributor's sales personnel — experts in ICs, perhaps — are simply not familiar enough with RF components to support their sales effectively.

However, there are some RF and microwave components available through distributors, albeit specialized distributors and not necessarily the full-line suppliers., that one is likely to call for carbon resistors and potentiometers.

Table 1 shows a brief summary of some of the types of products, by frequency range and manufacturer, that are carried by distributors. Among the products listed, Motorola RF semiconductors are carried by a large number of "full line" electronics distributors, as are ancillary components such as chip capacitors, chip resistors, RF connectos and RF-filtered feedthroughs. The other components from other manufacturers are available only through specialized RF and microwave products distributors.

As an example, Avantek stocking distributors carry all standard products operating through 18 GHz. This includes 200 types of semiconductors; 200 oscillators, including varactor- and YIG-tuned units; 1000 amplifiers, 400 mixers and 200 control devices, including PIN-diode switches and limiters; as well as cases, boards and hardware. Any distributor has access to the inventory of the full network of distributors. Most also carry complementary related lines. For example, one Avantek distributor also carries Comlinear operational, video and linear amplifiers; Mini-Circuits amplifiers, attenuators, frequency doublers, limiters, mixers, phase detectors, power splitters, switches and transformers; Inmet Corp. attenuators, terminations, equalizers and DC blocks; Palco adapters, connectors and cable assemblies; Teledyne Microwave isolators and switches; Wavetek programmable attenuators, turret isolators and fixed attenuators; and Huber & Suhner adaptors, cable assemblies and connectors. As more distributors and component manufacturers recognize their value to one another, the RF engineer will find greater convenience in obtaining the parts he needs. rf

About the Authors

John F. Locke manages worldwide distribution for the Microwave Components Group of Avantek, Inc. Northe K. Osbrink is Editorial Manager. They can be reached at Avantek, Inc., 3175 Bowers Avenue, Santa Clara, Calif. 95054-3292, or by telephone at (408) 727-0700.

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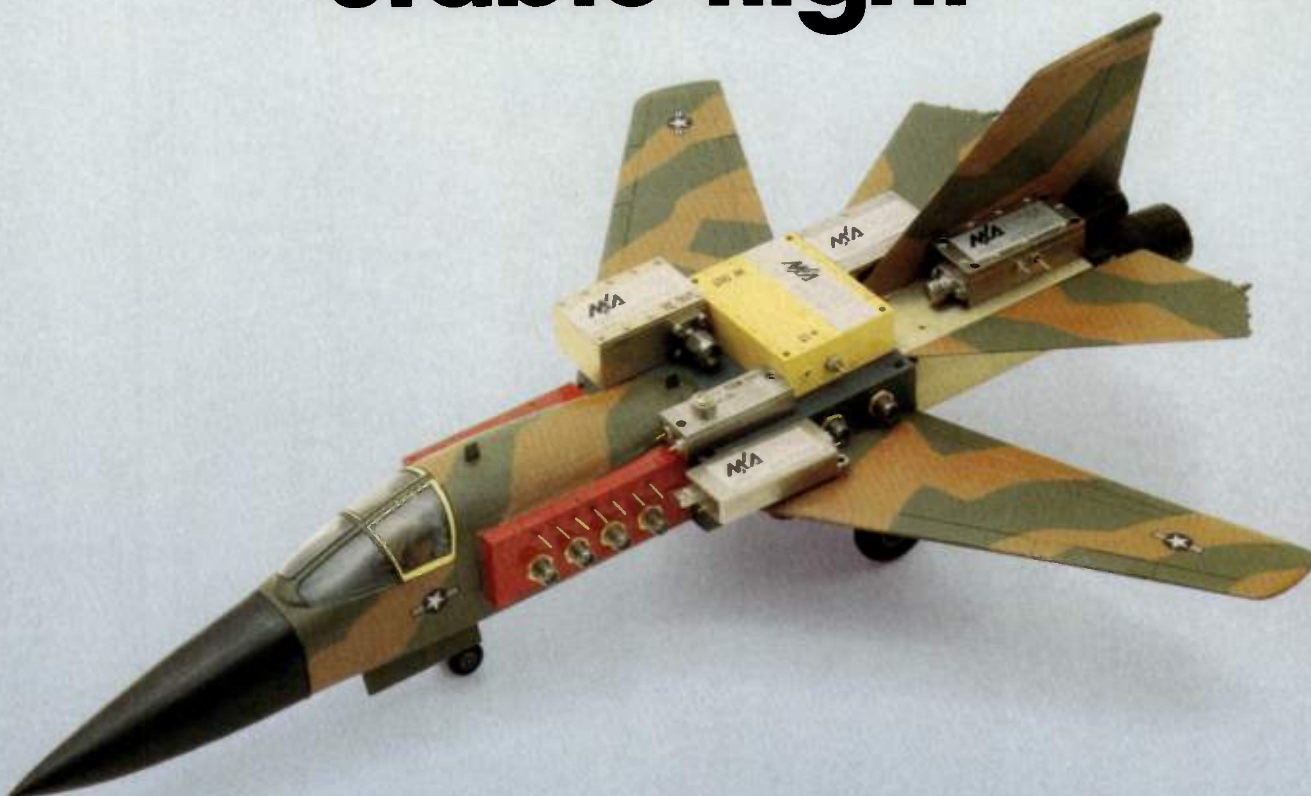

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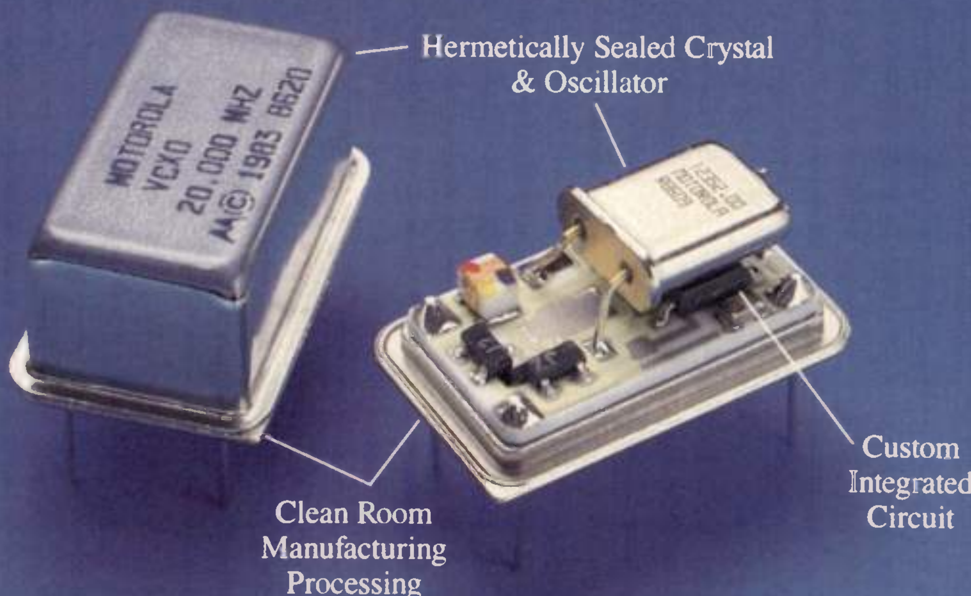

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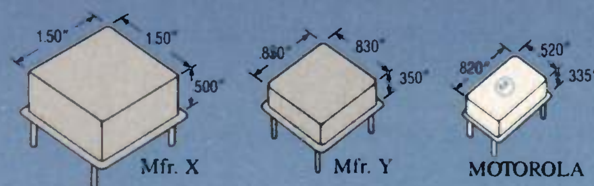

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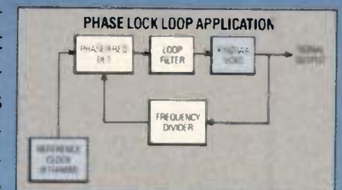

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Computer Enhanced S-Parameter Design

A Program for Rapid Exploration of Design Options

By Stanley Novak
Instituto Militar de Engenharia

In engineering practice we often need to design a high frequency amplifier using one particular device which best fits our requirements, for gain, frequency response, noise, etc. As S-parameters are increasingly used by manufacturers for characterization of high frequency transistors, a design procedure using those parameters, together with the Smith Chart to check stability conditions, is a natural choice.

Calculations using complex numbers are fairly tedious, repetitive, and subject to personal errors. The infinite multitude of choices makes it necessary to verify the design more than once to find best operating conditions for the amplifier. That purpose seems best suited for a computer synthesis program with various options for the designer to quickly check out alternate possibilities for realization of the circuit. To evaluate the alternatives, the author has developed the program presented below.

Amplifier Design

After selecting a suitable device the designer must match it at selected frequency to the chosen source and load. Source or load could be transmission line, another stage or some general complex quantity. To do this he needs to know the input and output reflection coefficients, which may be plotted on the Smith Chart. In case the device is potentially unstable (K<1), he also needs to plot stability circles to verify if the reflection coefficients will allow stable operation. At the same time he needs to know input and output impedances associated with the reflection coefficients, for matching-circuit design.

The process of amplifier design can be divided into the following steps: at first we need to find if the selected device is stable or potentially unstable at the required frequency. For this, S-parameter design uses

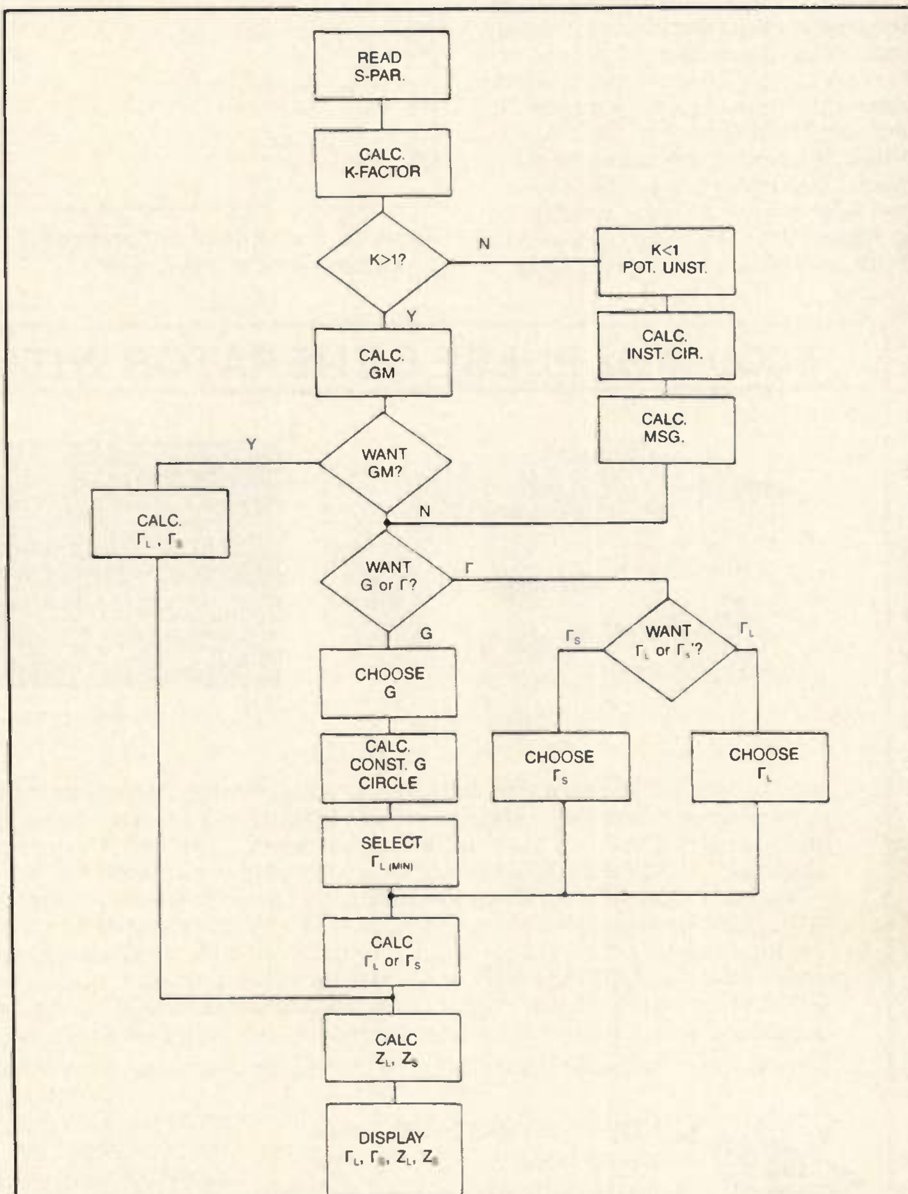

Figure 1. Program flow chart.

stability factor K (which for potentially unstable transistors is less than one), and is defined as:

$$K=\frac{1+|S_{11}S_{22}-S_{12}S_{21}|-|S_{11}|^2-|S_{22}|^2}{2|S_{12}S_{21}|} \quad (1)$$

Only after evaluation of the stability factor K can we proceed with amplifier design, because the approach will be different for amplifiers with K<1 than with K>1.

Transistors with K>1

Let us take the simplest case with K>1 where the amplifier will be unconditionally stable. In such a case we don't need to know parameters of the stability circles. The program skips the printout for stability circle values since we don't need to use the Smith Chart. If it is desired to include stability circle parameters, delete line 695 and values will appear on the screen.

Next, the program calculates the maximum available gain for the chosen device, GM. Again there is a choice: we may aim for highest GM or for some lower gain G. If we want GM, the program is fairly straightforward, calculating input and output reflection coefficients together with corresponding values of input and output impedance needed for matching. In this case we also obtain a perfect match on both ends which may be verified by using a circuit analysis program around the design frequency. The actual design of the matching network is not included in the program as many such programs are available. Also, the requirements for narrow or broad band matching circuits are out of spectrum on this paper.

The situation changes significantly if we requires lower gain than maximum (G<GM). Because the algorithm, so far, starts from output plane we need to find the location of so-called constant gain circles on the output plane for the chosen value of gain G. The treatment of this subject can be found in the references. Such a circle is calculated by the program for any chosen gain and displayed on the monitor. The values may be used later for plotting the circle on a Smith Chart, but for convenience the program has the option of automatic choice of minimum reflection coefficient on the output plane. This also provides for minimum standing wave ratio

```
PROGRAM CALCULATES STABILITY CIRCLES
FOR INPUT AND OUTPUT OF TRANSISTOR
AND CONSTANT GAIN CIRCLES

S-PARAMETERS OF THE DEVICE
GIVEN IN MAGNITUDE AND ANGLE

TRANSISTOR    MRF 571
FREQUENCY     1000 MHZ

INPUT PARAM.(11)=.61          178
REVERSE PARAM.(12)=.09        37
FORWARD PARAM.(21)=3          78
OUTPUT PARAM.(22)=.28        -69

CHAR. IMP. OF THE LINE(OHM)?      50
STAB. FACTOR K=1.036

AMPLIFIER UNCONDITIONALLY STABLE
MAX. GAIN IN DB'S=14.054
MAX. NUMERIC GAIN=25.438
WANT MAX. GAIN(Y/N)? Y   ——► TO TABLE 1b
                         (ALTERNATIVE CHOICE)
IMPEDANCE TO MATCH SOURCE
RS + XS=2.887    .56

IMPEDANCE TO MATCH LOAD
RL + XL=17.571     -73.95

RMS - SOURCE REFL. COEFF.
MAG=.89  ANGLE=-178.711

RML - LOAD  REFL. COEFF.
MAG=.806    ANGLE=66.097
```

Table 1a. Example of unconditionally stable device (max. gain).

at the output of the device for easier output matching. In this case we could still avoid use of the Smith Chart.

At this point it is also important to mention a fact often overlooked in the literature: By choosing gain of the device less than maximum, we *deliberately* mismatched the device. Therefore, the matching network can never provide a perfect match at the output, even if input is again perfectly matched by using values given by the program.

From now on we will need the Smith Chart to check on calculated values. We may elect to use a value other than minimum reflection coefficient provided by the computer. For this we plot a constant gain circle on the Smith Chart and choose any value of reflection coefficient which terminates on the constant gain circle. After determining its magnitude and angle from the Smith Chart we use the program option for selecting reflection coefficient instead of gain, *load* reflection coefficient in our case. Then we enter selected values and the program calculates the corresponding input reflection coefficient and impedances needed for match and the design is finished.

Transistors with K<1

Another case is design using a potentially unstable transistor (K<1). Here we

```
WANT MAX. GAIN(Y/N)? N

SELECT GAIN OR REFL.COEFF.(G/R)?G --> (ALTERNATIVE CHOICE)

GAIN IN DB'S? 12
NUMERIC GAIN=15.848

CONSTANT GAIN CIRCLE
CENTER=0.534  ANGLE=66.097
RADIUS=0.437

MIN. REFL.COEF.=.097  ANGLE=66.097

SELECT GAIN OR REFL.COEFF.(G/R)? R
SOURCE OR LOAD(S/L)? L        -->     TO TABLE 1c(ALTERNATIVE
LOAD REFL. COEFF.AMPL. AND ANGLE?     CHOICE)
.097,66.097

IMPEDANCE TO MATCH LOAD   <--
RL + XL =53.213   -9.538

IMPEDANCE TO MATCH SOURCE
RS + XS=11.993   .776

RMS - SOURCE REFL. COEFF.
MAG=.636   ANGLE=-178.128

RML - LOAD  REFL.COEFF.
MAG=.097  ANGLE=66.097
```

Table 1b. Example of unconditionally stable device with selected gain or reflection coefficient.

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also need the Smith Chart to check on computed values. As before we have a selection of alternatives. After calculation of stability factor K<1, the computer prints the parameters of input and output stability circles which may be plotted on a Smith Chart for further analysis. Then the value of maximum stable gain:

$$MSG = \frac{|S_{21}|}{|S_{12}|} \quad (2)$$

is displayed to guide the choice of gain G, which should be smaller than MSG.

In the simplest case we choose gain value rather than selection of reflection coefficient. From the chosen value of gain the computer calculates parameters of the constant gain circle which can be plotted again on the Smith Chart together with stability circles. The computer automatically chooses the minimum value of output reflection coefficient and calculates the corresponding value of input reflection coefficient and appropriate values of input and output impedance for design of matching networks.

In some instances we may find that the calculated input reflection coefficient will be inside or uncomfortably close to the input unstability region. In such a case we

```
SOURCE OR LOAD(S/L) ?S

SOURCE REFL. COEFF. AMPL.
AND ANGLE? .636,-178.128

IMPEDANCE TO MATCH SOURCE
RS+XS=11.127    .776

IMPEDANCE TO MATCH LOAD
RL+XL=39.924    -54.531

CMS-SOURCE REFL. COEFF.
MAG=.635    ANGLE=-178.129

RML-LOAD REFL. COEFF.
MAG=.559  ANGLE=66.101
```

Table 1c. Example of unconditionally stable device with selection of source reflection coefficient.

could either use another value of gain or choose a new value of reflection coefficient on the constant gain circle. In the first case the approach will be the same as before. In the second case we choose the value of output reflection coefficient, rerun the program and when we reach the point where choice between gain and reflection coefficient is offered, we choose reflection coefficient, and load reflection coefficient in particular. Then we enter magnitude and angle of the selected output reflection coefficient, and the program again calculates the value of input reflection coefficient and appropriate values of impedances for matching. The process obviously may be repeated for other values of gain after obtaining parameters of the constant gain circles. To be sure that none of the parameters falls into an unstable region, it is recommended to follow the design on the Smith Chart.

```
TRANSISTOR MRF 571
FREQUENCY 500 MHZ

INPUT PARAM.(11)=.62    -143
REVERSE PARAM.(12).08     33
FORWARD PARAM.(21)=5.5    97
OUTPUT PARAM.(22)=.41     59

CHARP. IMP. OF THE LINE(OHM) ?  50
STAB. FACTOR K=.577

STABILITY CIRCLES *****
CTR.INPUT=2.101    ANG.IN=150.15
RAD.IN=1.359

CTR.OUTPUT=4.745     ANG.OUT=73.554
RAD.OUT=4.097

AMPLIFIER POTENTIALLY UNSTABLE
MAX. STABLE GAIN=18.372

SELECT GAIN OR REFL.COEFF.(G/R)? G

GAIN IN DB'S? 15
NUMERIC GAIN=31.662

CONSTANT GAIN CIRCLE
CENTER=.478    ANGLE=73.554
RADIUS=.741

MIN.REFL.COEF.=.262      ANGLE=-106.446

IMPEDANCE TO MATCH LOAD
RL+XL=38.232      20.682

IMPEDANCE TO MATCH SOURCE
RS+XS=17.663    -16.148

RMS-SOURCE REFL.COEFF.
MAG.=.519    ANGLE=140.042

RML-LOAD REFL. COEFF.
MAG.=.262  ANGLE=-106.446

TABLE 1d.
EXAMPLE OF POTENTIALLY UNSTABLE DEVICE
```

Table 1d. Example of potentially unstable device.

Finally, in some cases we prefer to use a certain value of input reflection coefficient and find the corresponding value of output reflection coefficient. This is particularly advantageous in case of minimum noise design, when the manufacturer gives the value of input reflection coefficient for minimum noise. The program gives the option of choosing the input reflection coefficient and from its value calculates the output reflection coefficient. Again, it is strongly recommended to use the Smith Chart to remain in the stable region.

As in the case for K>1, it is important to consider that whenever we choose the gain or output reflection coefficient representation for K<1 we could never achieve perfect match at the output, because the stable operation requires certain mismatch at the output. Similarly, if we choose certain input reflection coefficient we are deliberately introducing mismatch at the input, which results in certain standing wave ratio at the input. It is standard practice to do that in design of high frequency amplifiers, as this is one way to achieve stable operation of the amplifier without introducing feedback.

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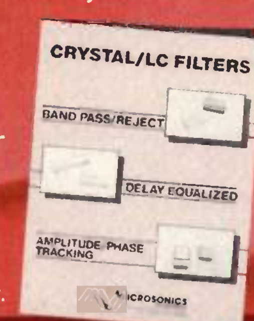

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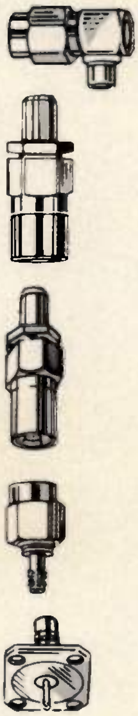

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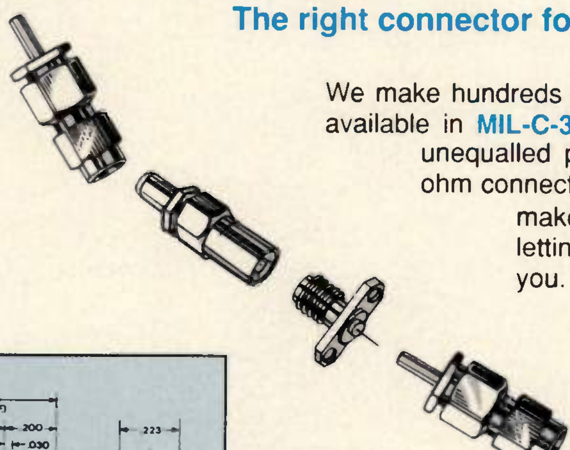

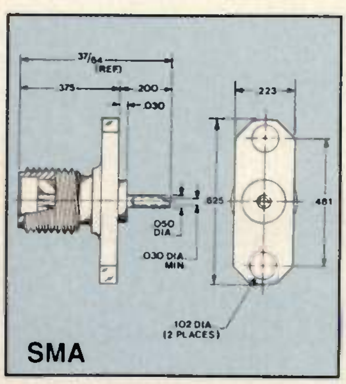

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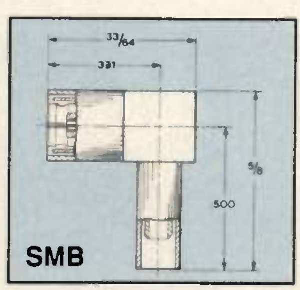

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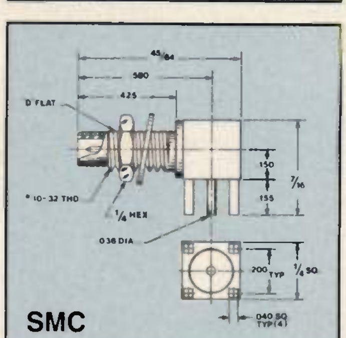

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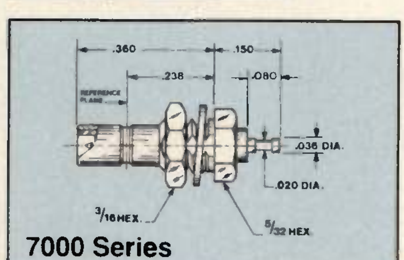

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INFO/CARD 51

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```
5 PRINT"{CLR}"
10 REM AMP.DESIGN, S.NOVAK FEB.1986
15 POKE53281,1:POKE53280,1:PRINTCHR$(144)
20 DIM V(9),R(9),I(9),M(9),A(9),A$(9)
25 PRINT"PROGRAM CALCULATES STABILITY CIRCLES"
30 PRINT"FOR INPUT AND OUTPUT OF TRANSISTOR"
35 PRINT"AND CONSTANT GAIN CIRCLES"
40 PRINT":PRINT"S-PARAMETERS OF THE DEVICE"
45 PRINT"GIVEN IN MAGNITUDE AND ANGLE"
50 A$(1)="INPUT PARAM.(11)="
55 A$(2)="REVERSE PARAM.(12)="
60 A$(3)="FORWARD PARAM.(21)="
65 A$(4)="OUTPUT PARAM.(22)="
80 A$(8)="RMS-SOURCE REFL.COEFF."
85 A$(9)="RML-LOAD REFL.COEFF."
90 E=1E3
95 PI=3.14159265
100 READ T$
110 PRINT:PRINT"TRANSISTOR",T$
120 READF
130 PRINT"FREQUENCY",F/1E6"MHZ":PRINT
140 FORJ=1TO4
150 PRINTA$(J)
160 READ M(J),A(J)
170 GOSUB1800
180 PRINTM(J),A(J)
190 NEXTJ
200 PRINT
210 INPUT"CHAR.IMP.OF THE LINE[OHM]";ZO
220 REM CALC.S12*S21 AND DS***********
230 R1=R(2)
240 I1=I(2)
250 R2=R(3)
260 I2=I(3)
270 GOSUB1700
280 P=R
290 Q=I
300 R1=R(1)
310 I1=I(1)
320 R2=R(4)
330 I2=I(4)
340 GOSUB1700
350 R(5)=R-P
360 I(5)=I-Q
370 REM CALC.C1,C2 VALUES ************
380 R1=R(5)
390 I1=I(5)
400 R2=R(4)
410 I2=-I(1)
420 GOSUB1700
430 R(6)=R(1)-R
440 I(6)=I(1)-I
450 R2=R(1)
460 I2=-I(1)
470 GOSUB1700
480 R(7)=R(4)-R
490 I(7)=I(4)-I
500 REM POLAR CONV.DS,C1,C2 **********
510 FOR J=5TO7
520 GOSUB1900
530 NEXTJ
540 REM CALC SQUARED VALUES **********
550 FORJ=1TO7
560 V(J)=M(J)*M(J)
570 NEXTJ
580 REM S12S21
590 V(2)=SQR(P*P+Q*Q)
600 REM D-B PARAM ********************
610 D1=V(1)-V(5)
620 D2=V(4)-V(5)
630 B1=1-V(4)+D1
640 B2=1-V(1)+D2
670 REM CALC STAB.FACTOR *************
680 K=(1+V(5)-V(1)-V(4))/(2*V(2))
690 PRINT"STAB.FACTOR K="INT(K*E)/E
695 IF K>1 THEN 820
700 PRINT:PRINT"STABILITY CIRCLES *****"
710 CI=M(6)/ABS(D1)
720 CO=M(7)/ABS(D2)
730 AI=-A(6)
740 AO=-A(7)
750 IF D1<0 THEN AI=AI-180
760 IF D2<0 THEN AO=AO-180
770 RI=V(2)/ABS(D1)
780 RO=V(2)/ABS(D2)
790 PRINT"CTR.INPUT"INT(CI*E)/E,"ANG.IN="INT(AI*E)/
```


INFO/CARD 52

```
E,"RAD.IN="INT(RI*E)/E
795 PRINT
800 PRINT"CTR.OUTPUT="INT(CO*E)/E,"ANG.OUT="INT(AO*
E)/E,"RAD.OUT="INT(RO*E)/E
810 IF K 1 THEN 1050
820 REM CALC.GM *********************
825 PRINT:PRINT"AMPLIFIER UNCONDITIONALLY STABLE"
830 U=1
840 IF B1>0 THEN U=-1
850 GM=(M(3)/M(2))*(K+U*SQR(K*K-1))
860 PRINT"MAX.GAIN IN DB'S=",INT(10*LOG(GM)/LOG(10)
*E)/E
870 PRINT"MAX.NUMERIC GAIN=",INT(GM*E)/E
880 INPUT"WANT MAX.GAIN (Y/N)";B$
890 IF B$<>"N" THEN 910
900 GOTO 1070
910 REM CALC. ZS & ZL ***************
920 M(8)=M(6)*(B1+U*SQR(B1*B1-(4*V(6))))/(2*V(6))
930 A(8)=-A(6)
940 J=8
950 GOSUB1800
960 GOSUB1520
970 U=1
980 IF B2>0 THEN U=-1
990 M(9)=M(7)*(B2+U*SQR(B2*B2-(4*V(7))))/(2*V(7))
1000 A(9)=-A(7)
1010 J=9
1020 GOSUB1800
1030 GOSUB1450
1040 GOTO 1425
1050 PRINT:PRINT"AMPLIFIER POTENTIALLY UNSTABLE"
1060 PRINT"MAX.STABLE GAIN=",INT(10*LOG(M(3)/M(2))
/LOG(10)*E)/E"DB"
1070 PRINT:INPUT"SELECT GAIN OR REFL.COEFF.(G/R)";
C$
1075 IF C$<>"G" THEN 1850
1080 PRINT:INPUT"GAIN IN DB'S";GP
1085 GP=10↑(GP/10)
1090 PRINT"NUMERIC GAIN =",INT(GP*E)/E
1100 G=GP/V(3)
1110 M(9)=G*M(7)/(1+D2*G)
1120 A(9)=-A(7)
1130 RC=SQR(1-2*K*V(2)*G+V(2)*V(2)*G*G)/(1+D2*G)
1140 PRINT:PRINT"CONSTANT GAIN CIRCLE"
1145 PRINT"CENTER="INT(M(9)*E)/E,"ANGLE="INT(A(9)*
E)/E,"RADIUS="INT(RC*E)/E
1150 REM CHOOSE MIN.LOAD REFL.COEFF.**
1155 M(9)=M(9)-RC
1160 IF M(9)<0 THEN A(9)=A(9)-180
1165 IF M(9)<0 THEN M(9)=ABS(M(9))
1170 PRINT:PRINT"MIN.REFL.COEF.="INT (M(9)*E)/E;"A
NGLE="INT (A(9)*E)/E
1175 REM CALC ZL *********************
1180 J=9:B=1:C=4
1190 GOSUB1800
1200 GOSUB1450
1220 REM CALC ZS OR ZL ***************
1230 R1=R(J)
1240 I1=I(J)
1250 R2=R(5)
1260 I2=I(5)
1270 GOSUB1700
1280 R3=R(B)-R
1290 I3=I(B)-I
1300 R2=R(C)
1310 I2=I(C)
1320 GOSUB1700
1330 R2=1-R
1340 I2=I
1350 R1=R3
1360 I1=-I3
1370 GOSUB1750
1375 IFJ=8THEN1435
1380 J=8
1390 R(J)=R
1400 I(J)=I
1410 GOSUB1900
1415 IFJ=9THEN1440
1420 GOSUB1520
1425 GOSUB1960
1430 END
1435 J=9:GOTO1390
1440 GOSUB1450
1445 GOTO1425
1450 REM CALC RL *********************
1460 PRINT:PRINT"IMPEDANCE TO MATCH LOAD"
```

```
1470 GOSUB1600
1480 RL=R*Z0
1490 XL=I*Z0
1500 PRINT"RL+XL="INT(RL*E)/E,INT(XL*E)/E
1510 RETURN
1520 REM CALC RS *********************
1530 PRINT:PRINT"IMPEDANCE TO MATCH SOURCE"
1540 GOSUB1600
1550 RS=R*Z0
1560 XS=I*Z0
1570 PRINT"RS+XS="INT(RS*E)/E,INT(XS*E)/E
1580 RETURN
1600 REM (1+COMPL.NO)/(1-COMPL.NO) ***
1610 R1=1+R(J)
1620 I1=-I(J)
1630 R2=1-R(J)
1640 I2=I(J)
1650 GOSUB1750
1660 RETURN
1700 REM COMPL. NO.MULTIPLY **********
1710 R=R1*R2-I1*I2
1720 I=I1*R2+R1*I2
1730 RETURN
1750 REM COMPL.NO.DIVIDE *************
1760 D=R2*R2+I2*I2
1770 R=(R1*R2+I1*I2)/D
1780 I=(I1*R2-R1*I2)/D
1790 RETURN
1800 REM POLAR TO RECT. **************
1810 A=A(J)*PI/180
1820 R(J)=M(J)*COS(A)
1830 I(J)=M(J)*SIN(A)
1840 RETURN
1850 REM REFL.COEFF.CHOICE ***********
1855 PRINT:INPUT"SOURCE OR LOAD (S/L)";D$
1860 IFD$<>"L"THEN1875
1865 PRINT:INPUT"LOAD REFL.COEFF.AMPL AND ANGLE";M
(9),A(9)
1870 GOTO1180
1875 PRINT:INPUT"SOURCE REFL.COEFF AMPL AND ANGLE"
;M(8),A(8)
1880 J=8:B=4:C=1
1885 GOSUB1800
1890 GOSUB1520
1895 GOTO1220
1900 REM RECT.TO POLAR ***************
1910 M(J)=SQR(R(J)*R(J)+I(J)*I(J))
1920 A(J)=90*(SGN(I(J))+(I(J)=0))
1930 IF R(J)=0 THEN 1950
1940 A(J)=ATN(I(J)/R(J))*180/PI+A(J)*(1-SGN(R(J)))
1950 RETURN
1960 REM PRINT REFL.COEFF. ***********
1965 PRINT
1970 FORJ=8TO9
1975 PRINTA$(J)
1980 PRINT"MAG="INT(M(J)*E)/E,"ANGLE="INT(A(J)*E)/E
1985 PRINT
1990 NEXTJ
1995 RETURN
3000 REM TRANSISTOR DATA STORAGE *****
3001 REM DATA MRF966,1E8,.89,-28,.006,79,1.56,132,.
94,-17
3002 REM DATA MRF966,5E8,.97,-14,.004,76,1.63,156,.
96,-9
3004 REMDATA 2N3570,5E8,.385,-55,.045,90,2.7,78,.89
,-26.5
3005 DATA 2N3570,750E6,.277,-59,.078,93,1.92,64,.84
8,-31
3010 REMDATA MRF571,2E8,.74,-86,.06,48,10.5,129,.69
,-42
3020 REMDATA MRF571,5E8,.62,-143,.08,33,5.5,97,.41,
-59
3030 DATA MRF571,1E9,.61,178,.09,37,3,78,.28,-69
3040 DATA MRF571,1.5E9,.65,158,.11,44,2,62,.26,-88
3050 DATA BFR91,2E8,.49,-90,.06,55,8.72,120,.66,-30
3060 DATA BFR91,5E8,.35,-150,.09,60,4.34,90,.45,-35
3070 DATA BFR91,8E8,.34,175,.13,65,2.84,75,.4,-40
```

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Program Description

All the previous discussion about various options offered by the program may be best illustrated on the flow chart (Figure 1). The program uses DATA statements to store transistor S-parameters at various frequencies, and allows storage of more transistors' data. All data storage is located at line 3000 upwards. Storage of data is accomplished by first typing device identification, frequency at which parameters are defined, then S parameters in order S11, S12, S21, S22.

The program first displays identification of device, frequency and all parameters. This serves as verification that we entered all data correctly. The program does all the needed complex algebra to calculate stability factor K at line 690. If K>1 it proceeds to offer choice between maximum gain, or selection between lower gain or specification of input or output reflection coefficients.

If we are not satisfied with the offered solution we could draw the constant gain circle on Smith Chart, select any other value of output reflection coefficient on the circle, and rerun the program. Instead of selecting the gain, we choose output reflection coefficient and enter the magnitude and angle as read from the Smith Chart. A similar approach may be used in case of K<1. The difference here is that the program first displays information on instability area circles and maximum stable gain. Circles should be drawn on the Smith Chart to follow the design.

If we prefer to use input reflection coefficient in the design, such as when low noise design is involved, we use the option for selecting input reflection coefficient and obtain other corresponding parameters.

Examples for all options are given in Table 1(a, b, c, d).

Final Notes

S-parameter design is rigorously described in the references, and the reader is referred to those sources to get a better understanding of the subject. The program does not operate for unilateral devices (S12 =0), as such devices rarely exist in the real world, and are usually the result of simplification of the device representation. As is, the program will run directly on Commodore 128 and 64. For other computers slight changes will be needed which should be no problem to implement for operators familiar with BASIC. rf

References

1. William H. Frochner, "Quick Amplifier Design with Scattering Parameters," *Electronics*, Oct. 16, 1967.

2. Ralph S. Carson, *High-Frequency Amplifiers*, (2nd Ed.), John Wiley, 1982, Chapter 7.

3. Tri T. Ha, *Solid State Microwave Amplifier Design*, John Wiley 1981, Chapters 2, 4.

4. *G.D. Vendelin, Design of Amplifiers and Oscillators by S-Parameters Method*, John Wiley 1982.

About the Author

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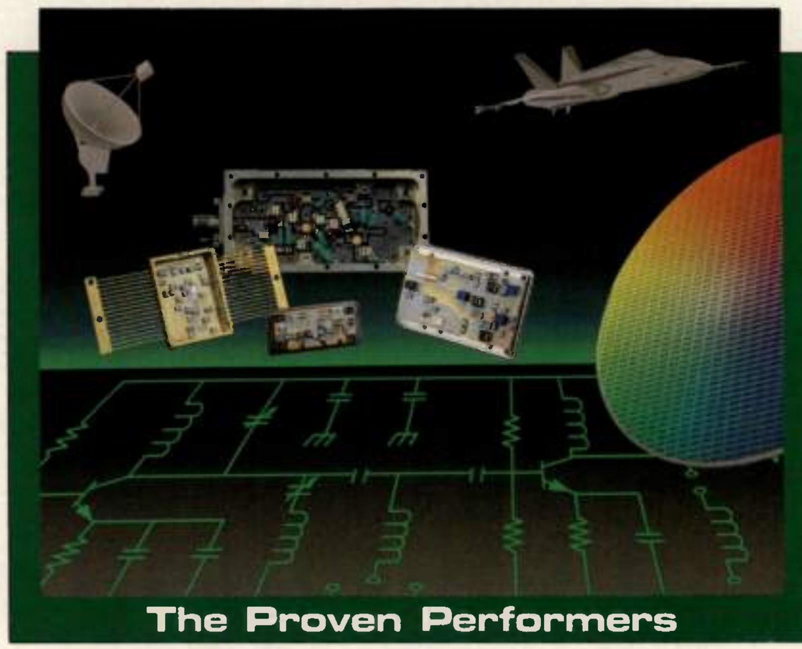

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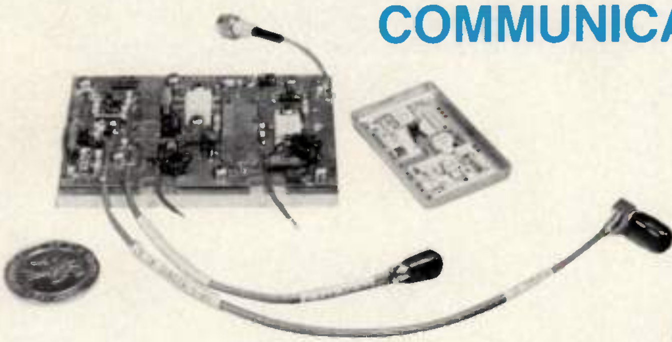

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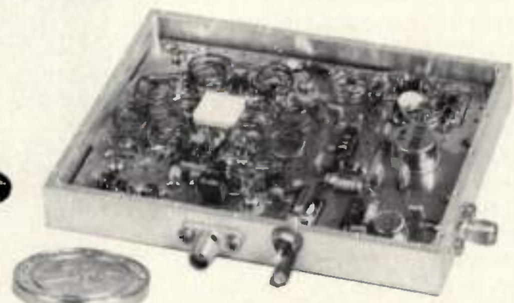

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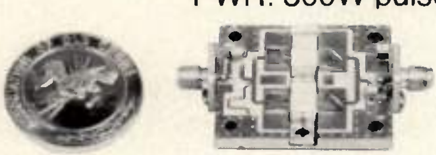

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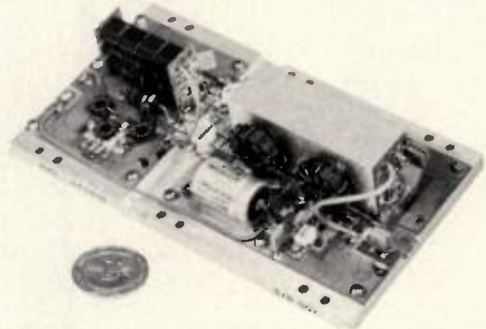

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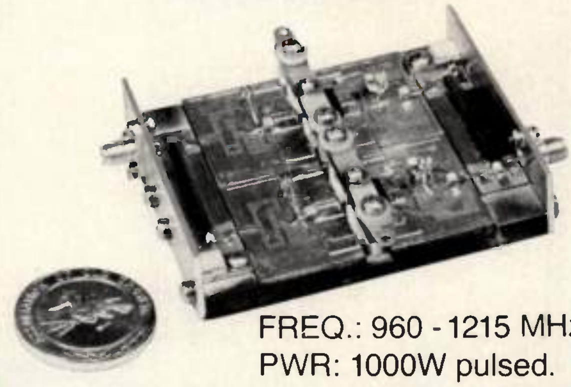

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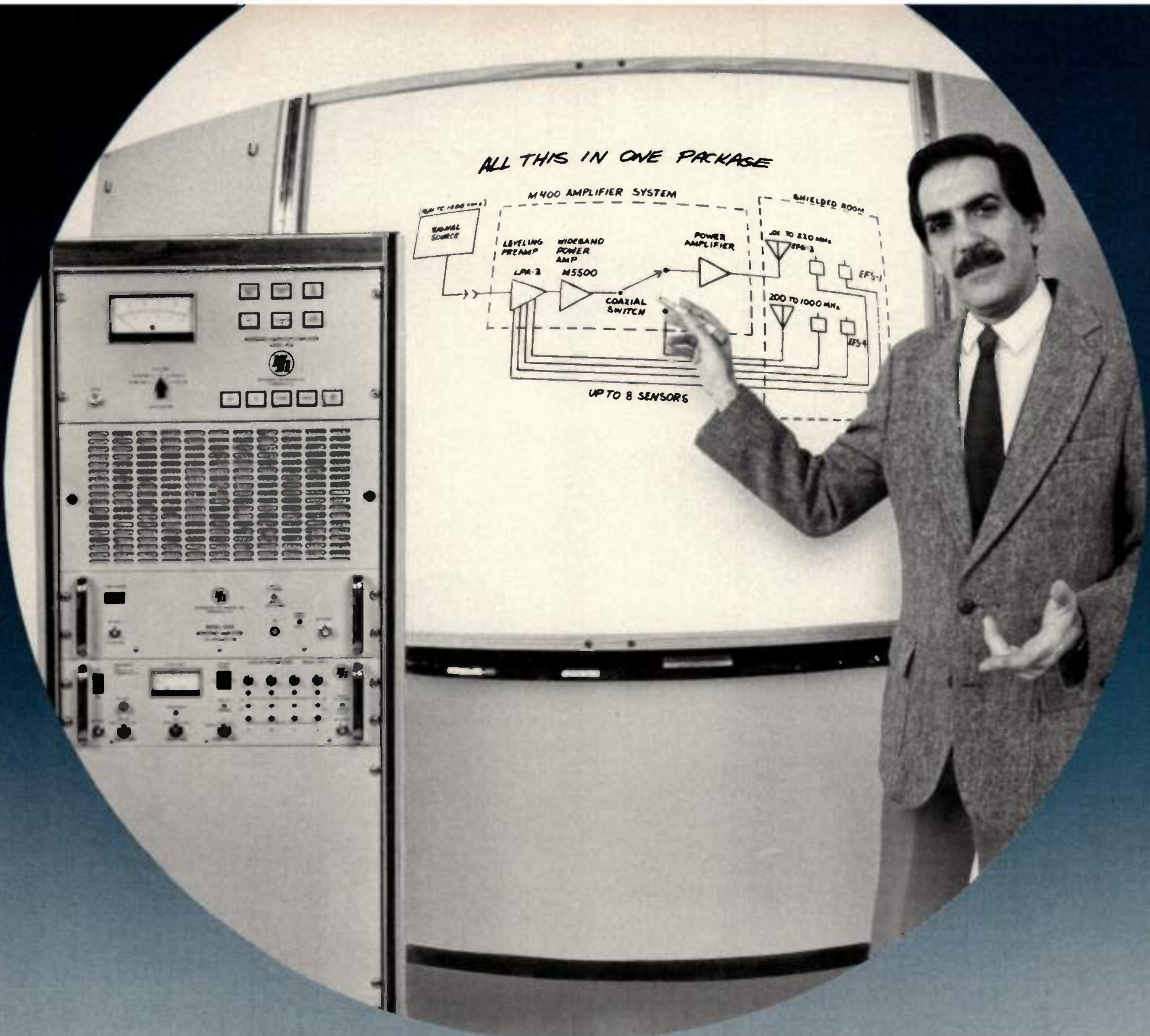

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INFO/CARD 58

A Tuned Circuit with Constant Trim Rate

A Solution to the Problem of Non-Linear Tuning

By William A. Edson
SRI International

Simple LC tuned circuits suffer from the problem of non-linear frequency change with linear capacitance change. The author has developed a circuit which closely approximates a linear capacitance vs. frequency relationship. This article is an abbreviated and updated version of his original paper on the subject, published in the IEEE Transactions on Instrumentation and Measurement, *Vol. 1M-18, No. 1, pp.22-27 (March 1969).*

The tuned circuit shown in Figure 1 has the interesting and valuable property that the trim rate of C_3 is amost independent of the resonant frequency selected by C_2, the main tuning capacitor, if the values of the other three capacitors are properly chosen. A derivation of the conditions tht must be met is contained in the original paper. Although it is not sophisticated, the analysis is complicated and tedious occupying a total of about three pages. The mathematically inclined reader is referred to the original paper.

As shown in Figure 2, the bridge of five capacitors is equivalent to a single capacitor, here designated C_0, with a value given by the equation:

$$C_O = \frac{I_O}{j\omega E_O} = \frac{C_2C_3(C_1+C_4+C_5)+C_2(C_1C_4+C_4C_5)+C_3(C_1C_4+C_1C_5)+C_1C_4C_5}{C_2C_3+C_2(C_1+C_5)+C_3(C_4+C_5)+C_1C_4+C_1C_5+C_4C_5} \quad (1)$$

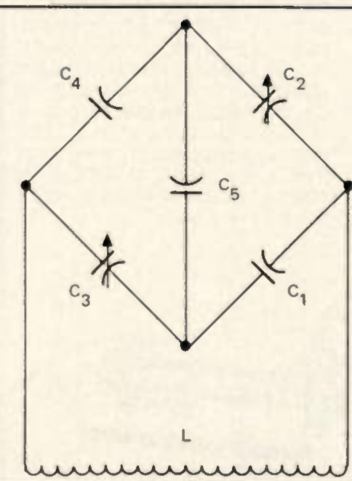

Figure 1. Basic circuit configuration.

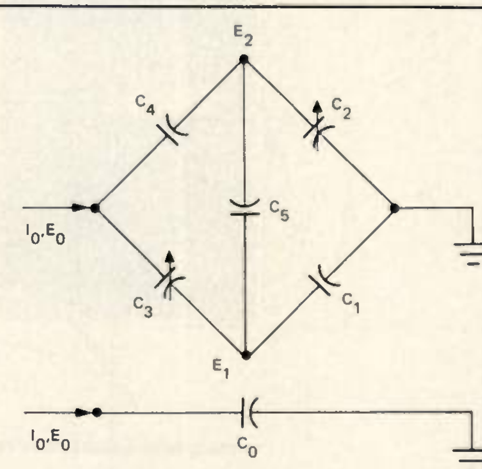

Figure 2. Equivalent circuit.

The resonant frequency of the system is given by the usual relation:

$$\omega = (LC_0)^{-1/2} \quad (2)$$

A practicing circuit engineer rarely has an opportunity (or excuse) for using a second partial differential equation, but this is one of those occasions. The condition for making the trim rate of C_3 independent of the value of C_2 is governed by the elegant expression:

$$\frac{\partial^2\omega}{\partial C_2 \partial C_3} = 0 \quad (3)$$

Stated in another way, this equation assures us that the left hand will not know what the right hand is doing. Most of the analysis in the original paper is devoted to evaluating this condition, which is satisfied by the equation

$$C_5 = \frac{3C_1C_4}{C_0} \quad (4)$$

This result is subject to the criticism that C_0 is, in general, a function of C_5. Although valid, this criticism is not serious because C_0 is always insensitive to C_5 and completely independent of C_5 whenever the other four capacitors form a balanced bridge in accordance with the equation:

$$\frac{C_1}{C_3} = \frac{C_2}{C_4} \quad (5)$$

This condition is met in most if not all of the numerical examples that follow.

Numerical Examples

The interpretation of the foregoing expressions is facilitated by numerical examples, which display both the merits and the limitations of the approach. We begin with a particularly simple case, in which $L = C_1 = C_2 = C_3 = C_4 = 1$, in which case C_0 is also equal to 1, and Eq. (5) is satisfied. For these values, Eq. (4) requires $C_5 = 3$. Starting from this reference, we explore the consequences of making small incremental changes in C_3 and wide variations in C_2.

Substitution of the selected values for L, C_1, C_4, and C_5, in Eqs. (1) and (2) yields:

$$\omega = \left[\frac{C_2C_3+4C_2+4C_3+7}{5C_2C_3+4C_2+4C_3+3}\right]^{1/2} \quad (6)$$

It is fairly easy to program a personal computer of hand-held calculator to determine the frequency that will result from any selected values for C_2 and C_3. To obtain the trim rate, we must limit our attention to C_3 values that are close to one, e.g., 0.99 and 1.00. From Eq. (4), we know that the trim rate will have either a maximum or minimum for $C_2 = 1$; therefore, the first step is to determine the frequency increment produced by the chosen increment in C_3 when $C_2 = 1$. This value can be entered into the program as the basis for comparison of subsequent values, which are determined by inserting appropriate values of C_2. The final program outputs are the frequency and the relative frequency increment (trim rate) for each value of C_2.

The results of such calculations are shown in Figure 3. As C_2 is varied from zero to infinity, the frequency varies through a ratio greater than 5/3. Within this range, the trim rate of C_3 varies no more than 6 percent. The trim rate passes through a minimum rather than a maximum at the critical point.

No one works with one-henry inductors or one-farad capacitors, so the obvious next step is to substitute a more typical inductance value for L and to assign a corresponding capacitance value to C_1 and C_4. The value of C_5 will be three times that of C_1. The C_3 arm will consist of a fixed capacitor slightly smaller than C_1 shunted by a relatively small variable capacitor that produces the desired trimming range. The needed capacitance range can be estimated from the fact that the trim rate of C_1 is the same as the tuning rate of C_2 in the vicinity of $C_2 = 1$.

The foregoing example has several drawbacks. The tuning range is inadequate for some applications, C_3 is in-

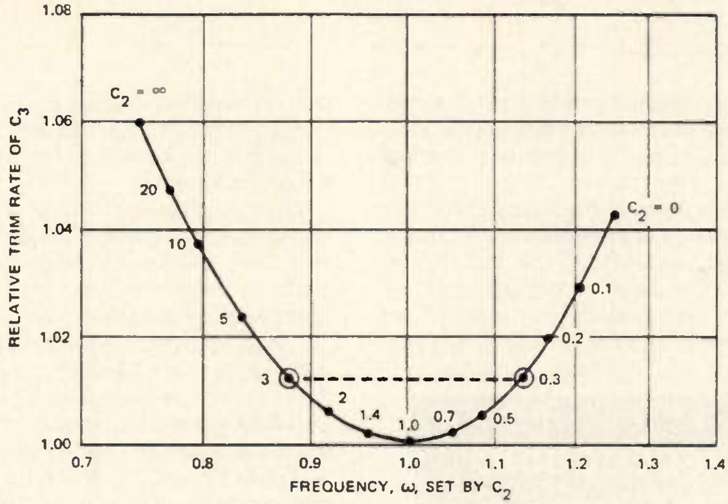

Figure 3. Tuning curve for prototype circuit.

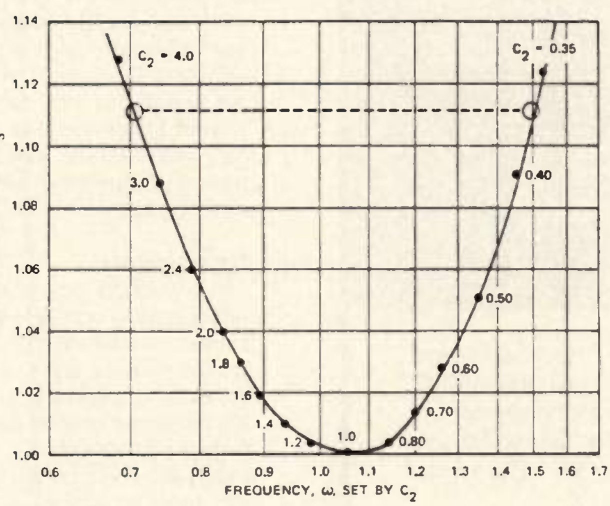

Figure 4. Tuning curve for modified circuit.

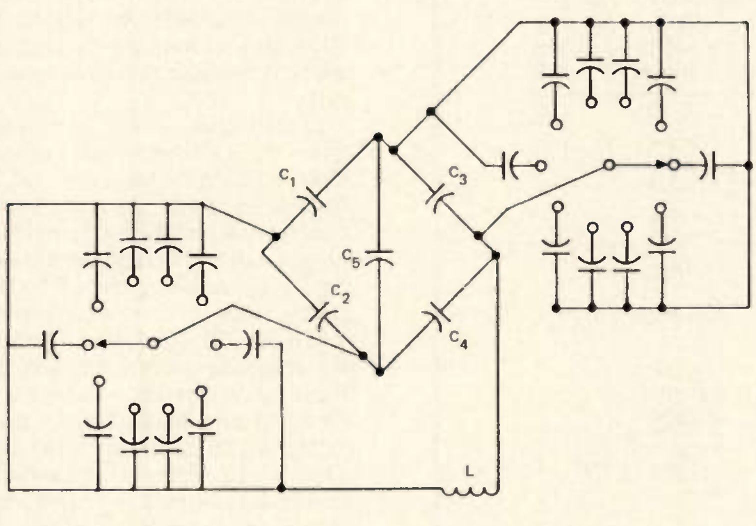

Figure 5. Decade tuning arrangement.

conveniently large, and the assumed range of C_2 is unrealistic. In an attempt to improve the situation, we set $C_4 = 4$, and $C_1 = 0.125$, which satisfies Eq. (5) if $C_2 = 1$ and $C_3 = 0.5$. Using the balanced bridge condition it is easy to show that $C_0 = 0.9$. Substitution of these values in Eq. (4) yields $C_5 = 5/3$. The results of calculations based on these numbers are shown in Figure 4. Note the logarithmic abscissa scale used in Figures 3 and 4 to facilitate interpretation and comparison of results obtained with different values of circuit parameters.

Two things are immediately apparent: (1) the change of parameters has greatly increased the tuning range, and (2) the shape of the curve in the region of the minimum is essentially unchaged. Other calculations not here included, strongly suggest that the degree of curvature is fundamental to the method and is not subject to control by the choice of the various circuit parameters.

The capacitance of typical variable air capacitors changes by a ratio of about 10:1 from minimum to maximum value. With a fixed inductor, this variation changes the resonant frequency by about 1.5 octaves. If shunted across this combination, a small variable capacitor will have a trim rate that varies by a factor of about 30 as the frequency is changed by the main capacitor. The horizontal dashed line in Figure 4 corresponds to a 10:1 capacitance variation (from 0.37 to 3.7). The resulting frequency variation is almost an octave, and the total variation of the trim rate is 11 percent. The horizontal dashed line in Figure 3 tells a very different story. A 10:1 capacitance variation (from 0.3 to 3.0) varies the frequency from 0.875 to 1.135, a ratio of 1.30 with a trim rate uniform to 1.28 percent.

From these two examples, it is clear that considerable design freedom is available by judicious choice of the circuit parameters.

Applications

The method described in preceding paragraphs is particularly advantageous for resonant circuits that are tuned in a decade manner with switched capacitors. Consider an oscillator that is to generate 100 uniformly spaced frequencies in the range 9.00 to 9.99 MHz. This condition is readily achieved by switching C_2 and C_3 with decade switches as shown in Figure 5. The element values should be chosen so that $C_1 = C_2 = C_3 = C_4 = C_5/3$ for a frequency of 9.50 MHz. The ten capacitors in the C_3 arm are chosen to produce frequency increments of 10 kHz. The ten capacitors in the C_2 arm are chosen to produce frequency increments of 100 kHz.

In particular, when C_3 has its maximum value the frequencies produced by switching C_2 form the series: 9.0, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8 and 9.9 MHz. The frequency error inherent in this method is quite small and can be determined from Figure 3. The tuning range 9.0 to 9.9 MHz produced by C_2 corresponds to the ratio 1.10 or ± 1.052. This ratio is identified with the abscissa interval 0.955 to 1.050 in Figure 3. Within this range the relative trimming rate of C_3 lies in the range 1.0000 to 1.0018; therefore, the method is valid to ± 9 parts in 10,000 or ± 9 Hz overall. An error of this magnitude is likely to be small compared with other errors inherent in an analog system of this sort.

The advantages of decade tuning are

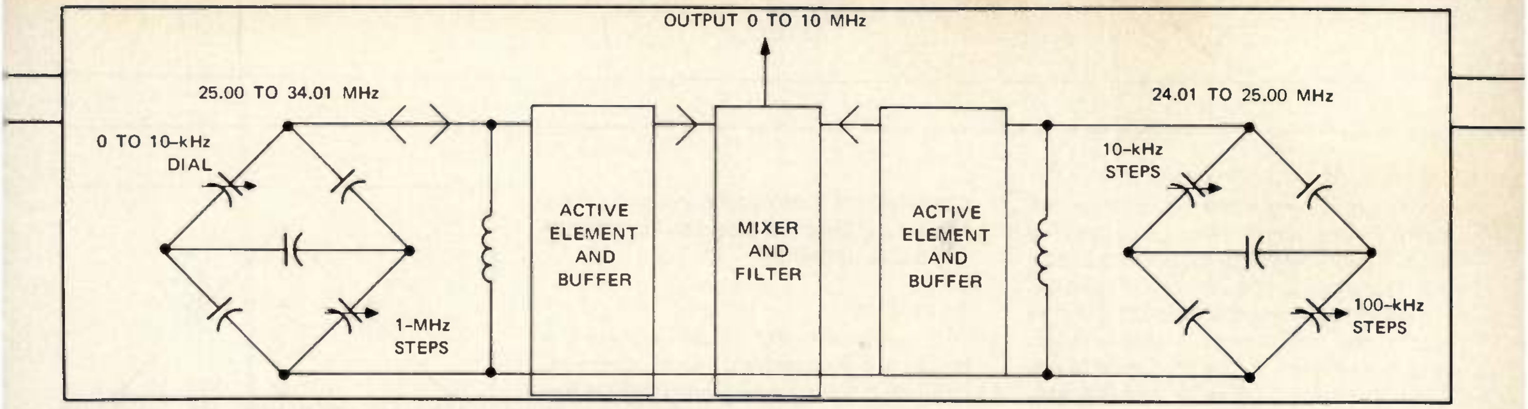

Figure 6. Decade-tuned beat-frequency oscillator.

compounded in a beat-frequency oscillator where the useful output represents the difference between two frequencies generated in trim-tunable oscillators. An appropriate arrangement is shown in Figure 6. Tuning errors are minimized by associating a continuously variable capacitor with the switched capacitor that produces the major steps in frequency in the left-hand oscillator. The other oscillator provides the two needed sets of intermediate steps. The frequency errors inherent in this arrangement can be estimated from Figure 3. The tuning range 25.0 to 34.0 MHz corresponds to the abcissa interval of 0.85 to 1.15, for which the relative tuning rate of C_3 lies in the range 1.00 to 1.02. Thus, the continuous tuning dial, which covers a total of 10 kHz and is probably resettable to ±10 Hz, is subject to a systematic error of ±1 percent or ±100 Hz. The frequency error inherent in the other oscillator is about ten times smaller, as can readily be demonstrated by reference to Figure 3.

Possible Variations

Although adequate for many applications, the foregoing results obviously leave much room for improvement, with several possible approaches. The results of adding a single capacitor in series or in shunt with the inductor have been calculated. These arrangements tend to reduce the total tuning range without appreciably altering the proportions of the almost parabolic shape of the curve shown in Figures 3 and 4. It seems unlikely that addition of two capacitors in series-shunt or shunt-series configuration will yield better results.

Eq. (4) indicates that the trimming rate of C_3 will be absolutely constant if C_5 varies inversely with C_0 while C_u varies as a result of variation of C_2. Increasing C_2 always increases C_0, which reduces the operating frequency. Therefore, it appears that we might improve results by adding an inductance in series with C_5 so that the "effective capacitance" of the C_5 arm will decrease as the operating frequency decreases in response to an increase of C_2. This arrangement suffers the fault of adding a second resonant frequency but offers the prospect of substituting a relatively flat cubic curve for the nearly parabolic curve of Figure 3.

An alternative approach which does not lead to two frequencies is shown in two version in Figure 7. The presence of two additional capacitors adds considerably to the complexity of the calculations required to establish the performance potentiality of these configurations. I have made no substantial progress toward solving these problems.

Summary

A singly-resonant circuit including a bridge of five capacitors has the desirable property of tuning over a substantial range of frequencies while maintaining a nearly constant rate of trimming. This property is useful in many circuit applications, including transmitters, receivers, signal generators and spectrum analyzers. A circuit of this kind was used in the Type 1900A Wave Analyzer manufactured by the General Radio Company.

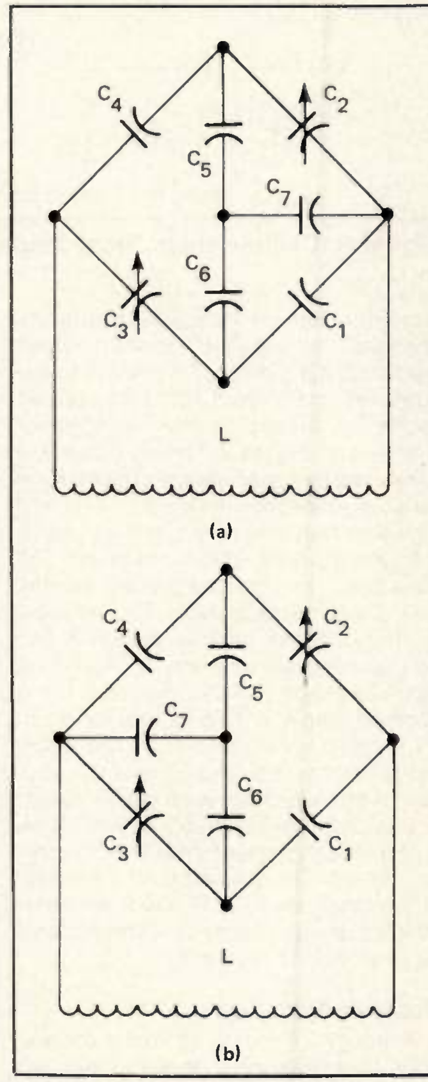

Figure 7. Alternative circuits.

About the Author

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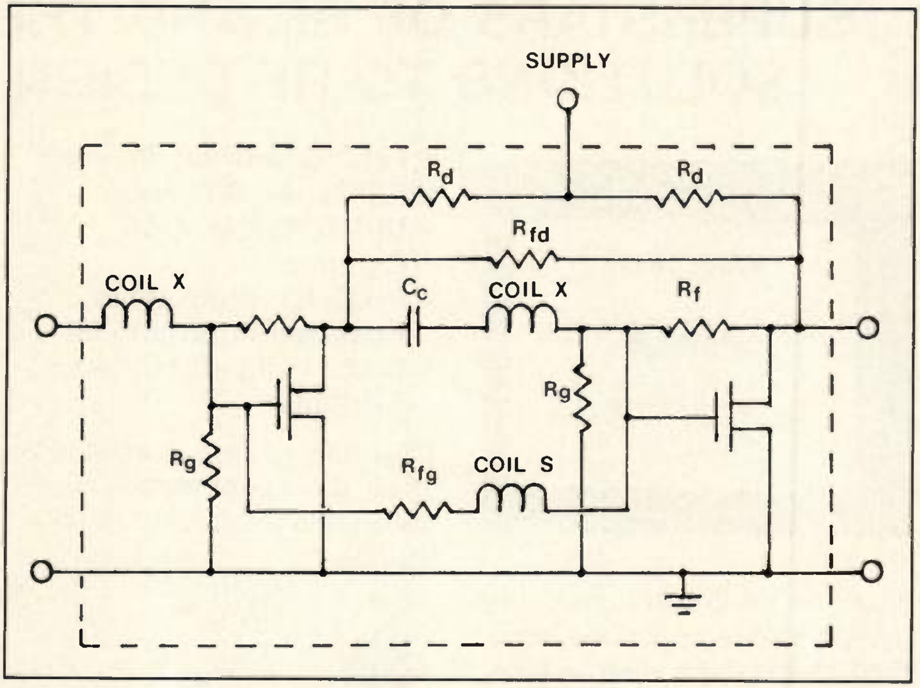
LTI Debuts 10-500 MHz DMOS Amplifier

The LB950 is an example of the growing popularity of Double Diffused MOS (DMOS) transistors for RF applicaticns. The LB950 is a wideband amplifier with 13 dB power gain over a 10-500 MHz bandwidth, 50 ohm input and output impedances, and +17 dBm output level at 1 dB compression. The entire circu t is fabricated monolithically, including inductors.

The 10-500 MHz rated bandwidth is the ±0.5 bandwidth; the 3.0 dB bandwidth is 5-650 MHz. Recommended operating voltage is 12 volts (single supply), with an operating bias to obtain 100 mA current. Under these conditions, the typical noise figure is 6.5 dB and the 3rd order intermodulation products are −40 dB with a 0 dBm input level.

The device is currently available in sample quantities, with production quantities available in March 1987. Packaging options include a TO-79 metal case and a 7 mm stripline (SOE) package. **Linear Technology Inc., Burlington, Ontario. INFO/CARD #220.**



2.6 GHz Spectrum Analyzer
IFR Systems, Inc.

IFR will make the first public showing of their Model A-8000 Spectrum Analyzer at the RF Technology Expo 87. Representing continued development of the IFR product line, the A-8000 includes these

features: 10 kHz to 200 MHz per division span, plus zero and full scan; 300 Hz to 3 MHz resolution bandwidth; an internal tracking generator; receiver; RS-232 and IEEE-488 interfaces; and battery power. **IFR Systems, Inc., Wichita, Kan. Please circle INFO/CARD #219.**

Touchstone 1.5
EEsof Inc.

The latest version of EEsof's Touchstone features four new optimizers, 18 additional RF/microwave element models, refinements of existing models, and an advanced General User Interface™. The interface includes windowing capabilities, versatile graphics and the ability to handle much larger networks than previous versions. **EEsof, Inc., Westlake Village, Calif. INFO/CARD #218.**

Single Chip FM/Data Receiver
Motorola Semiconductor, Inc.

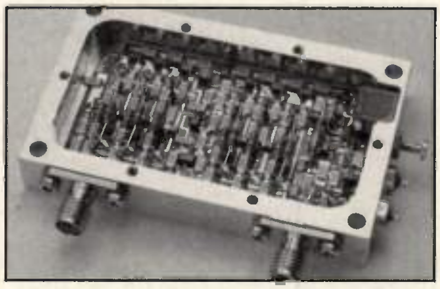
Motorola introduces a single chip (MC3367DW) single conversion VHF FM/Data receiver. It features low voltage operation along with less than 1.5 microvolt 20 dB quieting sensitivity. The circuits include an internal voltage regulator, low battery indicator, internal crystal oscillator, dual filter capability and voice/data output. **Motorola, Inc., Phoenix, Ariz. Please circle INFO/CARD #217.**

Customized RF Capacitors
Polyflon Company

Polyflon introduces custom design, high voltage, high Q, non magnetic, fixed and variable RF capacitors. The capacitors are shock and vibration resistant, have a Q greater than 5000, 1 to 1000 pF and a voltage rating of 50 kV. Also being introduced is CUFLON ultra low loss, high Q microwave substrates. Cuflon features a pure TFE dielectric with a constant of 2.1. Cuflon's copper cladding is electroplated directly to the TFE which eliminates added loss and instability of a secondary dielectric. **Polyflon Company, New Rochelle, N.Y. INFO/CARD #216.**

Miniature Log Amplifiers
Merrimac Industries Inc.

Merrimac introduces a range of log amplifiers measuring 2.5 × 1.5 × .47" and weighing 1.5 oz. They are available for center frequencies from 30 to 600 MHz.



They provide an 80 dB dynamic range with a linearity of better than ±1 dB and at 160 MHz center frequency, the pulse rise time is less than 20 ns. Prices commence at $695 in quantites of 1 to 9. **Merrimac Industries, Inc., West Cardwell, N.J. INFO/CARD #215.**

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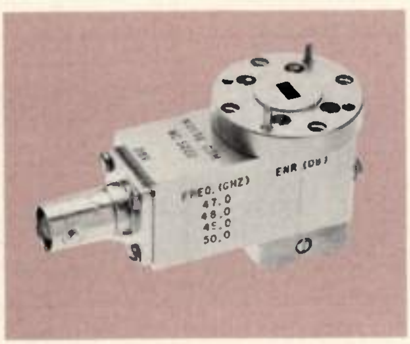

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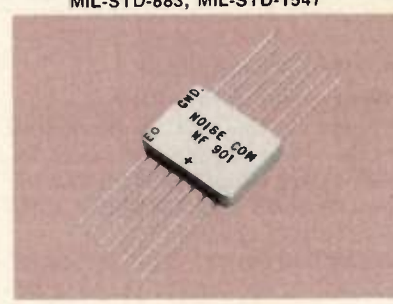

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600 MHz Log Amplifier Plessey Semiconductors

Plessey introduces a monolithic amplifier which operates at center frequencies up to 600 MHz, 80 dB dynamic range with ±1 dB log linearity and as low as a 10° phase shift.

Another new device is a high speed A/D converter that operates at 110 MHz with an accuracy of within ±½ LSB resolution. It is priced at $102 for 1000 pieces. **Plessey Semiconductors, Irvine, Calif. INFO/CARD #214.**

Mixers in Hermetic Packaging Watkins-Johnson Company

Watkins-Johnson introduces the new Z series Versapac mixer in a small hermetic package measuring 0.520 × .560 × 0.190 in. All models cover 6 to 18 GHz at a variety of power levels. Also being introduced are broadband double balanced microwave mixers. All models cover the range from 2 to 26.5 GHz.

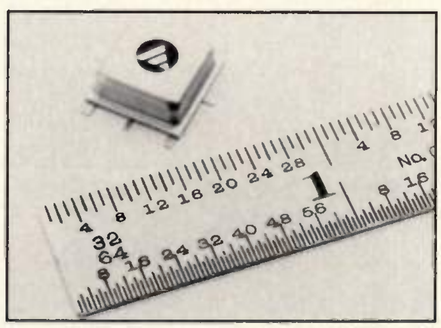
Being unveiled will be the KL80 monolithic limiter with less than a 4.0 dB insertion loss over the 1 to 8 GHz frequency range with 2.0:1 VSWR and 10 mA current draw. **Watkins-Johnson Company, Palo Alto, Calif. INFO/CARD #213.**

Digital Attenuators KDI Electronics, Inc.

KDI introduces the DAP series of digital attenuators with internal TTL drivers. In the frequency range from 500 MHz to 2.0 GHz, the attenuation is 0 to 30 dB with a 0.5 dB monolithic resolution. The switching speed is as low as 100 ns. **KDI Electronics, Inc., Whippany, N.J. Please circle INFO/CARD #212.**

Microwave Amplifier is Surface Mounted Avantek, Inc.

Avantek introduces a surface mount amplifier having a minimum gain of 20.0 dB with a typical gain of 22.0 dB over the full 1000-4000 MHz frequency range. The



device has a maximum noise of 6.0 dB; minimum 1 dB compressed output power of +17 dB. The maximum input and output VSWR is 2.0:1. **Avantek, Inc., Santa Clara, Calif. INFO/CARD #211.**

Beam Lead PIN Diodes Frequency Sources Semiconductor-Loral Corporation

Frequency Sources introduces beam lead PIN diodes that are small in size, have low impedance, low capacitance and fast switching. **Frequency Sources Semiconductor, Loral Corporation, Chelmsford, Mass. INFO/CARD #210.**

Low Cost Spectrum Analyzer Tektronix, Inc.

Being unveiled is the 2710 spectrum analyzer. The features include a wide 5 MHz IF bandwidth filter, 10^{-5} frequency

accuracy and a time domain measurement capability. This unit is priced at $8250. A 400 MHz SAW resonator oscillator joins the new lineup. This clock provides 7 dBm of output power into a 50 ohm load. **Tektronix, Inc., Beaverton, Ore. INFO/CARD #209.**

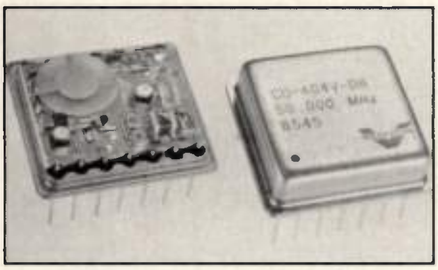
2 to 18 GHz Single Band Noise Source Noise Com, Inc.

Noise Com has expanded into rack mount programmable noise generators that span from 2 to 18 GHz. The instrument produces −20 dB/band minimum, −10 dBm/band typical and an output with a 14 dB minimum creast factor into a 50

ohm load. The programmable functions include attenuator setting, attenuator step decrement and increments, dummy load and filter selection, time delay and program/recall operational sequences. The unit is priced at $16,000. **Noise Com, Inc., Hackensack, N.J. INFO/CARD #208.**

Hybrid DIP ECL VCXO
Vectron Laboratories, Inc.

The CO-434V series hybrid VCXOs provide ECL output for 8 MHz through 200 MHz complementing Vectron's previous-



ly introduced line of TTL and Sinewave Hybrid VCXOs. **Vectron Laboratories, Inc., Norwalk, Conn. INFO/CARD #207.**

Fixed Attenuators for PC Board
Alan Industries, Inc.

Alan's PI series of fixed attenuators is ideal for PC board or socket mount applications. They are available with at-

tenuation values for 1 to 20 dB, a frequency range of DC-500 MHz and accuracy of ±0.5 dB. **Alan Industries, Inc., Columbus, Ind. INFO/CARD #206.**

Cables Get QPL Approval
Applied Engineering Products

Applied Engineering announces 93 qualified part numbers in configurations for cable, receptacles, and PC board mountings under MIL-C-39012. Both gold and silver plating are available for SMB and SMC. **Applied Engineering Products, New Haven, Conn. Please circle INFO/CARD #205.**

Power Amplifier at 10 Watts
Amplifier Research

Amplifier Research introduces a 10 watt RF amplifier covering the frequency range of 10 kHz to 250 MHz. The amplifier is ideally suited for pulsed and non-sinusoidal waveforms, ultrasonics, NMR spec-

troscopy, plasma physics and susceptibility testing. **Amplifier Research, Souderton, Penn. INFO/CARD #204.**

Ultra Wideband RF Amplifier
Kalmus Engineering International, Ltd.

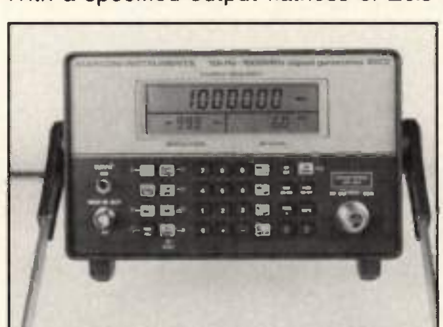
Kalmus introduces a new ultra wide band RF amplifier. The model 502LC, covering the broadband frequency range from 10 kHz to 525 MHz, has a power output level of greater than 2 W. The amplifier has a gain of 36 dB and is priced at $1395. **Kalmus Engineering International, Ltd., Woodinville, Wash. Please circle INFO/CARD #203.**

Board Mountable Shielded Enclosures
Compac Development Corp.

Compac Development introduces the flat pac series of board mountable RFI/EMI shielded enclosures which provides 70 dB attenuation at 4 GHz. **Compact Development Corp., Holbrook, N.Y. INFO/CARD #202.**

Portable Signal Generator
Marconi Instruments, Inc.

The model 2022A is the newest addition to the family of small and portable signal generators in the Marconi family. With a specified output flatness of ±0.5



dB over the entire frequency range and low harmonically related signals typically better than −35 dBc, the device provides high performance at reasonable cost. **Marconi Instruments, Inc., Allendale, N.J. INFO/CARD #201.**

2-18 GHz Digital Phase Modulator
Premier Microwave Corporation

Premier Microwave introduces the BP series of biphase modulators. These devices are digitally controlled and cover the 2 to 18 GHz frequency range with an insertion loss of 2 dB, SWR of 2, phase error of +20 degrees and amplitude ripple of 0.25 dB for the BP1000 model. Also being introduced is a SPST doubly absorbtive switch with 100 dB of isolation with a 1.5 dB insertion loss. The switching speed is less than 100 ns and operates on TTL logic. **Premier Microwave Corporation, Port Chester, N.Y. INFO/CARD #196.**

Millimeter Gunn Diodes
Epsilon Lambda, Inc.

Epsilon Lambda announces the capability to design and produce high power fixed frequency Gunn diode oscillators for millimeter wave applications. The devices operate from 55 GHz to 60 GHz with an output power of 500 mW. Currently being developed are devices in the 90 GHz to 95 GHz range with power outputs of 120 mW. The devices are tailor-made to customer specifications. **Epsilon Lambda, Inc., Geneva, Ill. Please circle INFO/CARD #195.**

Cesium Frequency Standard
Austron, Inc.

Model 2310 Disciplined Cesium Standard utilizes a precision cesium physics package with circuitry to change the natural resonant frequency of the oscillator.

The 2310 also features an IEEE-488 two-way communications bus. **Austron, Inc., Austin, Texas. INFO/CARD #200.**

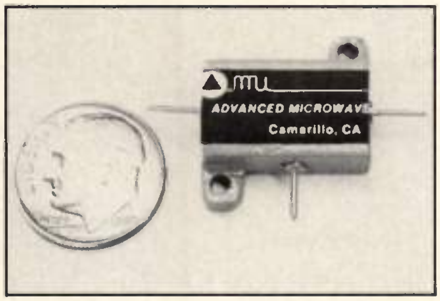
Sweeper Covers Millimeter Waves
Micro-Now Instruments

Micro-Now Instruments Company introduces the model 706 mm-wave sweeper. The instrument was originally developed for Gunn oscillators operating

in the 33-110 GHz range. The 706 includes digital display of signal and marker frequencies plus sweep duration, up to five preset frequencies, and sweep times from 10 ms to 100 s **Micro-Now Instruments Company, Skokie, Ill. INFO/CARD #199.**

Amplifier Modules are Broadband
Advanced Microwave, Inc.

AMI introduces the A-Pak series of solid state amplifiers designed for frequencies from 0.2 GHz through 18.0 GHz. The design offers low noise with a selection of various gain levels. Consistent gains over temperature specification for most models



is guaranteed over the temperature range from −54° to 85°. **Advanced Microwave Inc., Camarillo, Calif. INFO/CARD #198.**

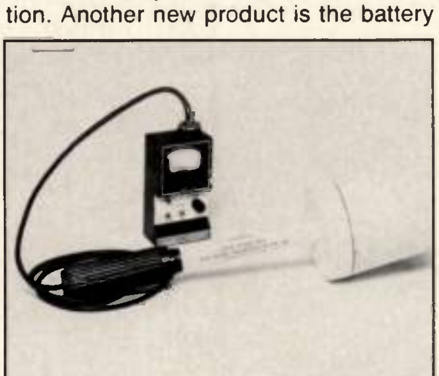
Combline Bandpass Filters Daden Associates

Daden Associates introduces Daden Combline Filters in the CS series covering the frequency range from 500 MHz to 26.5 GHz with bandwidths from 2 percent

to over 75 percent. Three to 22 sections are available for extremely tight stopband requirements. This compact rugged construction affords low insertion loss and low VSWR. **Daden Associates, Laguna Hills, Calif. INFO/CARD #197.**

Radiation Hazard Test Set Narda Microwave Corp.

Narda introduces a radiation hazard test set that is useful for RF hazard identification, safety and compliance modification. Another new product is the battery



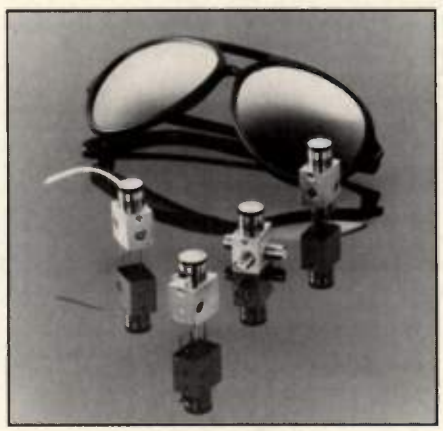
powered electric and magnetic field meter in the 10 to 40 MHz frequency range. **The Narda Microwave Corporation, Hauppauge, N.Y. INFO/CARD #194.**

Programmable Attenuators Alan Industries, Inc.

Alan Industries introduces a series of programmable attenuators. Their ranges are 0-31 dB, DC-1250 MHz; 0 to 63 dB, DC to 1250 MHz, and 0-127 dB, DC to 1 GHz. VSWR at 500 MHz is 1.3:1 and a maximum switchg speed of 6 ms. The prices ranges from $445 to $575. **Alan Industries, Inc., Columbus, Ind. Please circle INFO/CARD #193.**

Miniature Microwave Relays FL Jennings

A new line of miniature microwave relays rated at DC to 2.5 GHz with a VSWR of 1.20:1, an isolation near 40 dB



and insertion loss of .15 dB is introduced by FL Jennings. PCB terminals, flying leads and solder lugs connections are available. **FL Industries, Inc., Jennings Division, San Jose, Calif. Please circle INFO/CARD #192.**

Lockable Ultra Low Phase-Noise Sources Communication Techniques, Inc.

New series XSMP-low profile phased — locked microwave signal source product line utilizes an internal crystal oscillator in the 100 MHz region to produce ultra low noise performance up to 21 GHz. The output frequency does not have to be an integer multiple of the reference frequency. A list of options is available for this product. They include field changeable crystals, FM modulation, auxiliary outputs and RF muting. **Communication Techiques, Inc., Whippany, N.J. Please circle INFO/CARD #191.**

Precision RF Power Meter Bird Electronics Corporation

Bird introduces the laboratory grade model 4421 RF power meter. This product measures forward/reflected power in watts or dBm, VSWR, max/min with wide range heads guaranteed against burnout for life. The 4421 measures 300 mW to 1 kW with 3 percent accuracy. **Bird Electronics Corporation, Cleveland, Ohio. Please circle INFO/CARD #190.**

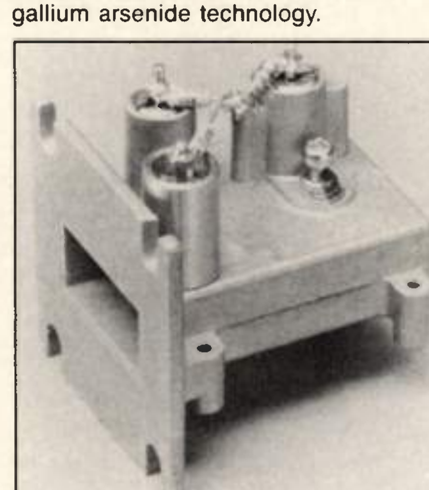
Cascadable Amplifiers are Wideband Hewlett Packard

HP announces a new family of wideband automatic gain control amplifiers. The devices offer a gain control range of 30 dB with gain flatness from 2-1900 MHz.

HP also introduces the HSMP-38XX series of PIN diodes, which are designed to be used in typical applications such as duplexers, switches, phase shifters, pulse and amplitude modulators, limiters, leveling circuits and attenuators. **Hewlett Packard, San Jose, Calif. Please circle INFO/CARD #189.**

New Ceramic Substrates Alpha Industries, Inc.

Alpha Industries introduces the DMAT series of ceramic substrates. The materials feature "O" porosity, are dense, and are laser cuttable with low power. Their dielectric constants are compatible with gallium arsenide technology.



Also being unveiled is a CW motion and direction detector module. The transmitter operates in the frequency range from 9.47-10.7 GHz. **Alpha Industries, Inc., Woburn, Mass., and Adamstown, Md. INFO/CARD #188.**

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FREQUENCY RANGE = 2 MHz TO 200 MHz
TMOS™ REPLACEABLE
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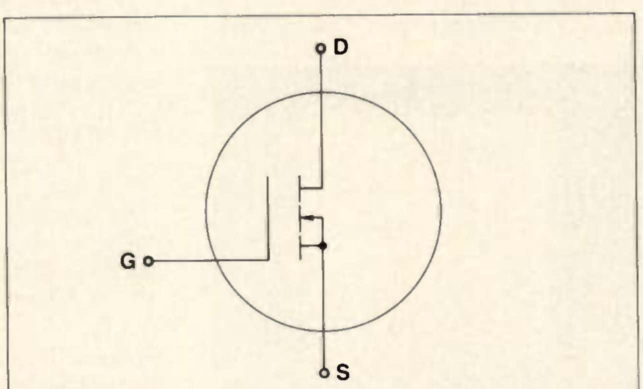
PRODUCTS:

TYPE:	POUT(W):	Vdd(V):	Pg(dB):	Idg(mA):	PKG:	Fo(MHz):
SD1906	45W	28.	12.	25.	.3804LFL	150.
SD1908	80W	28.	10.	50.	.5004LFL	150.
SD1912	150W	28.	15.(TYP)	250.	.5004LFL	30.
SD1920	150W	50.	17.(TYP)	250.	.5004LFL	30.

TMOS is a trademark of Motorola.



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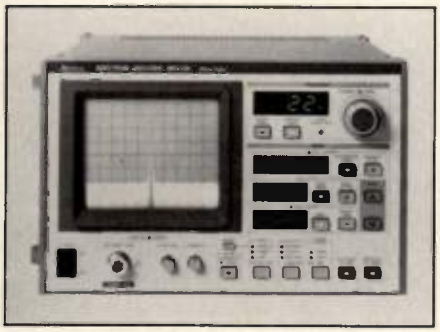
In addition to RF and microwave transistors, Thomson-Mostek manufactures MOS and bipolar devices for both commercial and military applications: microcomponents, memories and linear circuits as well as Discrete, passive components and ASIC.

See us at RF Technology Expo, Booth #528.

INFO/CARD 68

Spectrum Analyzer is Portable
Anritsu Corporation

Anritsu features a portable 10 kHz to 2 GHz spectrum analyzer (model MS610B/J/J1) with an 80 dB dynamic range. The analyzer incorporates a coupling function for measurements to be



made by setting the frequency, frequency span and reference level. This product is priced around $8,000. **Anritsu Corporation, Oakland, N.J. INFO/CARD #187.**

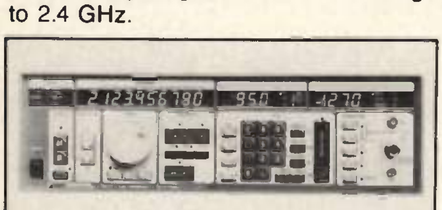
Chip Resistor Receives QPL Approval
Barry Industries, Inc.

Barry Industries will be featuring their TRX division's chip resistors. These pro-

ducts have just been QPL approved under MIL R 55342. **Barry Industries, Attleboro, Mass. INFO/CARD #186.**

Signal Generator to 2.4 GHz
Comstron Corporation

Comstron introduces their 742A synthesized signal generator with coverage to 2.4 GHz.



Also being introduced is the FS 2000 frequency synthesizer. The features include sub-microsecond switching and a frequency range of 10 MHz to 4 GHz. **Comstron Corporation, Melville, N.Y. INFO/CARD #185.**

Bidirectional Transfer Between IBM and HP
Compact Software, Inc.

Compact Software introduces computer aided design and synthesis programs that allow bidirectional transfer of S parameters between IBM computers and the Hewlett Packard 8510 network analyzers. Also being introduced is a standalone CIRCLES program which uses the properties of the Smith chart to aid the design of matching networks, perform stability analysis, and optimize circuits. **Compact Software, Inc., Paterson, N.J. INFO/CARD #184.**

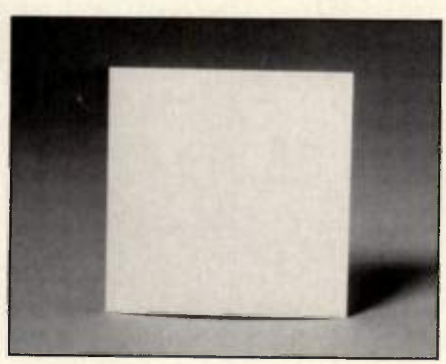
Mixers for SMT
Synergy Microwave Corporation

Synergy introduces lumped-element mixers and power devices in surface mounted packaging. The mixers cover a range from 1 to 2500 MHz and L.O. powers from +7 dBm to +23 dBm. The power dividers offer a 20 dB isolation and a 1 dB insertion loss.

Also being introduced are standard Bi-Phase Modulators covering frequencies of 800-2500 MHz and modulation frequencies up to 200 MHz. **Synergy Microwave Corporation, Paterson, N.J. INFO/CARD #183.**

Ceramic Substrate for Microwave Circuits
Kyocera International, Inc.

Kyocera introduces the A493 ceramic substrate for the fine-line deposition of thin film microwave circuits. The substrate



is 99.6 percent aluminum and has an ultra smooth surface. **Kyocera International, Inc., San Diego, Calif. Please circle INFO/CARD #182.**

Anti-Aliasing Filters
TTE, Inc.

TTE Incorporated introduces elliptical function low pass filters with any specified cut-off frequency from 1 kHz to 100 MHz. **TTE, Inc., Los Angeles, Calif. Please circle INFO/CARD #181.**

35-400 MHz VCOs
Magnum Microwave

Magnum Microwave voltage control oscillators that deliver a minimum of +10 dBm with up to octave frequency coverage. They employ thin film MIC construction and are available in TO-8 or flatpack packages. **Magnum Microwave Corporation, Fremont, Calif. INFO/CARD #180.**

Cold Switching at 200 Watts
Lorch Electronics

An electronic switch rated at 200 W (800 W peak), covering a frequency range of 80 to 500 MHz, is introduced by Lorch Electronics. The insertion loss is typically

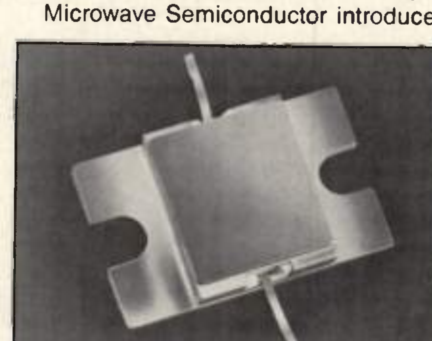
0.35 ddB (0.5 dB max.) with an isolation of 40 dB and VSWR of 1.2:1. **Lorch Electronics, Englewood, N.J. Please circle INFO/CARD #179.**

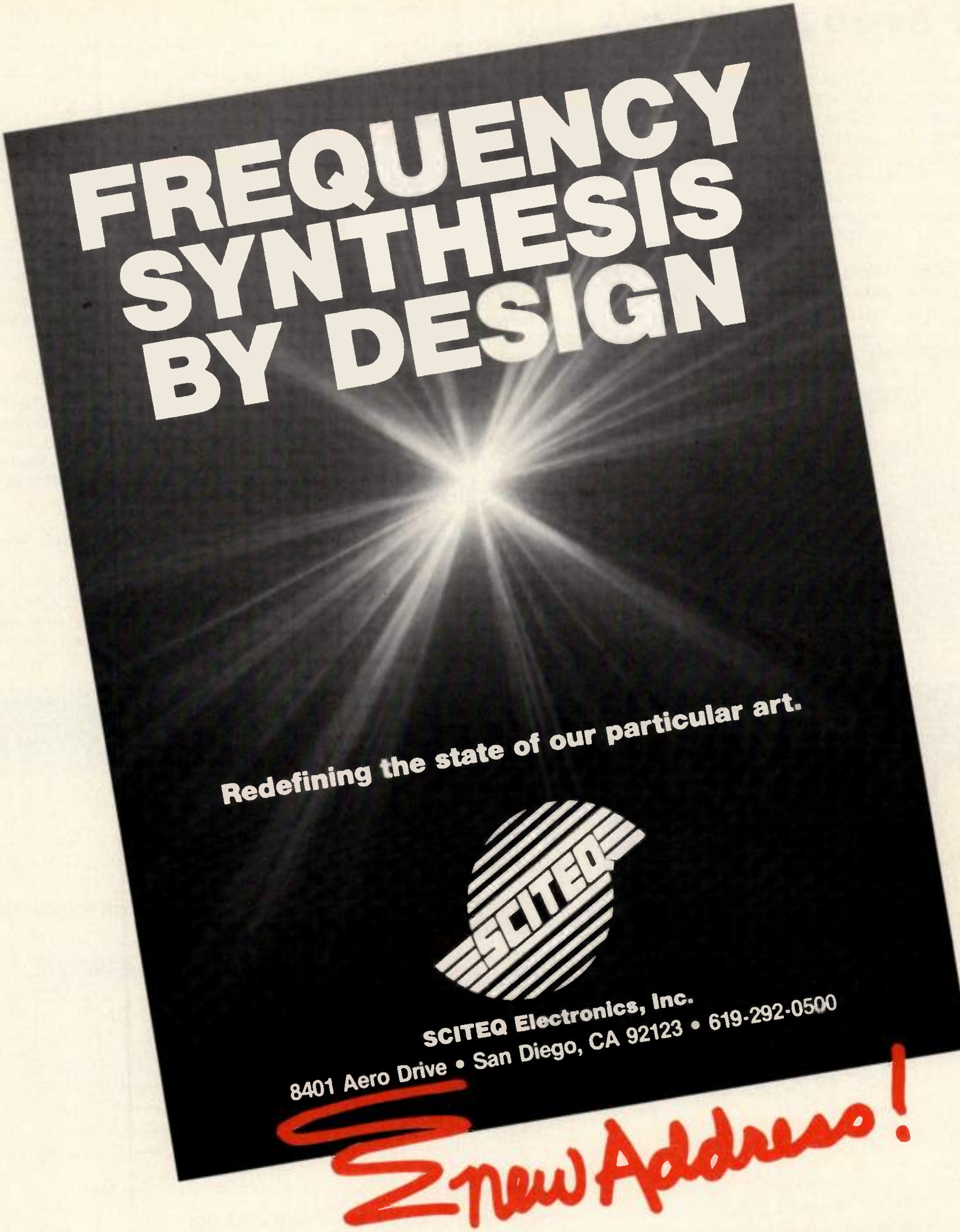
UHF Amplifier Covers 1.5-500 MHz
RF Power Labs, Inc.

RF Power Labs introduces a new series of wideband amplifiers, model RF 2002, with a ±1 dB gain flatness from 1.5 to 500 MHz, 33 dB gain and 2 W of linear power output. The amplifier design utilizes MOSFET and SMT technology. The features include LCD power meter, fast RF blanking control and a built-in DC power supply. **RF Power Labs, Inc., Bothell, Wash. INFO/CARD #178.**

Power FETs are Broad Band
Microwave Semiconductor Corp.

Microwave Semiconductor introduces





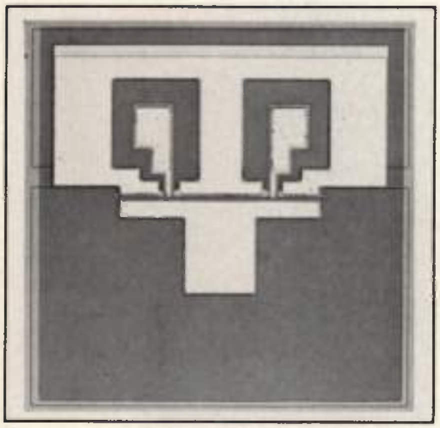
See our exhibit at the
RF Expo '87 in Anaheim.
Booth 311.

INFO/CARD 69

an internally input matched balanced pair of silicon FET power transistors for broad band applications. The transistors operate in the 225 to 400 MHz frequency range. The features include refractory/gold metalization, VSWR capability of 3:1 and metal/ceramic hermetic packaging. **Microwave Semiconductor Corp., Somerset, N.J. INFO/CARD #176.**

GaAs FET Offers Low Noise
California Eastern Laboratories

California Eastern Laboratories introduces a low noise GaAs FET from NEC. The new devices achieve a noise figure of 1.0 dB at 12 GHz with 12 dB associated gain. The NE202 is priced at $120 for quantities of 500. **California Eastern Laboratories, Santa Clara, Calif. INFO/CARD #177.**



IFF Tunable Oscillators
Andersen Laboratories

Andersen has introduced two new models to its SAW Hybrid Oscillator line. The devices operate at 1030 MHz and 1090 MHz. The advantaged of these oscillators include tunability, spectral purity, and low power consumption. The oscillators maintain a phase noise characteristic of −90 dBc at 1 kHz. **Andersen Laboratories, Bloomfield, Conn. Please circle INFO/CARD #175.**

New Waveguide Coupler
Aerowave, Inc.

Aerowave's newly created coupler design (series #02) enhances sensitivity and stability of detected signal response in network analyzers and reflectometer measurement systems or for signal sampling or injecting in design configurations.

Aerowave, Inc., Medford, Mass. Please circle INFO/CARD #174.

1 Cubic Inch Power Amplifier
Microwave Modules and Devices

MMD introduces a 2 kW pulsed power amplifier weighing 1 ounce and measuring 1 cubic inch. **Microwave Modules and Devices, Mt. View, Calif. Please circle INFO/CARD #173.**

Amplifier Modules are High Power
TRW RF Devices

TRW introduces a line of high power, class A amplifier modules with a frequency range from 800-1000 MHz, linear power from 3 to 25 W, and reverse polarity protection. These devices are also available in other frequency ranges and output power levels. **TRW RF Devices Div., Lawndale, Calif. INFO/CARD #172.**

Filter is Tunable Microlab/FXR

Microlab introduces a tunable filter (BF-A67) featuring a narrow band preselect fil-

ter response, less than 2.0 dB insertion loss, and screwdriver adjustability. **Microlab/FXR, Livingston, N.J. Please circle INFO/CARD #171.**

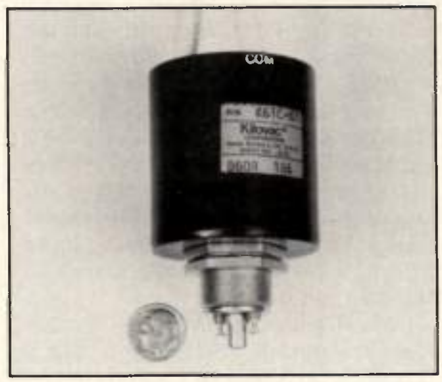
IEEE Bus Interface Controller: Dow-Key Microwave

Dow-Key Microwave Corporation introduces the Model DK-688 IEEE Bus Interface Controller. This IEEE-488 Bus controller is designed to provide a low cost, high performance interface to any electronic device with BCD Control or Data

Signals. Capabilities include the ability to drive or sense data on two 24-line bi-directional binary data ports using standard TTL logic signal levels. These data lines can be configured as either eight bit BCD data ports or binary status/enable/inhibit lines. **Dow-Key Microwave Corporation, Carpinteria, Calif. INFO/CARD #130.**

HV Relay is Gas Filled: Kilovac Corp.

Kilovac introduces the K61C gas filled high voltage relay. The switch will isolate or hot switch up to 35 kV. The device can carry a continuous current of 10 A. It is



suited for hipot and cable insulation testing, military radar and sonar applications, capacitive discharge circuits, electrostatic discharge testing and microwave tube testing. **Kilovac Corporation, Santa Barbara, Calif. INFO/CARD #129.**

Class A Power Amplifier: Epsco, Inc.

The Epsco model AM0250D0015 is a miniature class A, linear high power amplifier with 15 W minimum at the 1 dB compression point across the 20-500 MHz frequency band. The amplifier has a minimum gain of 40 dB. **Epsco, Inc., RF Div., Westlake Village, Calif. Please circle INFO/CARD #128.**

Flexible Cable Assembly: Huber & Suhner, Inc.

Huber & Suhner introduces the Sucoflex flexible microwave assembly, C.Grip

solderless/non-crimp SMA connector and in-cable subminiature microwave attenuators. **Huber & Suhner, Inc., Woburn, Mass. INFO/CARD #127.**

The Engineer's "Toolkit"

By Richard Bain
E-Systems, ECI Division

Did you ever forget which reference book or scrap of notepaper had that important conversion factor for Rho to VSWR or signal-to-noise degradation for a given interference level? Here is a program with 14 conversions common to RF systems, design to take the "plug and chug" out of routine computations and eliminate the need to thumb through books looking for the formula.

The program menu in Figure 1 shows the 14 different conversion routines. A useful feature of the program is the ability to reuse the results of a conversion in another conversion. The numbers beside each manu selection indicate the subroutines from which data will be accepted by the selected subroutine. As an example, data of the form: return loss and angle can be converted to Rho and angle in (7), converted to Rs $\pm jX_s$ in (5), then converted to either R_p, $\pm jX_p$ in (11) or to Z(impedance) at angle theta in (13). The program issues a warning if the data type is not proper for the conversion selected. There are checks for division by zero where appropriate to prevent an error that would stop the program.

Another feature that is useful is the ability to provide a formatted printout of the results of any of the last ten conversion selections. The formatted output can appear on the screen, be printed on the printer, or both. However, the output for the first four menu items is printed only to the screen but can be sent to the printer using the screen dump function on the keyboard.

The structures of the first four subroutine modules are similar to one another. The same holds true for the last ten subroutine modules. Therefore, only one module of each will be discussed. The formulas used in the last ten subroutines are shown in Table 1. The Basic code for the formulas used in the first four subroutines is shown in Figures 2 and 3.

System Analysis Selections

The first four menu selections are especially useful for systems analysis work. Selection 1 asks for the present signal to noise ratio and the signal to interference ratio for the added signal, then calculates the new noise ratio resulting from the addition. Selection 2 requests the present signal to noise ratio and the known amount of signal to noise ratio degradation and uses these to calculate the interference level needed to cause that amoung of degradation. Selection 3 calculates the power or voltage sum of two powers in dBm. Selection 4 requests the known sum and one of the powers added to give that sum and asks if the sum was a power or voltage sum, then calculates the unknown power.

The subroutine for menu selection 3 is shown in Figure 3. The program asks if the addition is a power or a voltage operation. The power addition is used for the addition of two uncorrelated powers, such as a sine wave signal and noise, or two noise powers, whereas the voltage addition is used when the two powers may be correlated and peak addition could occur. A different header is printed for the two cases. At the end of the power addition subroutine, the program gives the user three options. The first option allows the user to add another power to the sum just calculated. Both options print out under the same header. The third option directs the program back to the main menu. The other three of the four subroutines also have three options appearing at the end.

Conversion Subroutine Example

Figure 4 contains the listing for menu selection 6. The first few lines of the program check to see whether the data is to be supplied by the user, or its data from another subroutine. If the data is from another subroutine, the program checks to make sure that is is of the proper type by checking the value of the variable DATYPE. The value of this variable is set after the calculation of data in each subroutine. If the data type is not proper, the user is sent back to the main menu. Line 1990 checks for data from another subroutine; if the data is from another subroutine, calculations begin immediately. If previous data are not used, the variable NUMB is set to 1. This variable keeps track of the array size generated during data input. Data input is terminated when zeros are input for data. The IF statement from lines 2040 to 2100 tests for the zero dat entry, and allows the FOR NEXT loop to begin execution if the data are zeroes.

Selection	Conversion Formulas	
5	$R_s \pm jX_s = \dfrac{Z_o(1 + P\angle a)}{(1 - P\angle a)}$	
6	$P\angle a = \dfrac{Z - Z_0}{Z + Z_0} = \dfrac{R_s \pm jX_s - Z_0}{R_s \pm jX_s + Z_0}$	
7	$P\angle a = 10^{\text{ret loss}/20}\angle a$	
8	Return Loss $= -20 \log_{10}P$	
9	$\text{VSWR} = \dfrac{1 + P}{1 - P}$	
10	Mismatch Loss $= -10 \log_{10}(1 - P^2)$	
11	$R_p = \dfrac{R_s^2 + X_s^2}{R_s}$	$X_p = \dfrac{R_s^2 + X_s^2}{X_s}$
12	$R_s = \dfrac{(R_p)X_p^2}{R_p^2 + X_p^2}$	$X_s = \dfrac{R_p^2(X_p)}{R_p^2 + X_p^2}$
13	$Z = \sqrt{R_s^2 + X_s^2}$	$\Theta = \text{ARCTAN}(X_s/R_s)$
14	$R_s = (Z)\text{COS}(\Theta)$	$X_s = (Z)\text{SIN}(\Theta)$

Z_0 — Characteristic impedance
$R_s \pm jX_s$ — Series resistance and reactance
$P\angle a$ — Voltage reflection coefficient magnitude and angle
R_p, jX_p — Parallel resistance and reactance
$Z\angle\Theta$ — Impedance magnitude and angle

Table 1. Conversion Equations 5 to 14.

In line 2120 of the subroutine the value of Rs is tested before each series of calculations; if the value of R_s is equal to Z_o (50 ohms), a small increment is added to Rs to prevent division by zero in line 2180. Z_o is set to 50 at the begining of the program, but this could certainly be made an optional selection for those who work with other impedances. Lines 2190 and 2200 check for that familiar trigonometric problem of: "what the heck quadrant are we in anyhow?" Since R_s+Z_o is always positive, the check does not have to be performed for THETA2. Another check must be performed for the specific case of $jX_s=0$ and $R_s=50$ so the angle displayed will be 180 degrees and not 0 degrees. The problem does not occur for even very small jX_s, only for $jX_s=0$. After calculation, the user may print the data, which is passed to the subprogram PRINTDAT. The variable FORM tells the subprogram whether the data requires a two-column format or a four-column format.

The program can be easily expanded to incorporate other familiar conversions, though it might be necessary to resort to sub-menus since more selections will not fit on the screen. The program has already been useful to me and certainly worth the time needed to develop it; I hope that it is of similar value to others. The program can be easily modified for various versions of BASIC used on different computers.

The author has developec the IBM PC version and a version for the HP200 series with BASIC 3.0. Disk copies of both versions of the program are available directly from the author for $8.00 ($5.00 for requests accompanied by a disk.) Send your requests to Richard Bain, 6010-18th Ave. N., St. Petersburg, Fla. 33710. The program listing follows on pp. 136-141. rf

```
80    PRINT "****************** MAIN MENU ******************"
90    PRINT
100   !
110   !BY RICHARD BAIN 4/10/86
120   PRINT " 1 = SNR DEGREDATION FOR A GIVEN LEVEL OF INTERFERENCE"
130   PRINT " 2 = INTERFERENCE LEVEL FOR A GIVEN SNR DEGRADATION"
140   PRINT " 3 = POWER OR VOLTAGE SUM OF TWO POWERS IN DBM"
150   PRINT " 4 = UNKNOWN POWER IN DBM GIVEN SUM & ONE POWER"
160   PRINT "        MENU ITEMS 5 TO 14 ACCEPT DATA FROM:      MENU ITEMS"
170   PRINT " 5 = RHO ANGLE ALPHA TO Rs+/-JXs    ----------------   (7)"
180   PRINT " 6 = Rs+/-JXs TO RHO ANGLE ALPHA    ---------------- (12,14)"
190   PRINT " 7 = RETURN LOSS ANGLE ALPHA TO RHO ANGLE ALPHA"
200   PRINT " 8 = RHO TO RETURN LOSS  -------------------------    (6)"
210   PRINT " 9 = RHO TO VSWR  ---------------------------------  (6,7)"
220   PRINT "10 = RHO TO MISMATCH LOSS -------------------------  (6,7)"
230   PRINT "11 = Rs+/-JXs TO Rp,JXp --------------------------  (5,14)"
240   PRINT "12 = Rp,JXp TO Rs+/-JXs --------------------------    (11)"
250   PRINT "13 = Rs+/-JXs TO Z ANGLE THETA -------------------  (5,12)"
260   PRINT "14 = Z ANGLE THETA TO Rs+/-JXs -------------------    (13)"
270   INPUT "TYPE YOUR SELECTION, 1 TO 14",Elect
```

Figure 1. Toolkit menu.

```
460   PRINT "SNR DEGRADATION VS SIGNAL TO INTERFERENCE RATIO (SIR)"
510   Nsrabs=10^(-Snr/10)     !NSRABS=NOISE TO SIGNAL RATIO
520   Israbs=10^(-Sir/10)     !ISR=INTERFERENCE TO SIGNAL RATIO
530   Newsnr=-10*LGT(Nsrabs+Israbs)
540   Degrad=Snr-Newsnr

650   PRINT "SIGNAL TO INTERFERENCE(SIR) RATIO GIVEN SNR AND DEGRADATION"
700   Nsrabs=10^(-Snr/10)
710   Newsnr=Snr-Degrad
720   Newnsrabs=10^(-Newsnr/10)
730   Israbs=-Nsrabs+Newnsrabs   !INTERFERENCE TO SIGNAL RATIO
740   Sirdb=-10*LGT(Israbs)    !SIG TO INTERFERENCE RATIO IN DB

1060        PRINT "   CALCULATES POWER ADDED TO KNOWN POWER TO GIVE KNOWN SUM"
1220  P2dbm=10*LGT(10^(Psumdbm/10)-10^(P1dbm/10))
1230  IF Which=2 THEN P2dbm=20*LGT(10^(Psumdbm/20)-10^(P1dbm/20))
```

Figure 2. Formulas for menu selections 1, 2 and 4.

```
820 Pwradd:   !ADD TWO POWERS IN DBM
830    PRINT "POWER OR VOLTAGE ADDITION OF TWO POWERS"
840    PRINT
850   INPUT "ENTER 1 FOR POWER ADDITION, 2 FOR VOLTAGE",P_or_v
860   IF P_or_v=1 THEN
870   PRINT "  P1   dBM       P2 dBM       Psum dBM (POWER ADDITION)"
880   ELSE
890   PRINT "  P1   dBM       P2 dBM       Psum dBM (VOLTAGE ADDITION)"
900   END IF
910   INPUT "ENTER FIRST POWER IN dBM",P1
920   INPUT "ENTER SECOND POWER IN dBM",P2
930   Psum=10*LGT(10^(P1/10)+10^(P2/10))
940   IF P_or_v=2 THEN Psum=20*LGT(10^(P1/20)+10^(P2/20))
950 Fmta:  IMAGE 2X,S3D.2D,6X,S3D.2D,5X,S3D.2D
960   PRINT USING Fmta;P1,P2,Psum
970   INPUT "1=SUM 2 NEW POWERS, 2=NEW POWER+OLD SUM, 3=MENU",Ques
980   IF Ques=1 THEN 910
990   IF Ques=2 THEN
1000  P1=Psum
1010  GOTO 920
1020  END IF
1030  IF Ques=3 THEN 70
1040  RETURN
```

Figure 3. Subroutine for menu selection 3.

About the Author

Richard Bain is a senior design engineer for E-Systems, ECI Division, Box 12248, St. Petersburg, FL 33733. His current work is in the design and analysis of receiver systems.

```
10 'save toolkit
20 DIM RHO(100),ALPHA(100),RETLOS(100),RS(100),JXS(100),VSWR(100),THETA(100)
30 DIM RP(100),JXP(100),HEADER$(80),DAT1(100 ,DAT2(100),DAT3(100),DAT4(100)
40 DIM IMPED(100),SNR(100),SIR(100),NSRABS(100),ISRABS(100),NEWSNR(100),DEGRAD(1
00)
50 ZO=50:KLOG=4.34294:PI=3.14159265#
60 '
70 CLS
80 PRINT "********************MAIN MENU***************************"
90 PRINT
100 '
110 'BY RICHARD BAIN 10/24/86
120 KEY ON
130 PRINT " 1 = SNR DEGREDATION FOR A GIVEN LEVEL OF INTERFERENCE"
140 PRINT " 2 = INTERFERENCE LEVEL FOR A GIVEN SNR DEGRADATION"
150 PRINT " 3 = POWER OR VOLTAGE SUM OF TWO POWERS IN dBM"
160 PRINT " 4 = UNKNOWN POWER IN dBM  GIVEN SUM & ONE POWER"
170 PRINT "        MENU ITEMS 5 TO 14 ACCEPT DATA FROM:        MENU ITEMS"
180 PRINT " 5 = RHO ANGLE ALPHA TO Rs+/-JXs ----------------  (7)"
190 PRINT " 6 = Rs+/-JXs TO RHO ANGLE ALPHA ------------------(12,14)"
200 PRINT " 7 = RETURN LOSS TO RHO (REFLECTION COEFFICIENT)"
210 PRINT " 8 = RHO TO RETURN LOSS ---------------------------- (6)"
220 PRINT " 9 = RHO TO VSWR ----------------------------------- (6,7)"
230 PRINT "10 = RHO TO MISMATCH LOSS -------------------------- (6,7)"
240 PRINT "11 = Rs+/-JXs TO Rp,JXp ---------------------------- (5,14)"
250 PRINT "12 = Rp,JXp TO Rs+/-JXs ---------------------------- (11)"
260 PRINT "13 = Rs+/-JXs TO Z ANGLE THETA --------------------- (5,12)"
270 PRINT "14 = Z ANGLE THETA TO Rs+/-JXs --------------------- (13)"
280 INPUT "TYPE YOUR SELECTION, 1 TO 14"; ELECT
290 CLS:KEY OFF
300 IF ELECT=1 THEN GOSUB 460
310 IF ELECT=2 THEN GOSUB 790
320 IF ELECT=3 THEN GOSUB 1140
330 IF ELECT=4 THEN GOSUB 1520
340 IF ELECT=5 THEN GOSUB 1880
350 IF ELECT=6 THEN GOSUB 2410
360 IF ELECT=7 THEN GOSUB 2980
370 IF ELECT=8 THEN GOSUB 3330
380 IF ELECT=9 THEN GOSUB 3720
390 IF ELECT=10 THEN GOSUB 4080
400 IF ELECT=11 THEN GOSUB 4460
410 IF ELECT=12 THEN GOSUB 4890
420 IF ELECT=13 THEN GOSUB 5320
430 IF ELECT=14 THEN GOSUB 5770
440 GOTO 120
450 '*********  START OF SUBROUTINES  *********************
460 'THIS SUB CALCULATES SNR DEGRADATION VS INTERFERING SIG LEVEL
470 NUM=0
480 PRINT "SNR DEGRADATION VS SIGNAL TO INTERFERENCE RATIO (SIR)"
490 NUM=NUM+1
500 INPUT "SIGNAL TO NOISE RATIO(dB)=? ",SNR(NUM)
510 INPUT "SIGNAL TO INTERFERENCE RATO(dB)=? ",SIR(NUM)
520 NSRABS(NUM)=10^(-SNR(NUM)/10) 'NSRABS=NOISE TO SIGNAL RATIO
530 ISRABS(NUM)=10^(-SIR(NUM)/10) 'ISRABS=INTERFERENCE TO SIGNAL RATIO
540 NEWSNR(NUM)=-4.34294*LOG(NSRABS(NUM)+ISRABS(NUM))
550 DEGRAD(NUM)=SNR(NUM)-NEWSNR(NUM)
560 INPUT "1 = NEW SET OF VALUES, 2 = PRINT RESULTS ",CHOOSE
570 IF CHOOSE=1 THEN GOTO 490
580 CLS
590 PRINT "SNR DEGRADATION VS SIGNAL TO INTERFERENCE RATIO (SIR)"
600 PRINT
610 PRINT "   SNR dB      SIR dB    NEW SNR dB   DEGRAD dB"
620 FOR M=1 TO NUM
630 PRINT USING "    +###.##";SNR(M),SIR(M),NEWSNR(M),DEGRAD(M)
640 NEXT M
650 LOCATE 25,1
660 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ",DUMPIT
670 IF DUMPIT=2 THEN 740
680 LPRINT "SNR DEGRADATION VS SIGNAL TO INTERFERENCE RATIO (SIR)"
690 LPRINT
700 LPRINT "   SNR dB      SIR dB    NEW SNR dB   DEGRAD dB"
710 FOR M=1 TO NUM
720 LPRINT USING "    +###.##";SNR(M),SIR(M),NEWSNR(M),DEGRAD(M)
730 NEXT M
740 LOCATE 25,1
750 INPUT"PRESS ENTER TO RETURN TO MENU     ";ANYKEY
760 CLS
770 ELECT=20  'MENU VAR SET OUT OF RANGE
780 RETURN
790  '*********** MENU ITEM 2 *****************
800 NUM=0
810 PRINT "SIGNAL TO INTERFERENCE RATIO (SIR) GIVEN SNR AND DEGRADATION"
820 NUM=NUM+1
830 INPUT "ENTER KNOWN SIGNAL TO NOISE RATIO ",SNR(NUM)
840 INPUT "ENTER KNOWN DEGRADATION IN dB ",DEGRAD(NUM)
850 NSRABS=10^(-SNR(NUM)/10)
860 NEWSNR(NUM)=SNR(NUM)-DEGRAD(NUM)
870 NEWNSRABS=10^(-NEWSNR(NUM)/10)
880 ISRABS=-NSRABS+NEWNSRABS
890 SIRDB(NUM)=-KLOG*LOG(ISRABS)
900 INPUT"1 = NEW SET OF VALUES, 2 = PRINT RESULTS ",CHOOSE
910 IF CHOOSE=1 THEN GOTO 820
920 CLS
930 PRINT"SIGNAL TO INTERFERENCE RATIO (SIR) GIVEN SNR AND DEGRADATION"
940 PRINT
950 PRINT"      SNR dB      DEGRAD dB    NEW SNR dB   SIR dB"
960 PRINT
970 FOR M=1 TO NUM
980 PRINT USING"      +###.##";SNR(M),DEGRAD(M),NEWSNR(M),SIRDB(M)
990 NEXT M
1000 LOCATE 25,1
1010 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ",DUMPIT
1020 IF DUMPIT=2 THEN 1090
1030 LPRINT"SIGNAL TO INTERFERENCE RATIO (SIR) GIVEN SNR AND DEGRADATION"
1040 LPRINT
1050 LPRINT"      SNR dB      DEGRAD dB    NEW SNR dB   SIR dB"
1060 FOR M=1 TO NUM
1070 LPRINT USING"      +###.##";SNR(M),DEGRAD(M),NEWSNR(M),SIRDB(M)
1080 NEXT M
1090 LOCATE 25,1
1100 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
1110 CLS
1120 ELECT=20
1130 RETURN
1140 '***************** MENU ITEM 3  *********************
1150 NUM=0
1160 PRINT"    POWER OR VOLTAGE SUM OF TWO POWERS IN dBm"
1170 PRINT
1180 INPUT"ENTER 1 FOR POWER ADDITION, 2 FOR VOLTAGE ADDITION ",P.OR.V
1190 NUM=NUM+1
1200 PRINT
1210 INPUT"ENTER FIRST POWER IN dBm ",P1(NUM)
1220 INPUT"ENTER SECOND POWER IN dBm ",P2(NUM)
1230 PSUM(NUM)=KLOG*LOG(10^(P1(NUM)/10)+10^(P2(NUM)/10)) 'POWER ADDITION
1240 IF P.OR.V=2 THEN PSUM(NUM)=2*KLOG*LOG(10^(P1(NUM)/20)+10^(P2(NUM)/20))
1250 INPUT"1 = ADD ANOTHER POWER TO SUM, 2 = CONTINUE ",WHICH
1255 'NOTE THAT P1 AND P2 WILL NOT BE CORRECT ON PRINTOUT FOR ABOVE STEP
1260 IF WHICH=1 THEN  P1(NUM)=PSUM(NUM): GOTO 1220
1270 INPUT"1 = NEW SET OF VALUES, 2 = PRINT RESULTS ",CHOOSE
1280 IF CHOOSE=1 THEN  1190
1290 CLS
1300 IF P.OR.V=1 THEN PRINT"     POWER ADDITION OF TWO POWERS IN dBm"
1310 IF P.OR.V=2 THEN PRINT"    VOLTAGE ADDITON OF TWO POWERS IN dBm"
1320 PRINT
1330 PRINT"     P1 dBm      P2 dBm      Psum dBm"
1340 PRINT
1350 FOR M=1 TO NUM
1360 PRINT USING "     +###.##";P1(M),P2(M),PSUM(M)
1370 NEXT M
1380 LOCATE 25,1
1390 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP  ",DUMPIT
1400 IF DUMPIT=2 THEN 1470
1410 IF P.OR.V=1 THEN LPRINT"     P1 dBm      P2 dBm      Psum dBm  (POWER SUM)"
1420 IF P.OR.V=2 THEN LPRINT"     P1 dBm      P2 dBm      Psum dBm  (VOLTAGE SUM)"
'ADDED COMMENT
1430 LPRINT
1440 FOR M=1 TO NUM
1450 LPRINT USING "     +###.##";P1(M),P2(M),PSUM(M)
1460 NEXT M
1470 LOCATE 25,1
1480 INPUT"PRESS ENTER TO RETURN TO MENU      ",ANYKEY
1490 CLS
1500 ELECT=20
1510 RETURN
1520 '*************** MENU ITEM 4 **********************
1530 PRINT"  UNKNOWN POWER ADDED TO KNOWN POWER TO GIVE KNOWN SUM (dBm)"
1540 NUM=0
```

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1550 PRINT
1560 INPUT"ENTER 1 FOR POWER SUBTRACTION, 2 FOR VOLTAGE ",P.OR.V
1570 NUM=NUM+1
1580 INPUT"ENTER KNOWN POWER (P1) IN dBm ",P1(NUM)
1590 INPUT"ENTER KNOWN SUM (Psum) IN dBm ",PSUM(NUM)
1600 IF P1(NUM))PSUM(NUM) THEN PRINT"Psum MUST BE ) P1! ":INPUT"PUSH ENTER TO CO
NTINUE",ANYCHAR:GOTO 1580
1610 P2(NUM)=KLOG*LOG(10^(PSUM(NUM)/10)-10^(P1(NUM)/10)) 'POWER DIFFERENCE
1620 IF P.OR.V=2 THEN P2(NUM)=2*KLOG*LOG(10^(PSUM(NUM)/20)-10^(P1(NUM)/20))
1630 INPUT"1 = NEW SET OF VALUES, 2 = PRINT RESULTS ";CHOOSE
1640 IF CHOOSE=1 THEN 1570
1650 CLS
1660 PRINT"   UNKNOWN POWER ADDED TO KNOWN POWER TO GIVE A KNOWN SUM (dBm)"
1670 IF P.OR.V=1 THEN PRINT"                POWER SUBTRACTION"
1680 IF P.OR.V=2 THEN PRINT"               VOLTAGE SUBTRACTION"
1690 PRINT
1700 PRINT"     Psum dBm      P1 dBm      Punknown dBm"
1710 FOR M=1 TO NUM
1720 PRINT USING "      +###.##";PSUM(M),P1(M),P2(M)
1730 NEXT M
1740 LOCATE 25,1
1750 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ",DUMPIT
1760 IF DUMPIT=2 THEN 1850
1770 LPRINT"   UNKNOWN POWER ADDED TO KNOWN POWER TO GIVE A KNOWN SUM (dBm)"
1780 IF P.OR.V=1 THEN LPRINT"                POWER SUBTRACTION"
1790 IF P.OR.V=2 THEN LPRINT"               VOLTAGE SUBTRACTION"
1800 LPRINT
1810 LPRINT"     Psum dBm      P1 dBm      Punknown dBm"
1820 FOR M=1 TO NUM
1830 LPRINT USING "      +###.##";PSUM(M),P1(M),P2(M)
1840 NEXT M
1850 LOCATE 25,1
1860 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
1870 CLS:ELECT=20:RETURN
1880 '******************** MENU ITEM 5 *************************
1890 '
1900 PRINT"    CONVERTS RHO ANGLE ALPHA TO Rs+/-JXs"
1910 PRINT"          (RHO IS REFLECTION COEFFICIENT)"
1920 PRINT
1930 PRINT"PLEASE INDICATE IF THE DATA TO BE USED IS MENU SELECTION 7"
1940 PRINT"THAT IS TO BE CONVERTED OR IF NEW DATA IS BEING ENTERED."
1950 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
1960 IF WHICH=2 AND DATYPE()7 THEN PRINT"WRONG DATA TYPE, PRESS CONTINUE FOR MEN
U":STOP:GOTO 120
1970 CLS
1980 IF WHICH=2 THEN 2060
1990 NUM=1 'NOTE THAT NUM IS IMPORTED FROM MENU ITEM 7 IF OLD DATA USED
2000 PRINT
2010 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
2020 INPUT"ENTER RHO,ANGLE ",RHO(NUM),ALPHA(NUM)
2030 IF RHO(NUM)=0 AND ALPHA(NUM)=0 THEN NUM=NUM-1:GOTO 2060
2040 NUM=NUM+1
2050 GOTO 2020
2060 FOR N=1 TO NUM
2070 A=1+RHO(N)*COS(ALPHA(N)*PI/180)
2080 C=1-RHO(N)*COS(ALPHA(N)*PI/180)
2090 B=RHO(N)*SIN(ALPHA(N)*PI/180)
2100 D=(A^2+B^2)^.5
2110 E=(C^2+B^2)^.5
2120 K=D/E
2130 ANG=(ATN(B/A)-ATN(-B/C))
2140 RS(N)=ZO*K*COS(ANG)
2150 JXS(N)=ZO*K*SIN(ANG)
2160 NEXT N
2170 DATYPE=5
2180 CLS
2190 PRINT"     RHO ANGLE ALPHA CONVERTED TO Rs+/-JXs"
2200 PRINT
2210 PRINT"        RHO       ALPHA Deg.     Rs Ohms       JXs Ohms"
2220 FOR N=1 TO NUM
2230 PRINT USING"      +###.##";RHO(N),ALPHA(N);
2240 PRINT USING"      +#.###^^^^";RS(N),JXS(N)
2250 NEXT N
2260 LOCATE 25,1
2270 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
2280 IF DUMPIT=2 THEN 2360
2310 LPRINT"        RHO       ALPHA Deg.     Rs Ohms       JXs Ohms"
2320 FOR N=1 TO NUM
```

```
2330 LPRINT USING"     +###.##":RHO(N),ALPHA(M);
2340 LPRINT USING"     +#.###^^^^":RS(N),JXS(M)
2350 NEXT N
2360 LOCATE 25,1
2370 INPUT"PRESS ENTER TO RETURN TO MENU",ANYKEY
2380 CLS
2390 ELECT=20
2400 RETURN
2410 '******************** MENU ITEM 6 ********************
2420 '
2430 PRINT"   CONVERTS Rs+/-JXs TO RHO ANGLE ALPHA"
2440 PRINT
2450 PRINT"PLEASE INDICATE IF OLD DATA IS BEING USED, OR"
2460 PRINT"IF NEW DATA WILL BE ENTERED"
2470 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
2480 IF WHICH=2 AND DATYPE()12 AND DATYPE()14 THEN PRINT"WRONG DATA TYPE, PRESS
CONTINUE FOR MENU":STOP:GOTO 120
2490 CLS
2500 IF WHICH=2 THEN 2580
2510 NUM=1
2520 PRINT
2530 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
2540 INPUT"ENTER Rs,JXs IN OHMS, WITH SIGN ",RS(NUM),JXS(NUM)
2550 IF RS(NUM)=0 AND JXS(NUM)=0 THEN NUM=NUM-1:GOTO 2580
2560 NUM=NUM+1
2570 GOTO 2540
2580 FOR N=1 TO NUM
2590 IF RS(N)=ZO THEN RS(N)=ZO+.001
2600 A=((RS(N)-ZO)^2+JXS(N)^2)^.5
2610 B=((RS(N)+ZO)^2+JXS(N)^2)^.5
2620 RHO(N)=A/B 'MAGNITUDE OF RHO
2630 COSANG1=JXS(N)/A
2640 SINANG1=(RS(N)-ZO)/A
2650 THETA1=ATN(JXS(N)/(RS(N)-ZO))*180/PI 'CALC ARCTAN & CONVERT TO DEGREES
2660 IF COSANG1(0 AND SINANG1(0 THEN THETA1=THETA1-180
2670 IF COSANG1)0 AND SINANG1(0 THEN THETA1=THETA1+180
2680 'ABOVE 2 STEPS PUT ANGLE IN PROPER QUADRANT
2690 THETA2=ATN(JXS(N)/(RS(N)+ZO))*180/PI
2700 ALPHA(N)=THETA1-THETA2
2710 IF JXS(N)=0 AND RS(N)(50 THEN ALPHA(N)=180  'CORRECTS ANAMOLY @ JXS(N)=0
2720 NEXT N
2730 DATYPE=6
2740 CLS
2750 PRINT"      Rs+/-JXs CONVERTED TO RHO ANGLE ALPHA"
2760 PRINT
2770 PRINT"     Rs ohms          JXs ohms          RHO      ALPHA deg."
2780 FOR N=1 TO NUM
2790 PRINT USING"     +#.###^^^^";RS(N),JXS(N);
2800 PRINT USING"      .####";RHO(N);
2810 PRINT USING"      +###.#";ALPHA(N)
2820 NEXT N
2830 LOCATE 25,1
2840 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
2850 IF DUMPIT=2 THEN 2940
2880 LPRINT"     Rs ohms          JXs ohms          RHO      ALPHA deg."
2885 LPRINT
2890 FOR N=1 TO NUM
2900 LPRINT USING"     +#.###^^^^";RS(N),JXS(N);
2910 LPRINT USING"      .####";RHO(N);
2920 LPRINT USING"      +###.#";ALPHA(N)
2930 NEXT N
2940 LOCATE 25,1
2950 INPUT"PRESS ENTER TO RETURN TO MENU      ",ANYKEY
2960 CLS:ELECT=20:RETURN
2970 '
2980 '******************** MENU ITEM 7 ********************
2990 '
3000 PRINT"          RETURN LOSS IN dB CONVERTED TO RHO"
3010 PRINT"             (RHO IS REFLECTION COEFFICIENT)"
3020 PRINT
3030 NUM=1
3040 PRINT"ENTER 0  FOR DATA TO END INPUT"
3050 INPUT"ENTER RETURN LOSS IN dB (POSITIVE VALUE) ",RETLOSS(NUM)
3060 IF RETLOSS(NUM)=0 THEN NUM=NUM-1:GOTO 3100
3070 NUM=NUM+1
3080 GOTO 3050
3090 CLS
3100 FOR N=1 TO NUM
3110 RHO(N)=10^(-RETLOSS(N)/20)
3120 NEXT N
3130 DATYPE=7:CLS
3140 PRINT"       RET LOSS dB     RHO"
3150 PRINT
3160 FOR N=1 TO NUM
3170 PRINT USING"        +##.##";RETLOSS(N);
3180 PRINT USING"       #.###^^^^";RHO(N)
3190 NEXT N
3200 LOCATE 25,1
3210 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
3220 IF DUMPIT=2 THEN 3290
3230 LPRINT"       RET LOSS dB     RHO"
3240 LPRINT
3250 FOR N=1 TO NUM
3260 LPRINT USING"        +##.##";RETLOSS(N);
3270 LPRINT USING"       #.###^^^^";RHO(N)
3280 NEXT N
3290 LOCATE 25,1
3300 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
3310 CLS:ELECT=20:RETURN
3320 'NEXT SUB
3330 '******************** MENU ITEM 8 ********************
3340 '
3350 PRINT"          RHO CONVERTED TO RETURN LOSS IN dB"
3360 PRINT
3370 PRINT" PLEASE INDICATE IF OLD DATA WILL BE USED"
3380 PRINT" OR IF NEW DATA WILL BE ENTERED"
3390 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
3400 IF WHICH=2 AND DATYPE()6 THEN PRINT"WRONG DATA TYPE, PRESS CONTINUE FOR MEN
U":STOP:GOTO 120
3410 CLS: IF WHICH=2 THEN 3470
3420 NUM=1:PRINT
3430 PRINT"TO END INPUT: ENTER 0 FOR DATA"
3440 INPUT"ENTER RHO (REFL COEF) ",RHO(NUM)
3450 IF RHO(NUM)=0 THEN NUM=NUM-1:GOTO 3470
3460 NUM=NUM+1:GOTO 3440
3470 FOR N=1 TO NUM
3480 RETLOSS(N)=-2*KLOG*LOG(RHO(N))
3490 NEXT N
3500 DATYPE=8:CLS
3510 PRINT"          RHO CONVERTED TO RETURN LOSS IN dB"
3520 PRINT
3530 PRINT"          RHO          RETLOSS dB"
3540 PRINT
3550 FOR N=1 TO NUM
3560 PRINT USING"       #.###^^^^";RHO(N);
3570 PRINT USING"       +##.###";RETLOSS(N)
3580 NEXT N
3590 LOCATE 25,1
3600 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ",DUMPIT
3610 IF DUMPIT=2 THEN 1850
3640 LPRINT"          RHO          RETLOSS dB"
3650 LPRINT
3660 FOR N=1 TO NUM
3670 LPRINT USING"       #.###^^^^";RHO(N);
3680 LPRINT USING"       +##.###";RETLOSS(N)
3690 NEXT N
3700 LOCATE 25,1:INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
3710 CLS:ELECT=20:RETURN
3720 '******************** MENU ITEM 9 ********************
3730 '
3740 PRINT"          RHO CONVERTED TO VSWR (RHO NOT IN dB)"
3750 PRINT
3760 PRINT" PLEASE INDICATE IF OLD DATA WILL BE USED"
3770 PRINT" OR IF NEW DATA WILL BE ENTERED"
3780 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
3790 IF WHICH=2 AND DATYPE()6 AND DATYPE()7 THEN PRINT"WRONG DATA TYPE, PRESS CO
NTINUE FOR MENU":STOP:GOTO 120
3800 IF WHICH=2 THEN 3860
3810 NUM=1:PRINT
3820 PRINT"TO END INPUT: ENTER 0 FOR DATA"
3830 INPUT"ENTER RHO (REFL COEF) ",RHO(NUM)
3840 IF RHO(NUM)=0 THEN NUM=NUM-1:GOTO 3860
3850 NUM=NUM+1:GOTO 3830
3860 FOR N=1 TO NUM
3870 VSWR(N)=(1+RHO(N))/(1-RHO(N))
3880 NEXT N
3890 DATYPE=9:CLS
3900 PRINT"          RHO CONVERTED TO VSWR"
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```
3910 PRINT
3920 PRINT"        RHO         VSWR"
3930 FOR N=1 TO NUM
3940 PRINT USING"       #.####";RHO(N);
3950 PRINT USING"       ##.##";VSWR(N)
3960 NEXT N
3970 LOCATE 25,1
3980 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ",DUMPIT
3990 IF DUMPIT=2 THEN 4050
4000 LPRINT"        RHO         VSWR"
4010 FOR N=1 TO NUM
4020 LPRINT USING"       #.####";RHO(N);
4030 LPRINT USING"       ##.##";VSWR(N)
4040 NEXT N
4050 LOCATE 25,1:INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
4060 CLS:ELECT=20:RETURN
4070 '
4080 '********************* MENU ITEM 10 **********************
4090 '
4100 PRINT"              RHO CONVERTED TO MISMATCH LOSS IN dB"
4110 PRINT
4120 PRINT" PLEASE INDICATE IF OLD DATA WILL BE USED"
4130 PRINT" OR IF NEW DATA WILL BE ENTERED"
4140 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
4150 IF WHICH=2 AND DATYPE()6 AND DATYPE() 7 THEN PRINT"WRONG DATA TYPE, PRESS C
ONTINUE FOR MENU":STOP:GOTO 120
4160 CLS: IF WHICH=2 THEN 4220
4170 NUM=1:PRINT
4180 PRINT"TO END INPUT: ENTER 0 FOR DATA"
4190 INPUT"ENTER RHO (REFL COEF) ",RHO(NUM)
4200 IF RHO(NUM)=0 THEN NUM=NUM-1:GOTO 4220
4210 NUM=NUM+1:GOTO 4190
4220 FOR N=1 TO NUM
4230 MMLOSS(N)=-KLOG*LOG(1-RHO(N)^2) 'MISMATCH LOSS IN dB
4240 NEXT N
4250 DATYPE=10:CLS
4260 PRINT"              RHO CONVERTED TO MISMATCH LOSS IN dB"
4270 PRINT
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4280 PRINT"       RHO        MISMATCH LOSS dB"
4290 PRINT
4300 FOR N=1 TO NUM
4310 PRINT USING"        #.####";RHO(N);
4320 PRINT USING"      +##.###";MMLOSS(N)
4330 NEXT N
4340 LOCATE 25,1
4350 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP ',DUMPIT
4360 IF DUMPIT=2 THEN 4430
4370 LPRINT"       RHO        MISMATCH LOSS dB"
4380 LPRINT
4390 FOR N=1 TO NUM
4400 LPRINT USING"        #.####";RHO(N);
4410 LPRINT USING"      +##.###";MMLOSS(N)
4420 NEXT N
4430 LOCATE 25,1:INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
4440 CLS:ELECT=20:RETURN
4450 '
4460 '********************** MENU ITEM 11 ***********************
4470 '
4480 PRINT"      CONVERTS Rs+/-JXs TO Rp,JXp (ALL IN OHMS)"
4490 PRINT
4500 PRINT"PLEASE INDICATE IF OLD DATA IS BEING USED, OR"
4510 PRINT"IF NEW DATA WILL BE ENTERED"
4520 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
4530 IF WHICH=2 AND DATYPE()5 AND DATYPE()14 THEN PRINT"WRONG DATA TYPE, PRESS C
ONTINUE FOR MENU":STOP:GOTO 120
4540 CLS
4550 IF WHICH=2 THEN 4630
4560 NUM=1
4570 PRINT
4580 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
4590 INPUT"ENTER Rs,JXs IN OHMS, WITH SIGN ",RS(NUM),JXS(NUM)
4600 IF RS(NUM)=0 AND JXS(NUM)=0 THEN NUM=NUM-1:GOTO 4630
4610 NUM=NUM+1
4620 GOTO 4590
4630 FOR N=1 TO NUM
4640 IF RS(N)=0 THEN RS(N)=.000001
4650 IF JXS(N)=0 THEN JXS(N)=.000001
4660 JXP(N)=(RS(N)^2+JXS(N)^2)/JXS(N)
4670 RP(N)=(RS(N)^2+JXS(N)^2)/RS(N)
4680 NEXT N
4690 DATYPE=11:CLS
4700 PRINT"      Rs+/-JXs CONVERTED TO Rp,JXp"
4710 PRINT
4720 PRINT"      Rs ohms        JXs ohms        Rp ohms        JXp ohms"
4730 PRINT
4740 FOR N=1 TO NUM
4750 PRINT USING"     +#.###^^^^";RS(N),JXS(N),RP(N),JXP(N)
4760 NEXT N
4770 LOCATE 25,1
4780 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
4790 IF DUMPIT=2 THEN 4850
4800 LPRINT"      Rs ohms        JXs ohms        Rp ohms        JXp ohms"
4810 LPRINT
4820 FOR N=1 TO NUM
4830 LPRINT USING"     +#.###^^^^";RS(N),JXS(N),RP(N),JXP(N)
4840 NEXT N
4850 LOCATE 25,1
4860 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
4870 CLS:ELECT=20:RETURN
4880 '
4890 '********************** MENU ITEM 12 ***********************
4900 '
4910 PRINT"       CONVERTS Rp,JXp TO RS+/-JXS (ALL IN OHMS)"
4920 PRINT
4930 PRINT"PLEASE INDICATE IF OLD DATA IS BEING USED, OR"
4940 PRINT"IF NEW DATA WILL BE ENTERED"
4950 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
4960 IF WHICH=2 AND DATYPE()11 THEN PRINT"WRONG DATA TYPE, PRESS CONTINUE FOR ME
NU":STOP:GOTO 120
4970 CLS
4980 IF WHICH=2 THEN 5060
4990 NUM=1
5000 PRINT
5010 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
5020 INPUT"ENTER Rp,JXp IN OHMS, WITH SIGN ",RP(NUM),JXP(NUM)
5030 IF RP(NUM)=0 AND JXP(NUM)=0 THEN NUM=NUM-1:GOTO 5060
5040 NUM=NUM+1
5050 GOTO 5020
5060 FOR N=1 TO NUM
5070 IF RP(N)=0 THEN RP(N)=.000001
5080 IF JXP(N)=0 THEN JXP(N)=.000001
5090 RS(N)=RP(N)*JXP(N)^2/(RP(N)^2+JXP(N)^2)
5100 JXS(N)=RP(N)^2*JXP(N)/(RP(N)^2+JXP(N)^2)
5110 NEXT N
5120 DATYPE=12:CLS
5130 PRINT"      Rp,JXp CONVERTED TO Rs+/-JXs"
5140 PRINT
5150 PRINT"      Rp ohms        JXp ohms        Rs ohms        JXs ohms"
5160 PRINT
5170 FOR N=1 TO NUM
5180 PRINT USING"     +#.###^^^^";RP(N),JXP(N),RS(N),JXS(N)
5190 NEXT N
5200 LOCATE 25,1
5210 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
5220 IF DUMPIT=2 THEN 5280
5230 LPRINT"      Rp ohms        JXp ohms        Rs ohms        JXs ohms"
5240 LPRINT
5250 FOR N=1 TO NUM
5260 LPRINT USING"     +#.###^^^^";RP(N),JXP(N),RS(N),JXS(N)
5270 NEXT N
5280 LOCATE 25,1
5290 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
5300 CLS:ELECT=20:RETURN
5310 '
5320 '********************** MENU ITEM 13 ***********************
5330 '
5340 PRINT"       CONVERTS Rs+/-JXs TO Z (OHMS) ANGLE THETA (DEG.)"
5350 PRINT
5360 PRINT"PLEASE INDICATE IF OLD DATA IS BEING USED, OR"
5370 PRINT"IF NEW DATA WILL BE ENTERED"
5380 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
5390 IF WHICH=2 AND DATYPE()5 AND DATYPE()12 THEN PRINT"WRONG DATA TYPE, PRESS C
ONTINUE FOR MENU":STOP:GOTO 120
5400 CLS
5410 IF WHICH=2 THEN 5490
5420 NUM=1
5430 PRINT
5440 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
5450 INPUT"ENTER Rs,JXs IN OHMS, WITH SIGN ",RS(NUM),JXS(NUM)
5460 IF RS(NUM)=0 AND JXS(NUM)=0 THEN NUM=NUM-1:GOTO 5490
5470 NUM=NUM+1
5480 GOTO 5450
5490 FOR N=1 TO NUM
5500 IF RS(N)=0 THEN RS(N)=.000001
5510 IF JXS(N)=0 THEN JXS(N)=.000001
5520 THETA(N)=ATN(JXS(N)/RS(N))*180/PI
5530 Z(N)=(RS(N)^2+JXS(N)^2)^.5
5540 NEXT N
5550 DATYPE=13:CLS
5560 PRINT"      Rs+/-JXs CONVERTED TO Z ANGLE THETA"
5570 PRINT
5580 PRINT"      Rs ohms        JXs ohms        Z ohms        THETA deg."
5590 PRINT
5600 FOR N=1 TO NUM
5610 PRINT USING"     +#.###^^^^";RS(N),JXS(N),Z(N);
5620 PRINT USING"     +###.##";THETA(N)
5630 NEXT N
5640 LOCATE 25,1
5650 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
5660 IF DUMPIT=2 THEN 5730
5670 LPRINT"      Rs ohms        JXs ohms        Z ohms        THETA deg."
5680 LPRINT
5690 FOR N=1 TO NUM
5700 LPRINT USING"     +#.###^^^^";RS(N),JXS(N),Z(N);
5710 LPRINT USING"     +###.##";THETA(N)
5720 NEXT N
5730 LOCATE 25,1
5740 INPUT"PRESS ENTER TO RETURN TO MENU     ",ANYKEY
5750 CLS:ELECT=20:RETURN
5760 '
5770 '********************** MENU ITEM 14 ***********************
5780 '
5790 PRINT"       CONVERTS Z (OHMS) ANGLE THETA (DEG.) TO Rs+/-JXs (OHMS)"
5800 PRINT
```
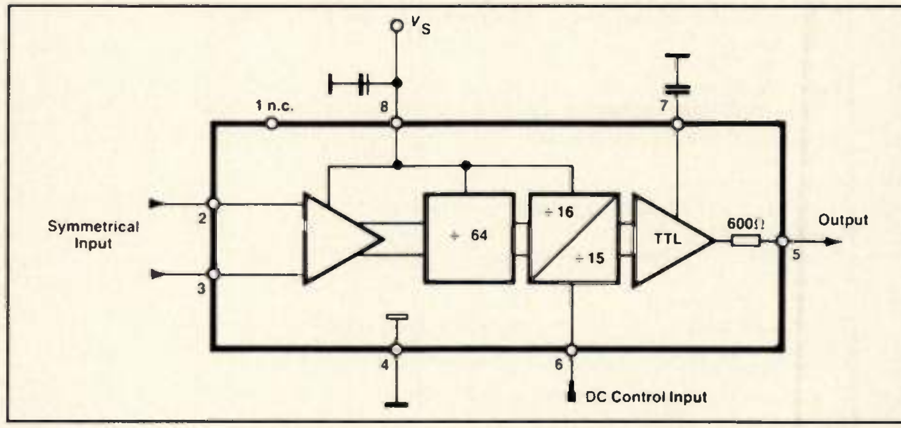

```
5810 PRINT"PLEASE INDICATE IF OLD DATA IS BEING USED, OR"
5820 PRINT"IF NEW DATA WILL BE ENTERED"
5830 INPUT"TYPE 1 TO ENTER NEW DATA, 2 TO USE OLD DATA ",WHICH
5840 IF WHICH=2 AND DATYPE()5 AND DATYPE()12 THEN PRINT"WRONG DATA TYPE, PRESS C
ONTINUE FOR MENU":STOP:GOTO 120
5850 CLS
5860 IF WHICH=2 THEN 5940
5870 NUM=1
5880 PRINT
5890 PRINT"TO END INPUT: ENTER 0,0 FOR DATA"
5900 INPUT"ENTER Z IN OHMS, THETA IN DEGREES ",Z(NUM),THETA(NUM)
5910 IF Z(NUM)=0 AND THETA(NUM)=0 THEN NUM=NUM-1:GOTO 5940
5920 NUM=NUM+1
5930 GOTO 5900
5940 FOR N=1 TO NUM
5950 JXS(N)=Z(N)*SIN(PI*THETA(N)/180)
5960 RS(N)=Z(N)*COS(PI*THETA(N)/180)
5970 NEXT N
5980 DATYPE=14:CLS
5990 PRINT"        Z ANGLE THETA CONVERTED TO Rs+/-JXs"
6000 PRINT
6010 PRINT"      Z ohms          THETA deg.       Rs ohms         JXs ohms"
6020 PRINT
6030 FOR N=1 TO NUM
6040 PRINT USING"      +#.###^^^^";Z(N),THETA(N),RS(N),JXS(N)
6050 NEXT N
6060 LOCATE 25,1
6070 INPUT"1 = DUMP TO PRINTER, 2 = NO DUMP",DUMPIT
6080 IF DUMPIT=2 THEN 6140
6090 LPRINT"      Z ohms          THETA deg.       Rs ohms         JXs ohms"
6100 LPRINT
6110 FOR N=1 TO NUM
6120 LPRINT USING"      +#.###^^^^";Z(N),THETA(N),RS(N),JXS(N)
6130 NEXT N
6140 LOCATE 25,1
6150 INPUT"PRESS ENTER TO RETURN TO MENU      ",ANYKEY
6160 CLS:ELECT=20:RETURN
6170 END
```

Telefunken Introduces UHF and Microwave Prescalers



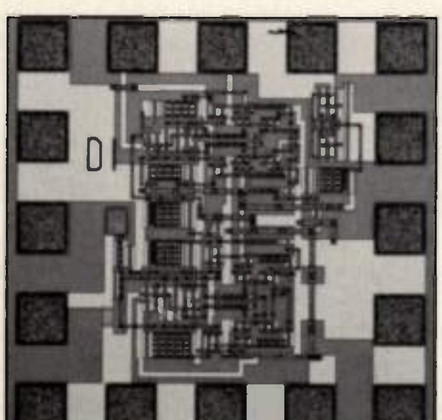
Telefunken introduces a prescaler with an operating frequency range from 1.5 to 5 GHz and a scaling factor of 2. The lower GHz frequencies can be divided by ratios from 2 to 4096. The divider functions as a regenerative analog divide-by-two prescaler. It contains a mixer, amplifier, and low pass filter. The filtered output signal is fed back to one of the two mixer inputs, the other mixer input being the applied signal. Noise appearing on the halved frequency activates the regenerative action when the circuit is turned on. After correct phasing is obtained, the divider locks up to a stable mode of operation. The device features either ECL or TTL outputs. Other features of the prescaler include non self-oscillation, low power consumption (typically 250 mW), few external components for complete utilization and it is available in DIP 8 packaging. High input sensitivity makes this prescaler suitable as companion devices to phased locked loop (PLL) ICs in GHz tuning systems. The device operates on a supply voltage from 4.5 V to 5.5. V with a typical supply current of 50 mA. The operating temperature range is −25 to 70°C. It is designed for optimum performance with the specified input frequency range. To avoid possible damage to the prescaler, it should be handled as a MOS device. In quantities of 100 the device is priced at $1.23. **Telefunken Electronic, Somerville, N.J. INFO/CARD #169.**

DMOS FET for RF Applicators

The SD2100 is a DMOS FET that Siliconix plans to offer as a low-cost alternative to GaAs products for applications under 1 GHz. It offers wide dynamic range and switching speeds as fast as 1 ns. Its features include high-frequency gain, low distortion, low capacitance (2.5 pF maximum) and low power consumption (75 mW typical). The device cost is $3.00/each in 1,000-piece quantities. **Siliconix, Inc., Santa Clara, Calif. INFO/CARD #168.**

GaAs Prescaler Runs at 3 GHz

A new gallium arsenide 3 GHz divide-by-4 prescaler has been developed by Anadigics, Inc. Key specifications for the ADV 3040 include −130 dBc/Hz phase noise, 50 ohm input matching, and ECL compatible output levels over a 0.8 to 3.0 GHz operating frequency range. Also, the device operates over the military temperature range (−55 to +125°C). The ADV 3040 has a single-ended input, 1.5:1 input VSWR, and is a GaAs monolithic chip. **Anadigics, Inc., Warren, N.J. Please circle INFO/CARD #167.**



SMT Inductors

Delevan introduces the series 0820 SMT components which are approximately 25 percent smaller than the 1330/1331 series inductors. They are available in an inductance range from .10 to 1000 uH with a standard tolerance of ±10 percent and are molded with flame retardant epoxy with high temperature internal soldered joints to provide maximum stability during any subsequent operation. **Delevan Division, American Precision Industries, East Aurora, N.Y. Please circle INFO/CARD #166.**

DMOS FET Replaces JFETs

SD2100DE is a D-MOS FET which is compatible with industry standard JFETs. Its gain/bandwidth product exceeds 1 GHZ while the operating bandwidth is 400 MHz. The device provides a performance bridge between conventional silicon FETs and GaAs, while retaining the cost advantages of silicon. The SD2100DE is priced at $1.15 in 100+ quantities. **Topaz Semiconductor, San Jose, Calif. Please circle INFO/CARD #165.**

Broadband Microwave Amplifiers

JCA announces a series of broadband microwave amplifiers that cover from 0.5 GHz to 8.0 GHz. Typical bands are 0.5 to 4 GHz, 1 to 6 GHz and 2 to 8 GHZ. Gain of the amplifiers are from 20 to 30 dB with noise figures as low as 3 dB. The amplifiers are available in miniature and drop-in packages with removeable SMA connectors. **JCA Technology, Inc., Newbury Park, Calif. INFO/CARD #164.**

VDE Approved Power Entry Filters

Curtis power entry filters feature multiple voltage select, power switches, and fusing options. They provide design flexibility and reduced cost over standard models. The filters also provide greater differential-mode attenuation for both general and switch mode power supply applications. **Curtis Industries, Inc., Milwaukee, Wis. INFO/CARD #153.**

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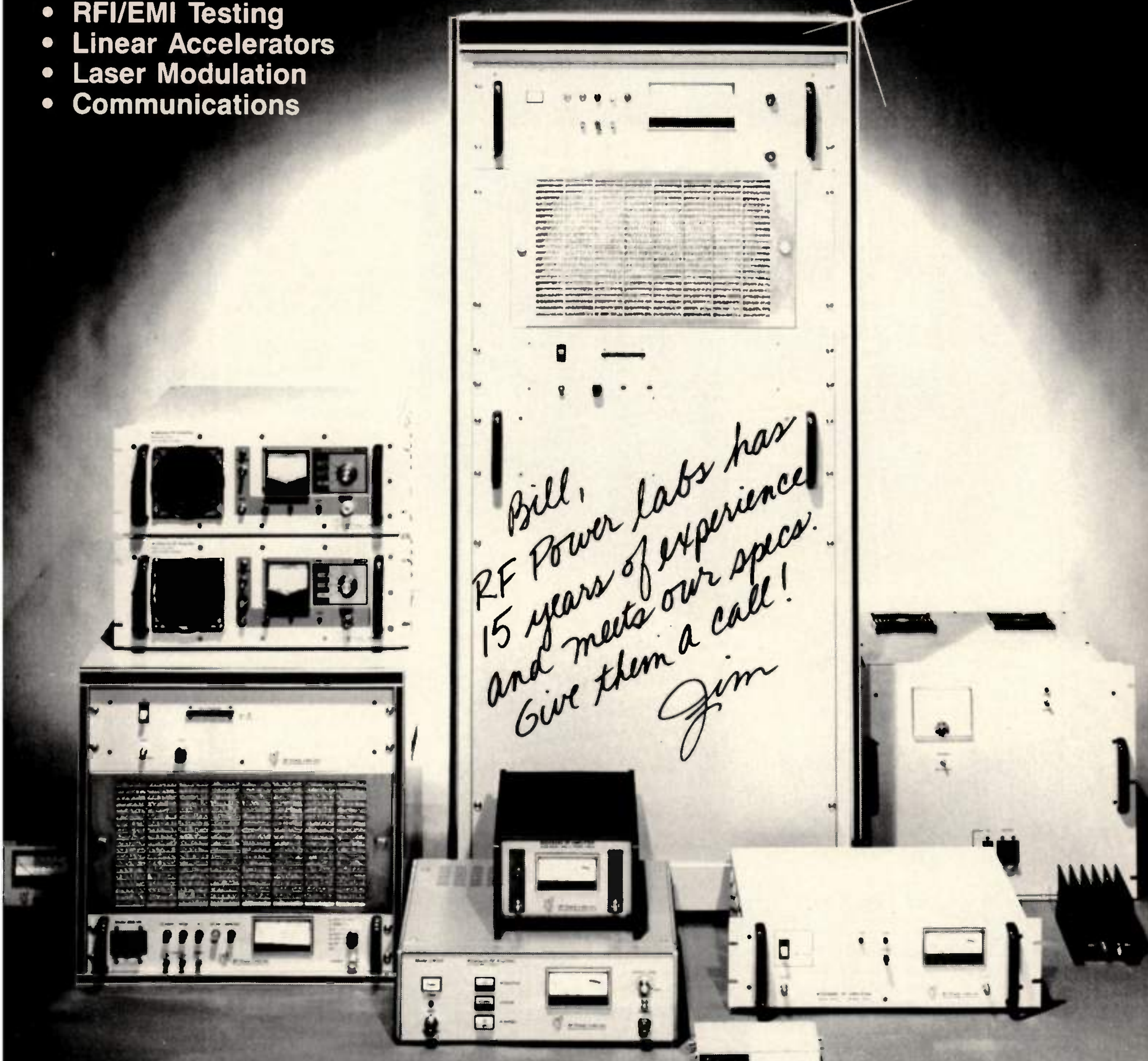

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New Broadband HF Amplifier

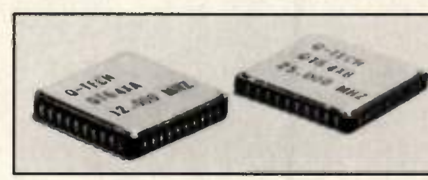
A broadband feedforward amplifier covering the frequency range from .4 MHz to 80 MHz has been introduced by Wi-Comm Electronics Inc. This unit employs a field proven feedforward linearization technique to achieve distortion performance equivalent to a 100 W linear power amplifier. The third order and second order intercept points are typically 62 dBm and 95 dBm. Noise figure is 6 dB and VSWR is better than 1.5:1. **Wi-Comm Electronics, Inc., Massena, N.Y. Please circle INFO/CARD #162.**

300 MHz D/A Converter

A new D/A converter introduced by Analog Devices offers high 300 MHz word rates and low 45 pV-s glitch impulse. The high word rate makes the AD9703 applicable in 2K pixel x 2K pixel displays; the low glitch impulse reduces distortion in displayed images. The AD9703 can be used in standard D/A applications such as waveform generation, video reconstruction and automatic test equipment. The AD9703 incorporates on-chip blanking, composite sync, 10 percent brightness, and reference white control signals. These internal synchronization and control logic capabilitiles combined with an on-chip voltage reference eliminate the need for external circuits. **Analog Devices, Norwood, Mass. Please circle INFO/CARD #161.**

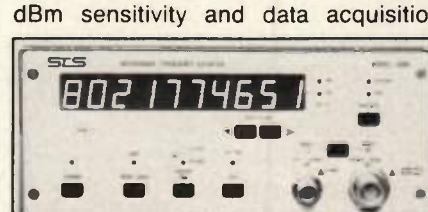
SMT Crystals

Q-Tech introduces a new line of surface mount crystals in two standard 480 mil square 40 pad leadless chip carrier (LCC) packages: the QT64XA and the QT64XB. The devices operate in a frequency range from 5 MHz to 125 MHz. **Q-Tech Corporation, Los Angeles, Calif. Please circle INFO/CARD #160.**



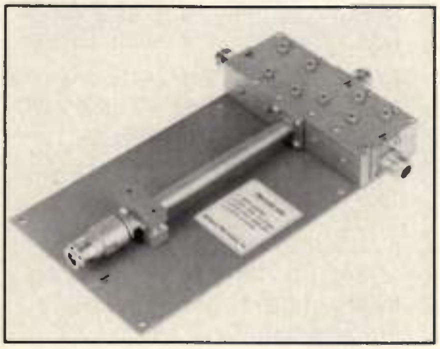
Microwave Counters are Low Cost

STS Instruments Corp. announces a series of high performance microwave counters. The models 3030-3 GHz and 3080-8 GHz feature −45 dBm and −35 dBm sensitivity and data acquisition speeds of less than 60 ms, 10 digit LED readout, power meter, +30 dBm damage levels and operate off either AC or DC power. The units are priced between $2200 and $2900. **STS Instrument Corporation, Oakland, Calif. Please circle INFO/CARD #159.**



Triplexer Handles UHF, ENG and ITFS Bands

Microwave Filter Co. introduces the model 5264 triplexer which combines or splits three separates bands: 0 to 500 MHz UHF, ENG band for 1900-2110 MHz and the 2450-2600 MHz ITFS microwave TV band. The three bands combine to (or split from) the common connector. The device is used in pairs to eliminate the use of three separate tower transmission lines.



One unit combines the UHF radio, ENG receiver and the ITFS receiver in the equipment room while a second tower mounted unit splits each band to its separate antenna. The unit is priced at $1450. **Microwave Filter Company, Inc., East Syracuse, N.Y. INFO/CARD #158.**

Sequence Generator/Scrambler

The model 100 sequence generator/scrambler is a high speed self-starting sequence generator or data scrambler which operates at clock frequencies from 10 MHz to 600 MHz. The sequence generator is a source of data for testing high speed coax, fiber optic or satellite digital communication links. In the sequence generator mode, the model 100 generates a periodic 31 bit maximal length pseudo-random data pattern along with a synchronous clock trigger signal. As a scrambler, the input data is randomized by a five stage register circuit and recovered by the model 200 self-synchronizing descrambler. The unit is priced at $2500. **Broadband Communications Product, Melbourne, Fla. Please circle INFO/CARD #155.**

GaAs MMIC Amplifier Chip

Celeritek's new model CMM-2 is a monolithic gallium arsenide amplifier that covers 2 to 6 GHz with 10 dB typical gain and consumes 125 mW of DC power. Typical gain flatness is +0.5 dB over full bandwidth. The CMM-2 provides a 10.5 dB gain and the associated noise figure is less than 7 dB with the power output at the 1 dB compression point being greater than +0.8 dBm. The unit is priced under $450. **Celeritek, San Jose, Calif. Please circle INFO/CARD #154.**

VCO for Pulse Compression Radars

The model VTS392001 features flat power output and ultra linear, high modulation/tuning speed. Tuning a 3.7 to 4.2 GHz range, power out is +13 dBm ±0.5 dB and tuning is linear to ±2 MHz of a best straight line. The MIC RF module contains a single ended bipolar VCO, a FET RF amplifier, a low pass RF filter, and a proportional DC heater. **Westec Communications, Inc., Scottsdale, Ariz. INFO/CARD #163.**

Universal Prototyping Kit

GigaBit Logic introduces a universal prototyping kit for quick prototyping and testing. The kit is designed for systems up to 3 GHz with 100 ps edges. Included with the package are SMA connectors, capacitors and mini-coax for interconnect wiring. **GigaBit Logic, Newbury Park, Calif. INFO/CARD #156.**

Drop-In Lowpass Filter

Sierra Microwave introduces a drop-in lowpass filter (model SM-1029) which allows microstrip or stripline integration. The unit has a cutoff frequency of 2.0 GHz with an insertion loss of 1.5 dB and a VSWR of 1.5:1. In quantities of 1 to 9, the filter is priced at $185. **Sierra Microwave Technology, Rancho Cordova, Calif. INFO/CARD #150.**

Function Generator Offers Cost/Performance

The new Krohn-Hite model 2100 synthesized function pulse generator is an IEEE-488 programmable instrument with a frequency range of 0.01 Hz to 31.16 MHz and a frequency accuracy of 0.00005 percent with 7 digits of resolution. The main output provides a range of 10 uV to 30 V p-p open circuit, with a resolution of 3½ digits and is settable in either AC peak of RMS over the entire range. Modes of operation include continuous, gate, trigger burst, trigger pulse, lin/log sweep and VC. The model 2100 is priced at $3800. **Krohn-Hite Corporation, Avon, Mass. INFO/CARD #152.**

Video Detector Diodes

Custom Components introduces a series of high reliability detector diodes designed for military and aerospace environments. These back diodes are characterized for video detectors up to 26 GHz. They feature high zero bias sensitivity (typically 1100 mV/mW) and low video resistance (typically 135 ohms). **Custom Components, Lebanon, N.J. INFO/CARD #151.**

rf software

Chebyshev Filter Design Program

RF Notes No. 3 Volume 3, is the fifth in a series of design aid programs for radio frequency/analog design. RF Notes No. 3 Vol. 3 will aid in the design of lowpass, highpass, bandpass and band-reject Chebyshev response filters to the 7th order. The program is fully menu driven, and very easy to use. Inputs are in graphical (response curve) form, and the outputs are in schematic diagram form with circuit constants included. The price is $220, color/monochrome selectable. For IBM PC and compatibles; PC/MS DOS 2.1, 256K and color graphics card required. **Etron RF Enterprises, Diamond Bar, Calif. INFO/CARD #149.**

Interactive Simulation Program

TUTSIM, the interactive simulation program for modeling continuous dynamic systems on a microcomputer, handles linear and non-linear functions with ease. With TUTSIM, the Realtime I/O option, and the User Defined Block option the user will be able to take advantage of 73 linear and non-linear functions. In addition, the user will be able to write custom functions with the DeSmet "C" development package supplied as part of the User Defined Block optiuon and use them as an extension of the TUTSIM program. **Applied i, Palo Alto, Calif. Please circle INFO/CARD #148.**

Program Matches Complex Impedances

Analop Engineering introduces, Netsyn-II, a complex impedance matching filter synthesis program for designing amplifier input, output or interstage matching networks. It allows the user to specify a topology up to 12 elements to absorb the parasitic elements of the connecting amplifier stages. The user can choose to do exact lumped or exact distributed synthesis. The program will synthesize exact equal ripple flat or sloped passband response with arbitrary slopes in either direction with user specified minimum insertion loss. The program will output circuit files that can be run by Analop, Touchstone, or Super-Compact. The Netsyn-II synthesis program is priced at $499. **Analop Engineering, Milpitas, Calif. INFO/CARD #147.**

rf literature

Test and Data Equipment Guide is Available

This guide provides information on 5,000 manufacturer's models of electronic test and measurement and data processing equipment. It contains specifications, descriptions, photos and other technical data on a broad variety of product categories. The products listed and described are analyzers, CAE/CAD equipment, microprocessor development systems, counters, desktop controllers, generators, meters, oscilloscopes, recorders, signal modifiers, telecommunications devices, and data processing equipment. The guide is available free of charge. **United States Instrument Rentals, San Mateo, Calif. Please circle INFO/CARD #145.**

Coaxial Products Catalog

The catalog contains a full line of coaxial adapters, coaxial connectors, coaxial attenuators, coaxial terminations and coaxial cable assemblies. Cable assemblies featured are both flexible and semi-rigid. Also featured are twinax connectors, twinax adapters and a full line of hex crimp tools. **Pasternack Enterprises, Irvine, Calif. INFO/CARD #144.**

Frequency Synthesizers Brochure

A 14-page brochure describes a series of 25 swept frequency synthesizers covering the 10 MHz to 40 GHz range. Features described include pulse modulation with a built-in, programmable pulse generator, 15 ms frequency switching speed, less than −60 dB harmonics, and up to 40 mW output power. Also described are characteristics, such as simultaneous FM, AM and pulse modulation, low SSB phase noise, and superb EMC performance, that make these instruments particularly well suited to EW/ECM, radar, and communications applications. **Wiltron Company, Morgan Hill, Calif. INFO/CARD #142.**

Electronics Assembly Sourcebook

The 112-page sourebook contains complete specification and ordering information on hundreds of products including component inserting machines, lead-formers, thru-hole soldering devices, wire processing equipment, PCB storage racks and fixtures, magnifiers, tools and inspection devices. Separate sections are dedicated to surface mount technology and static control devices. Black-and-white photos accompany product descriptions, and pricing for quantity purchases are included. **Henry Mann, Inc., Huntington Valley, Pa. INFO/CARD #141.**

HP Vectra PC Software Catalog

More than 245 technical-software vendors and 600 tested and vendor-verified software products are listed in the new HP Vectra PC Technical Software Catalog from Hewlett-Packard Company. Applications software in the catalog ranges from analog-circuit design to technical word processing. There also are listings for accessories such as light pens, image processors and voice cards. Software vendors contributing to the catalog range from small firms to corporate giants. **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #140.**

Monolithic Capacitors as Transmission Lines

A new brochure describes the results of network analyzer measurements (HP-8510) of ultra-high Q porcelain chip capacitors and shows that the devices have the characteristics of open circuited transmission lines. MIL Spec approved CDR12 and CDR14 capacitors, ranging in capacitance values from 4.7 to 1,000 pF were tested. A simple model of the periodically loaded line provides a dispersion relation that accounts for the distribution of resonant frequencies. The suppression with respect to the microstrip is explained in terms of a uniform line model with distributed excitation. **Dielectric Laboratories, Inc., Cazenovia, N.Y. INFO/CARD #139.**

Multi-Channel Filter Catalog

A short form catalog of dual and multi-channel signal processing filters covers product technology, features, specifications and applications for both benchtop and programmable instruments. It features filter types and methodology, applications for band limiting, digital signal processing, acoustic studies and distortion measurements. **Wavetek San Diego, San Diego, Calif. INFO/CARD #138.**

Buyers Guide for Electrical Contractors

Anixter Bros., Inc. has published a buyers guide entitled "New Buyers Guide of Products & Services for Electrical Contractors." This guide features the wide range of electrical/electronic and communications wire and cable, telecommunications products, and "feeding the job" services Anixter offers. **Anixter Bros., Inc., Skokie, Ill. INFO/CARD #137.**

ESD Protection Test Handbook

KeyTek Instrument Corp. announces the availability of its expanded Second Edition of the Electrostatic Discharge (ESD) Protection Test Handbook. Described are the basic ESD phenomena, various test specification, design alternatives, and test methods. Sections are included describing recently acknowledged effects such as hand capacitance for fast rising currents, and the importance of approach speed in accurately simulating human ESD. **KeyTek Instrument Corp., Wilmington, Mass. INFO/CARD #136.**

SMA Connector Catalog

Catalog 82-689 from AMP Incorporated reviews aspects of SMA coaxial connectors. The 16-page catalog provides electrical, mechanical, and environmental characteristics of SMA connectors for both flexible and semirigid cable. Connectors for flexible cable includes both military-qualified and commercial series. The catalog also features application tooling, including a cable preparation machine, hand and semiautomatic termination tools, and a phase match test connector kit. **AMP Inc., Harrisburg, Pa. INFO/CARD #135.**

Flight Test Systems Catalog

Aydin Vector's new catalog delineates a variety of telemetry and data acquisition systems, instrumentation and support components designed for various missile, aircraft and standoff weapon systems, flight test applications. Instruments detailed include Vector's micro-miniature 900 Series Data Acquisition System, and the ADAS-7000 Airborne Data Acqusition System. RF transmitters and receivers suitable for hi-rel and severe environment applications augment the flight test instrumentation line up. These include synthesized broadband multifrequency video transmitters and receivers, synthesized L/S Band airborne Command/Control receivers, Flight Termination receivers/decoders and accessories such as power amplifiers. **Aydin Vector Division, Newtown, Pa. INFO/CARD #134.**

Reconditioned Test Equipment Catalog

Accutest Instruments, Inc.'s 20-page electronic test equipment catalog features both new and custom-reconditioned items. All custom-reconditioned equipment is thoroughly checked and precision-calibrated. Test equipment offered includes: RF & microwave instruments calibration devices, oscilloscopes, counters and DVMs. **Accutest Instruments, Inc., Paramus, N.J. INFO/CARD #133.**

Precision Trimmer Capacitor Catalog

Voltronics Corporation has issued a catalog of its expanded line of precision trimmer capacitors. The trimmers have dielectrics of glass, quartz, air, Teflon and sapphire. They offer multiturn resolution and high stability. Most have non-rotating pistons and are internally sealed. Maximum capacitance is from 1.2 to 250 pF. High frequency surface mount parts are listed. The catalog specifies more than 109 MIL-C-14409D styles. Prototype kits are listed at less than half price. **Voltronics Corporation, East Hanover, N.J. INFO/CARD #132.**

1987 EMI Catalog

Filter Concepts' catalog details a power line of EMI filters. It features 18 different series of EMI filters, to cover the spectrum of EMI suppression requirements. **Filter Concepts, Inc., Santa Ana, Calif. INFO/CARD #143.**

Brochure Describes "Drop-in" Couplers

Anaren Microweave has published a brochure describing its entire line of miniature "drop-in" hybrid couplers. It lists 73 models of 90° standard and high power couplers. Frequencies range from 30 MHz to 8 GHz in octave and multi-octave bandwidths. Also offered are 4-way combiner/dividers and power handling curves showing power handling capability change as the frequency changes for a given coupler. **Anaren Microwave, Inc., E. Syracuse, N.Y. INFO/CARD #126.**

RCS and Antenna Measurements Brochure

Flam & Russell, Inc. has published a brochure highlighting the ADAM (Automated Digital Analysis and Measurement)/8003 System. The system uses the Hewlett Packard 8510 network analyzer, its associated signal source and a positioner programmer to provide a fully-integrated radar cross section and antenna measurement capability. ADAM/8003 provides broadband coverage, from .045 to 26.5 GHz, expandable to 110 GHz. Complementing its architecture is a menu-driven software package written in Fortran 77 and including on-line user help and extensive error trapping to minimize learning time. **Flam & Russell, Inc., Horsham, Pa. INFO/CARD # 125.**

Guidelines for Capacitor Selection

Dielectric Laboratories introduces a new Engineering Bulletin 0013, which provides guidelines for the selection of capacitors for four typical applications. These guidelines are based on measurements of insertion and return loss and were obtained with the HP-8510 network analyzer using monolithic High-Q porcelain capacitors. The applications are: DC blocking, connected in series in a broadband amplifier; bypassing RF signals, mounted in the shunt connection; low loss reactive circuit element in a filter; and DC blocking or by-passing capacitors are required to operate over a very broad band. **Dielectric Laboratories, Inc., Cazenovia, N.Y. INFO/CARD #124.**

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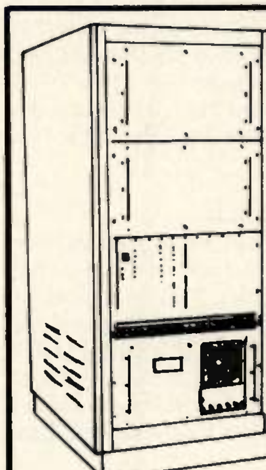

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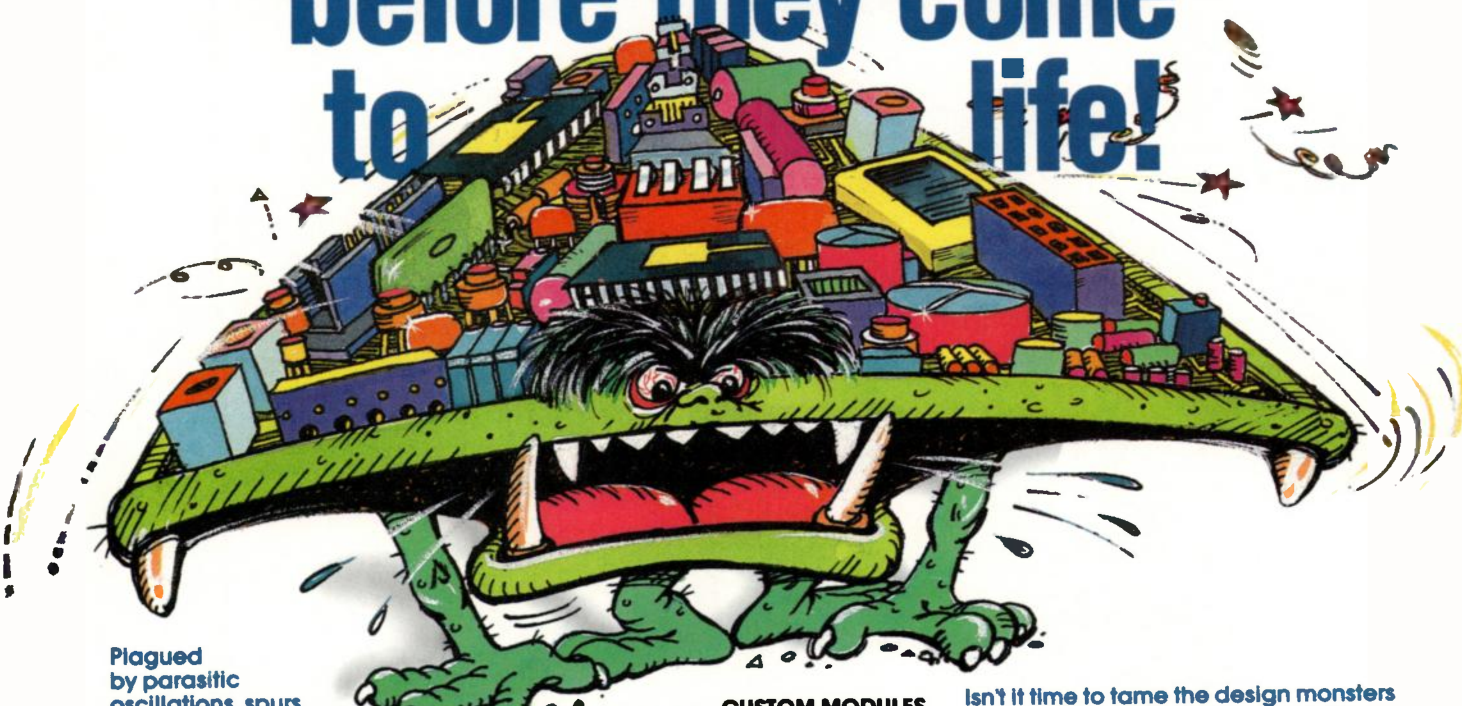
Advertiser's Index

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



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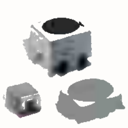
Toko has what you need, so you won't need to compromise... subminiature adjustable coils and transformers, molded coils, radial fixed coils and fixed coils with axial leads. Toko high-Q coils are engineered in sizes from 5mm to 15mm, and inductance ranges from .02 µH to 500 mH.

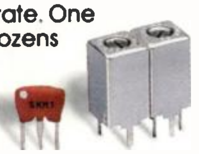
CHIP AND ADJUSTABLE SMD



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

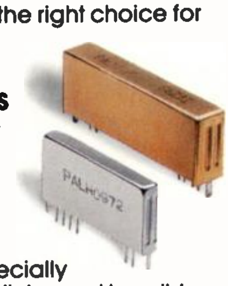
CUSTOM MODULES

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



FILTERS

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



ACTIVE FILTERS

If you're advancing the state-of-the-art in digital audio or PCM products you'll appreciate Toko active filters. Especially designed for small size and low distortion, they're also very cost-effective.

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

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

TOKO

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For more information on:
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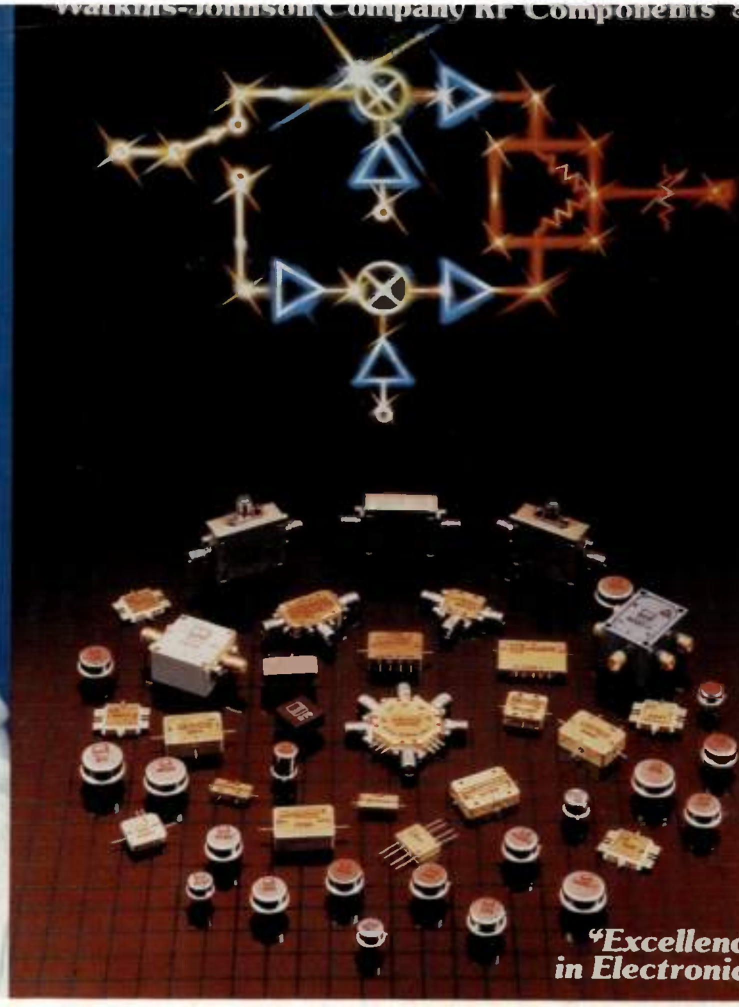
Chip/SMD, Circle 88
Custom Modules, Circle 89
RF & I-F Filters, Circle 90
Active Filters, Circle 91



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