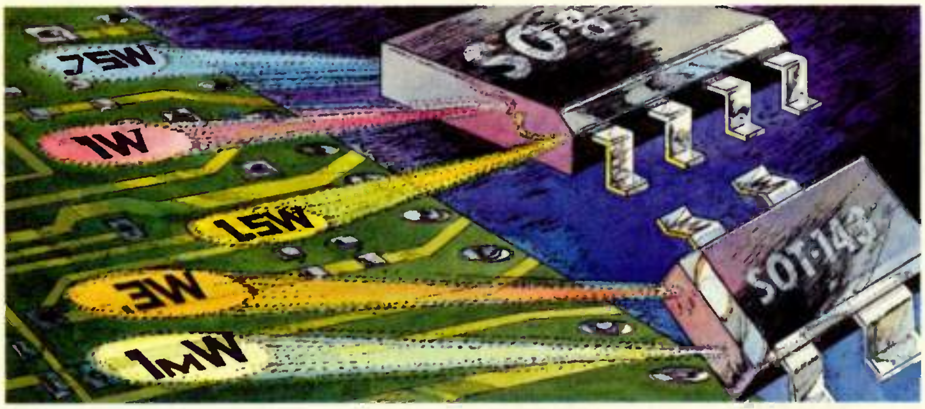
rf design

ideas for engineers

August 1986

Special Report – Mixers: Making the Right Choice

Motorola RF Design News



Take your choice of surface-mount power.

GHz gain, miniscule drain in SOT-143.

Operating at less than 1 mA I_C with a V_{CC} of only 1 V, the MRF9331 offers 13 dB typical gain at 1 GHz and 2 dB NF at 500 MHz. Use of a single emitter finger of a 1.25 micron die design achieves state-of-the-RF-art performance with high, 6 GHz f_T.

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And SOT-143s provide dual emitters for best performance in common emitter configurations.

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600 W, MRF430 bipolar unit not for the timid.

At 600 W P_{out}, the MRF430 is the most powerful bipolar RF transistor of its kind. It's for those who want to have it all in one potent package without water-cooling for linear amplifiers from 2 to 30 MHz, base station equipment, nuclear magnetic resonance, sputtering equipment or in 1 KW SSB amplifiers.

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And 50-up is only $315—30% less than MOSFETs.

900 MHz SO-8 grabs 1 W honors.

Providing 1 W and more P_D, equal to or exceeding that of MACRO-X and SOE packaging, the MRF8372 is the SMD version of the popular, 6 GHz f_T MRF837 used in wideband, large-signal, pre-driver, 900 MHz, land-mobile stages.

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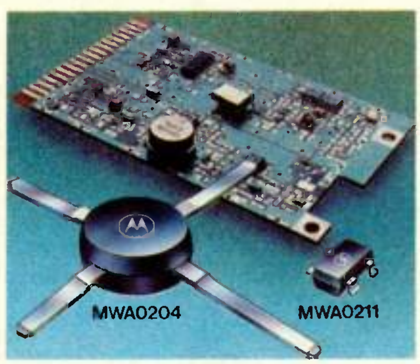
Typical performance is 10 dB gain at 870 MHz, 12.5 V, in a broadband circuit delivering 3/4 W RF power with 60% efficiency. It's also characterized at 7.5 V and at 512 MHz.

Little price, too: $1.65, 1K-up.



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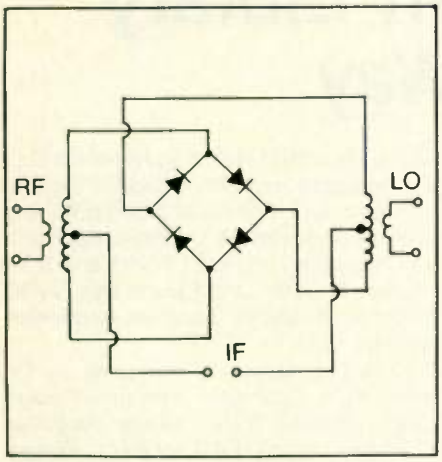
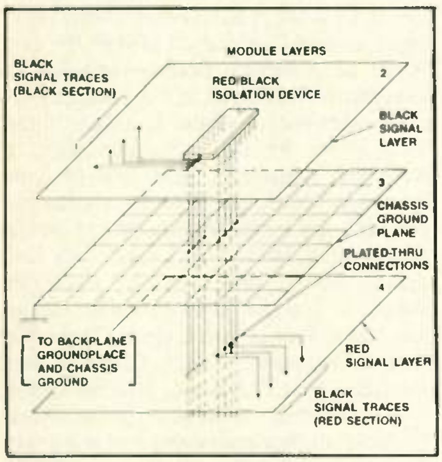
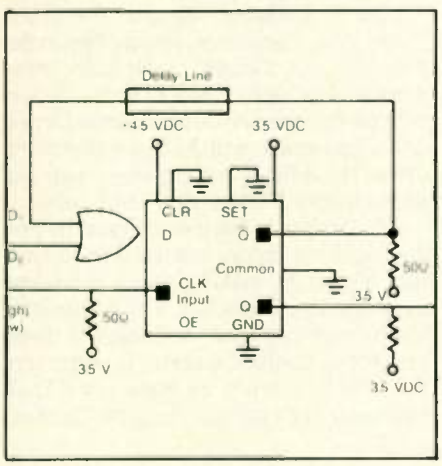
August 1986



Page 24 — Mixers



Page 32 — TEMPEST Requirements



Page 45 — GaAs IC Interfacing

Cover

This month's cover illustrates mixer development from the basic modulators of the 1960s to the higher integration levels of today's compact packages. Shown for the first time are Merrimac Industries' new 3 GHz synchronous detector compressed to a 0.8-inch square flatpack (center) and a quadraphase modulator reduced to a 5/8-inch square flatpack with no loss in performance (lower left, above surface mount mixers).

Features

Departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in August. August 1986, Volume 9, No. 8. Copyright 1986 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6530 S. Yosemite Street, Englewood, CO 80111 (303) 694-1522. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802, (218-723-9355). Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $22 per year in the United States; $29 per year in Canada and Mexico; $33 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $5.50 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.
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rf editorial

Public Domain Library Gets Under Way

By James N. MacDonald
Editor

About a year ago, Gerald Harrison approached us with an idea for a library of public domain software for RF engineers. Jerry offered to collect programs written by designers and often published in *RF Design* and other high frequency magazines and distribute them. This would avoid the problem of copying the listings from the magazines and would make the programs readily available.

Now Jerry has announced his first four disks for distribution. The first disk is one unpublished program by Christopher Trask, called ALMOND. Trask said ALMOND is "a high frequency analysis, design, and optimization program intended for the beginning professional or hobbyist whose workstation needs suffer from financial limitations." The program includes lumped element, distributed element, and S-parameters data files for design and optimization of filters, amplifiers, and oscillators. Optimization is accomplished by using an experimental second-order descent method.

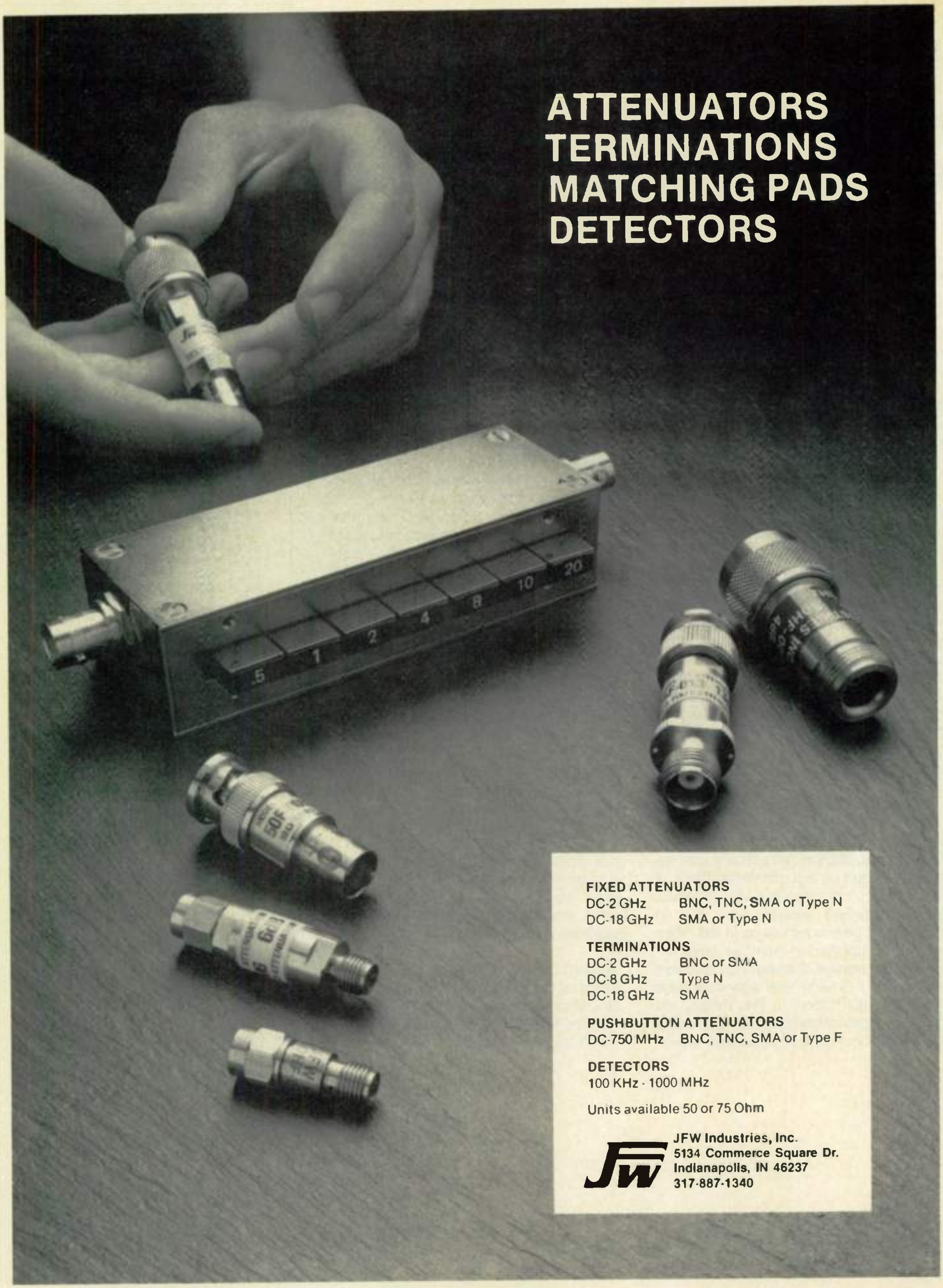
Disk 2 includes nine programs previously printed in *RF Design* or other magazines. They are: Intermodulation Products, Marc Goldfarb; Designing NBPF With a BASIC Program, William E. Sabin; BASIC Program Computes Values for 14 Matching Networks, Allen J. LaPenn; Transistor Parameter Conversion, Stanley Novack (and a modified version); Microstrip Matching Networks Can Be Designed Fast With a BASIC Program, James E. Lev; Computer Aided B.P. Filter Design, Jerry Hinshaw; A Basic Approach to Calculating Intercept Points and N.F., William E. Sabin; and Easy to Use BASIC Program Analyzes Transient Response, William Gill.

Disk 3 contains 13 programs by Dr. Allen Katz, Chairman, Electrical Design Dept., Trenton State College: Amplifier Analyses Using S-Parameters; Bessel Functions; Noise Figure and Gain of Cascaded Stages; Dimensions of BP Comb Line Micro Strip Filter; Design Butterworth and Chebysheff LP, HP, BP, and Band Stop Filters; Fourier Analysis of Waveform Described in File; Inductance of Straight Wire, Ribbon, and Coils; Intermod From Transfer Characteristics; L Matching Networks; Add and Multiply Complex Matrices; Analyze Microwave Network; Calculate Dimensions of Single or Coupled Microstrip Lines; and Calculate Shape and Gain of Parabolic Antenna. The disk also contains: Calculate Noise Figure and Gain of Cascaded Stages, Matthew S. Tietze; Calculate Bias for CB, CE, CC Stages, Roman Orzel; Fourier Analysis of Waveform, Described by Table, author unknown; and Intermod, Frequency, and Amplitude From Power Series, H. Charles Ross.

Disk 4 contains: Simple Bandpass Filters, Alex Burwasser; Helical Resonator Filter Design, Vincent G. Heeson; three programs by Kevin J. McClaning — Inductor, Low Impedance Double Tuned Circuit, and Synthesize and Analyze Microstrip Lines; Hone Filter, Jeff Crawford; and The Micro Magic Pi Designer, Gil Boelke.

RF Design is happy to have helped Jerry get his library started and to have had a part in making these programs available to our readers. For information on the nominal cost for copies of these programs contact Gerald S. Harrison, E.E. Public Library, 36 Irene Lane East, Plainview, NY 11803, or circle INFO/CARD #132.

James N. MacDonald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INFO/CARD 4

Proposed Radio LANs May Interfere with TIROS Satellites

The National Oceanic and Atmospheric Administration (NOAA) operates weather satellites which produce data used in the study of the earth, its weather and resources. Among these satellites are the TIROS-N series, whose data are sent to earth by radio on frequencies in the 1700-1710 MHz band. An unknown number of receiving ground stations have been built by weather forecasters, TV broadcast operators, universities, and private individuals. FCC regulations do not require licensing or registration of these receivers, so their existence and locations may be unknown to NOAA. Because they are unknown, NOAA can take no steps to protect them from interference.

The FCC is considering a proposal to allow an entirely new type of radio device in the band, a radio local area network, which has potential for causing severe interference to weather satellite receivers. This office is appealing to anyone who knows of such a receiver or plans to build one to tell us about it. We will provide additional information on how operators can protect themselves from potential interference. We propose to register such receivers in a master file, to help prevent interference from occurring.

Radio-linked LANs (RLANs for short) are potentially very useful devices. Their problem, from NOAA's perspective, is the frequency band chosen. The choice was apparently based on a fundamental piece of misinformation: the idea that Meteorological Satellite (MetSat) receivers are few in number and likely to remain so. In fact, since we began looking for them we have uncovered an average of several new receivers each week. Government agencies have them and didn't know it. The military are buying a significant number. We are finding them in the hands of colleges and universities around the country. NOAA has let a contract for the development of a new, low-cost design that will put even more of these earth stations in private hands.

Unlike fixed microwave links, whose antenna keep pointing in one direction, these MetSat receivers follow a moving target. The antennas may point at any azimuth and any elevation and must receive data from one horizon to the other. The zero elevation angles used make these receivers extremely vulnerable to interference from ground-based transmitters such as RLANs.

MetSat receivers in this band have what is termed a "primary" allocation status, and the proposed RLANs would have a "secondary" one. This means that RLANs would not be permitted to operate where they might cause interference to a MetSat receiver. Large numbers of prospective RLAN users would either be unable to obtain licenses at all, or would be required to undertake extensive (and expensive) coordination procedures to ensure that interference would not result from their operation. The secondary status of RLANs also means that an RLAN would be required to shut down, if necessary, to protect a MetSat receiver built after the RLAN was already in operation. The expense and disruption this would cause to RLAN users is obvious.

In sum, the proposed rules reflect a good idea gone awry. Putting this equipment in a more suitable band would benefit the users, the manufacturers, and all who depend on weather data from NOAA's satellites. And that's all of us.

Richard Barth
Office of Radio Frequency Management
U.S. Department of Commerce
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Washington, D.C. 20230

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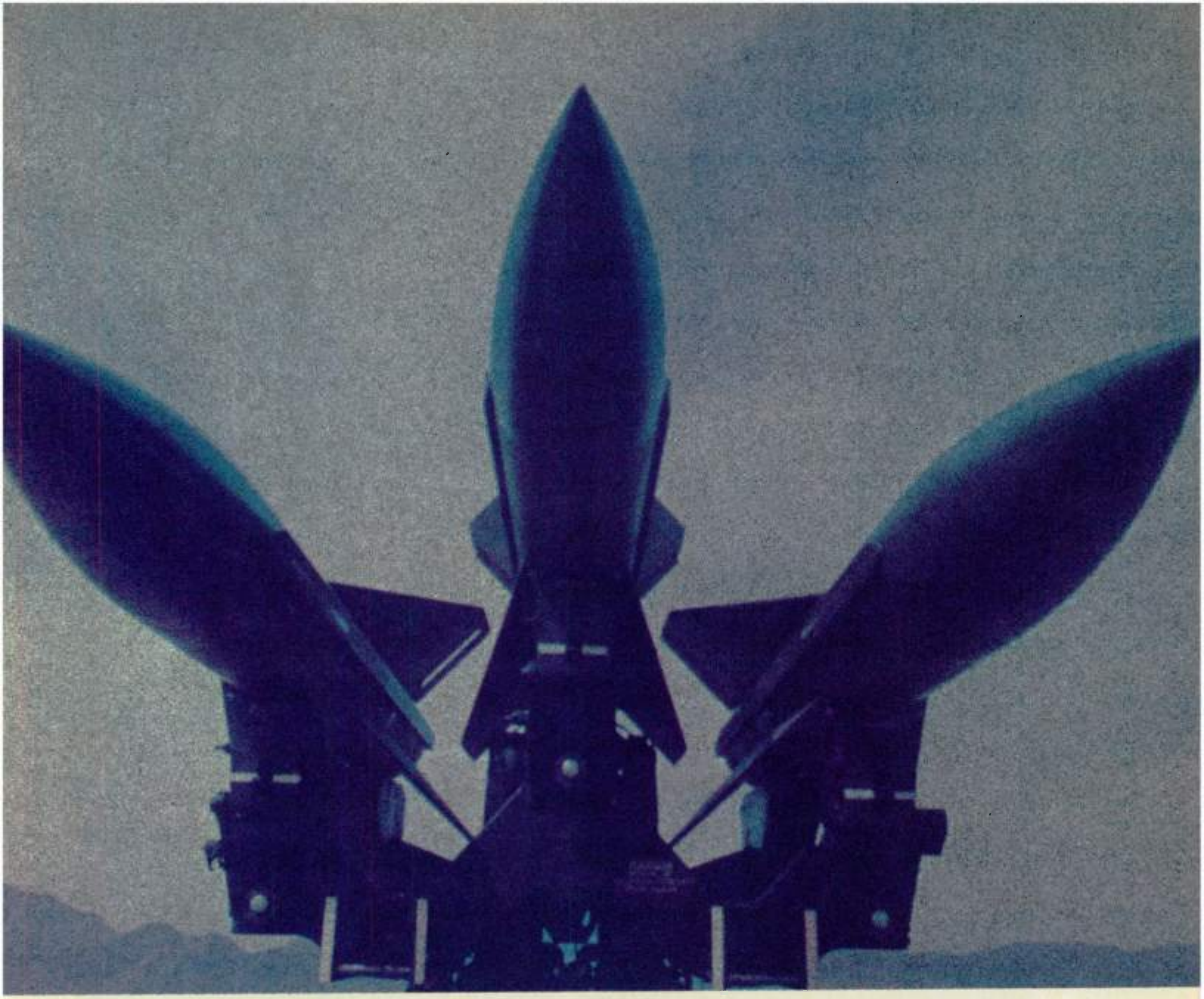

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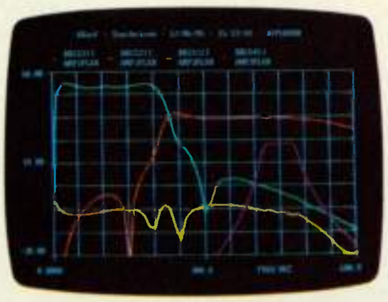
A. Touchstone analysis of an active triplexer circuit with sampled output

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

C. Schematic diagram of the active triplexer analyzed above

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



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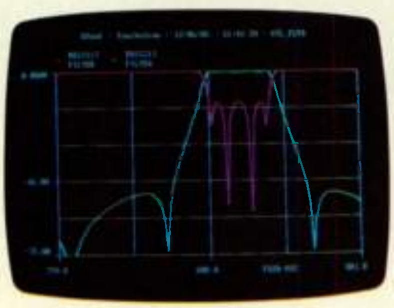

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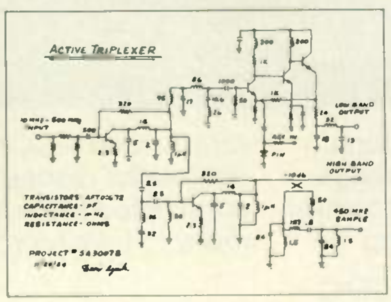

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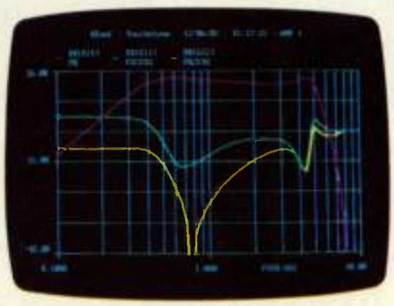

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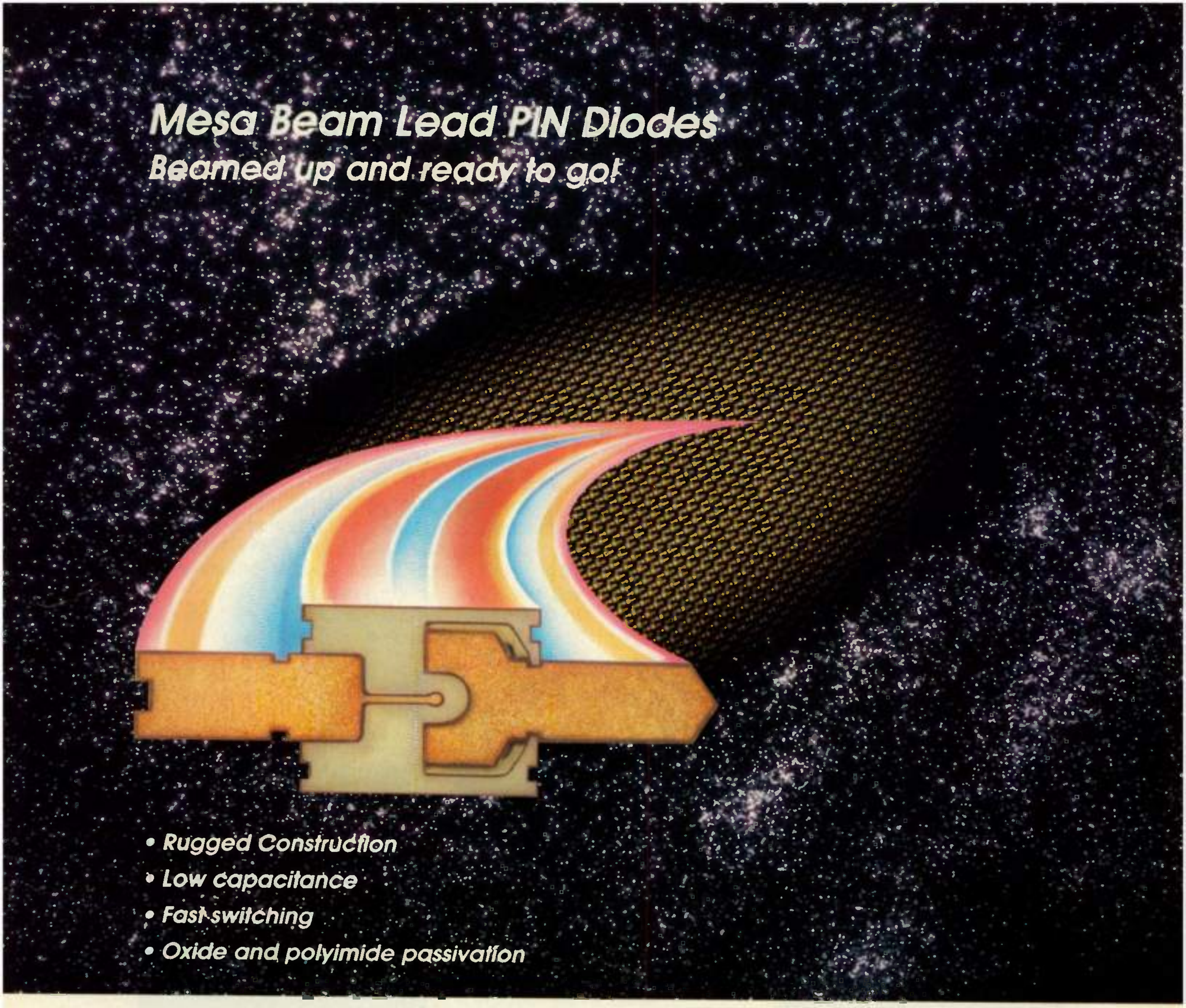

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rf letters

Silicon/GaAs Complementary, Not Competitive

Editor:

It was with some surprise I saw your article in the April edition extolling the virtues of Gallium Arsenide over silicon. As you can see from the enclosed data sheet, Plessey Semiconductors have had a silicon 2.4 GHz divide by 4 integrated circuit in production for some time and 4 GHz is not far away. There are some areas where GaAs is not the best answer and the enclosed graph of phase noise against offset from carrier for various divider technologies shows just how much worse GaAs is.

I do take issue with you on the virtues and otherwise of multiplying an oscillator when low phase noise is required. From Leeson's equation, phase noise is proportional to $1/Q^2$. Thus, if an oscillator at 800 MHz has a Qw of 1/3 to 1/4 of an equivalent oscillator at 400 MHz, the noise will be 9 to 16 times worse — but only 2 times if the 400 MHz oscillator is doubled. Practical component Qs are often in this ratio, so the choice of either the fundamental or multiplier approach is not as easy as might be imagined. For further analysis, see my paper, "Design Compromise in Single Loop Frequency Synthesizers," presented at the 1985 RF Technology Expo.

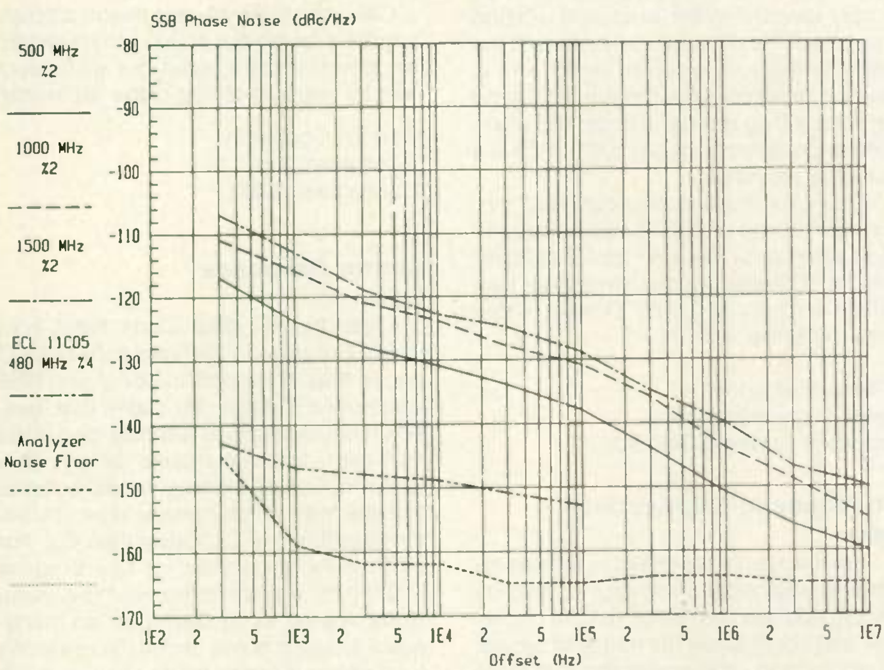
Another problem with higher frequency VCOs is that GaAs devices are worse than silicon for I/f noise: this noise intermodulates with the RF to give poor close-in noise. GaAs tuning diodes are also notorious for post-tuning drift which can lead to excessive group delay when modulating a VCO.

Another area in which to be careful is in frequency counters. If a translation is made from phase noise through the Allen Variance to jitter, then it may be seen that jitter (noise) in a prescaler can affect the accuracy of a counter — although, I admit, this is probably only a problem at parts in 10^{10}.

A-D converters using silicon are available from several companies besides Plessey Semiconductors operating at frequencies higher than 100 MHz, while DA converters operating at 200 MHz are available; Plessey will announce a 500 MHz silicon D-A this year.

In general, silicon is always likely to be cheaper than GaAs — it is, after all, more readily available. All this is not to suggest that Gallium Arsenide technology doesn't

Phase Noise of Dividers
10G065 GaAs FET Ripple Counter



have a place in RF engineering. It certainly does — for example in LNAs, microwave linear front ends, high power microwave amplifiers and so on. But it certainly isn't the "answer to the maiden's prayer" that the media are playing it up to be. Silicon's capabilities are steadily increasing, and are likely to do so for a long time to come. The two technologies are complementary, not competitive.

Peter E. Chadwick
Principal Applications Engineer
Plessey Semiconductors Ltd.
Swindon, Wiltshire, U.K.

Correct Equations More Important than Programming Language

Editor:

Judging from a recent letter you published, there still seems to be confusion on how best to present programs for computing designs based on articles you print. I believe the crux of the matter rests in the selection of the most useful form for providing the appropriate data for most readers.

I believe that the most important question is presenting the correct equations that must be solved, as busy engineers will only rarely be able to take the time to check derivations in the required detail to assure their validity. (I missed an error but I picked up another making a dimensional check.) The equations should if possible be in the most self-consistent form so that computing time and programming errors can be minimized.

The question of the best form in which to present a program of the equations (if any) is more complex. The reader choices probably are among the three most common:

1. BASIC format for a computer
2. Algebraic for one class of programmable calculator
3. Reverse Polish for another class

The choice can be difficult, but I believe it can be resolved.

I believe that BASIC is perhaps a reasonably universal computer language, and is in most cases adaptable to most personal computers. (The occasional publication of substitution tables covering most types such as the Sinclair-Timex, TI-99/4A, various Apple, the TRS, VIC, and the various near-compatible IBM types would be very useful.) And conversion of BASIC to FORTRAN, FORTH, PASCAL, etc., should offer no problems for those literate in these other languages.

It's really a question of ease of use and effectiveness. What basic forms are the most easily used by the majority of your readers? I believe the equations are important in any case, as they can be used with any programming language one uses. The next in order of flexibility of use would appear to be BASIC because of the wide use and relatively simple modification problems for going from computer to computer. I have invariably had to give up when only unknown dialects were presented, and the equations were missing.

Perhaps it would be worthwhile to survey your readers on this.

Keats A. Pullen, Jr.
Kingsville, Maryland

Constructive Criticism is Better

Editor:

I have always felt that those of us in the RF community are a more "tight-knit" group than most, a feeling very well reinforced when I attended RF Technology Expo 86 in Anaheim, Calif. The range of expertise in our ranks is impressive and interests widely varied.

Because of this, I am disappointed when readers write *RF Design* magazine to criticize an article and use words like "inadequate" and "misinformation." Anybody who writes an article for any magazine puts themselves on the line. Should we be so quick to "knock 'em down" when an error is detected? Wouldn't it be better to refrain from harsh words and make it a learning experience for all by simply identifying the error and offering a solution? Constructive criticism with the intent to teach is received better and is less apt to discourage the author. Those who are willing to write articles and share their experiences are few. Let's not kill a valuable resource.

Finally, for those purists out there who just can't sleep at night because an article had an error or didn't take a point far enough: I challenge you to write your own article and submit it to *RF Design*. Share your expertise with us.

T. Nick Hulbert
Texas Instruments Inc.
Colorado Springs, Colorado

No Money in Engineering

Editor:

I am always disappointed in articles regarding engineering manpower, for they always address the effect, not the cause. You and I both know the cause of almost all enginering problems is the fact there is no real money in engineering. As a result, engineers get out of the field, or remain in with the attitude of "screw it." Would you believe that public school teachers earn far more per hour than engineers? This is due to the fact that engineers cannot effectively organize and go out on strike. Who would notice? Engineers have had to rely upon supply and demand. This has not been successful because those who employ engineers flood the news media with inflated salary figures and the future need for engineers. There has never been a shortage of engineers or this would be reflected in increased salaries. Nevertheless, there is a copious supply of young engineers to replace those who leave the field for greener pastures.

We need to come out up front and admit that money is the prime driver in our society. There is nothing wrong with money. Money is how you keep score in the career game. This is why our keenest technical minds no longer opt for science and engineering but go into medicine, business and law where the financial rewards are from two to three times as great. Assigning our scientists and engineers to second class status has created a drain of the best minds from this field, as evidenced by our ever increasing negative balance of payments. Our second best simply isn't getting the job done. As Babe Ruth, Shakespeare or some great man once said, "Any country that does not place prime emphasis on science and technology is destined to be a second class nation."

Can you think of any major problem currently facing our country that wouldn't be solved if once again our technology was far superior to that of the Japanese?

Carl W. Chapman
Directware, Inc.
Carmichael, Calif.

Author Responds

Editor:

I read the RF letter (June 1986) from Ralph Burgess on the Varactorless VCO paper that appeared in the April 1986 issue of *RF Design*. He states that, based on his experience with this circuit, he considers the explanation of this particular VCO to be inadequate and believes that the modulation mechanisms are better described via C_{cb} rather than C_{eb}. For sufficiently low values of C_{cb} Burgess might have a point. However, his conclusions appear to be based on an inadequate analysis of this circuit. Considering a relatively large transistor collector impedance (R_c) and a C_{cb} of 0.4 pF to 1 pF (reasonable assumptions for small signal transistors) the impedance matrix for this

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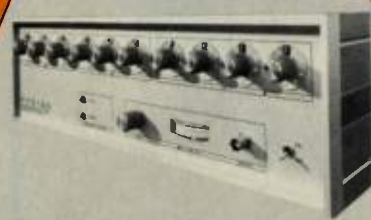

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circuit shows that the impact of C_{cb} on the VCO response frequency and modulation mechanism is minimal.

Burgess also mentions problems with this circuit concerning 1) control of spurious outputs, 2) non-linearities in deviation sensitivity, and 3) deviation sensitivity and non-linearities being sensitive to RF loading. Item 3) requires the services of an isolation amplifier. Items 1) and 2) certainly can be a problem, but if he wants to see evidence of the varactorless VCO's capability of providing a reasonable amount of linearity, I recommend taking a good look at reference 7 from this article.

George D. O'Clock, Professor
School of Physics,
Engineering and Technology
Mankato State University
Mankato, MN 56001

Questions for Our Readers

Editor:

I have three questions that your audience of RF people might answer. First, does anyone know what the "Red Book" of the CATV industry is? (Who are) the author and publisher?

Second, who makes a grip-dip meter in the class of the "Megacycle Meter" of the 1940s-1960? The last were made by McGraw-Edison — then the item seems to have vanished.

Third, does anyone know what the "Yehudi Circuit" mentioned in the MIT Rad Lab Series is? (No kidding, that was its name.)

Irv Bardetch
4007 Rosecrest Ave.
Baltimore, MD 21215

Amateur Equipment Not Low Quality

Editor:

I believe Mr. DeMaw's letter (your May '86 issue) raises a good point. Just because equipment is labeled as "homebrew" or "amateur radio" it should not be (but unfortunately often is) labeled as low quality. When RFI occurs, unfortunately "ham" radio is unjustly accused. Of the repeater work I've done (as an example), the amateur equipment definitely represents a higher standard of quality than some commercial equipment standing right next to it.

Clifford Spies
YBM Enterprises
Niles, Ill.

Siliconix Offers First Computerized Data Book for MOSPower Products

Siliconix, Inc., Santa Clara, Calif., has produced an innovative MOSPower Computer Data Book, providing designers with easy access to the latest power MOSFET technology. The entire MOSPower catalog is presented on a 5¼" floppy diskette and runs on any IBM PC or PC compatible.

Designed to be used with little computer experience, the program will search for and display device options from a specific part number input or from device parameters defined by the user. The program also includes an automatic power MOSFET cross reference to select alternate components from other manufacturers' part numbers.

"This provides a powerful engineering tool," said Larry Meiners, Siliconix MOS Power Strategic Marketing Manager. "The circuit designer who wants to use a power MOSFET just enters the parameter limitations required. In seconds the program will provide a list of optimized products, including device characteristics and package options, so he can choose the most efficient alternative.

"Another advantage of this medium," said Meiners, "is the ease of updating and distributing MOSPOWER product information to the engineering community. This format can be freely distributed among users more friendly than a conventional data book. Using this

technological bridge, we foresee a major expansion of the product information that can be made available. Future editions will include device modeling as well as interactive applications circuits and reliability data.

Siliconix has the broadest offering of power MOSFETs and package options in the industry," said Meiners, "and our 6-inch wafer fab will ensure that we are the market leader in availability and low cost. We needed an innovative means to convey this information to the market, and the MOSPower Computer Data Book satisfies that need."

The MOSPower Computer Data Book will be provided at no charge to Siliconix customers. For further information, contact Larry Meiners at (408) 988-8000, or circle INFO/CARD #131.

EEsof Installs Device Characterization Laboratory

EEsof, Inc. has installed a complete laboratory at its Westlake Village headquarters to offer device characterization services to RF/microwave component manufacturing companies. The lab will be used for the generation of parameters for models used in microwave SPICE and for test and verification of linear models used in Touchstone. The lab uses the following equipment:

- HP 8510 Automatic Network Analyzer
- HP 4145B Semiconductor Parameter Analyzer
- HP 4280A C Meter/C-V Plotter
- Software for extraction of SPICE model parameters.

"The new lab provides us with sophisticated test and measurement capabilities in three crucial areas," said Charles Abronson, president of EEsof. "First, it increases our ability to provide a library of commonly used devices to be utilized in conjunction with microwave SPICE. Secondly, it lets us offer a unique service whereby companies can submit active microwave devices directly to our lab, and we will perform the necessary SPICE parameter extraction. Finally, the network analyzer capabilities allow us to verify and refine our Touchstone linear models. As a result, manufacturers can avoid the costly investment in capital equipment and software for device characterization needed only perhaps a few days a year and turn their attention to other needs."

With the introduction of EEsof's on-site test laboratory, manufacturers can send their devices directly to EEsof for the required measurements. The cost of the service will be determined by individual design requirements.

"Most companies still characterize devices by trial and error," Steve Hamilton, vice president of engineering and operations at EEsof explains, "and that is a process that can consume several days of an engineer's time in hand calculations and manually optimizing the many interrelated model parameters. Our service will profoundly decrease the design time, increase the measurement accuracy, and complete the results in a model library that can be read directly into a SPICE circuit file."

GTE to Develop High-Power Transistors

GTE, Waltham, Mass., has received two separate military contracts totaling $1.8 million to continue development of a new GTE-designed transistor which will greatly improve the efficiency of electronic equipment calling for high-power, high frequency operation.

Designated static induction transistors (SITs), the new devices are expected to enhance operation of such items as phased-array radars used for coastal defense, television transmitters, microwave ovens, electrodeless lamps, and a variety of other equipment. GTE Laboratories Inc., the central research facility of Stamford, Conn.-based GTE Corp., will conduct research on the basic materials with which SITs are made; develop techniques for designing, processing, and packaging SITs; and demonstrate prototype SIT devices in power amplifiers. Researchers believe such work will yield much better performance than is possible with any currently available transistor.

A contract awarded by the U.S. Army Signal Warfare Center, Warrenton, Va., calls for GTE Laboratories to develop a 300-W transistor capable of operating over a frequency range 1 to 200 MHz — something no other transistor has yet achieved. Until now, such performance has been possible only by assigning different frequency ranges to several different transistor amplifiers. The SIT amplifier, in contrast, will combine both high power and wide frequency response in a single device.

Under a second contract awarded by the U.S. Air Force's Avionics Laboratory at Wright-Patterson AFB, Ohio, GTE Laboratories will study the use of gallium arsenide as a base material for SITs and develop a discrete pulse power GaAs SIT. Researchers believe GaAs may replace silicon as the material of choice in high-power transistors operating at very high microwave frequencies. Under this contract, GTE Laboratories expects to develop a transistor which will operate at

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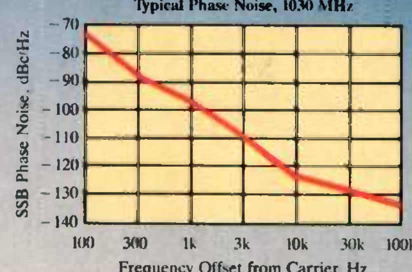

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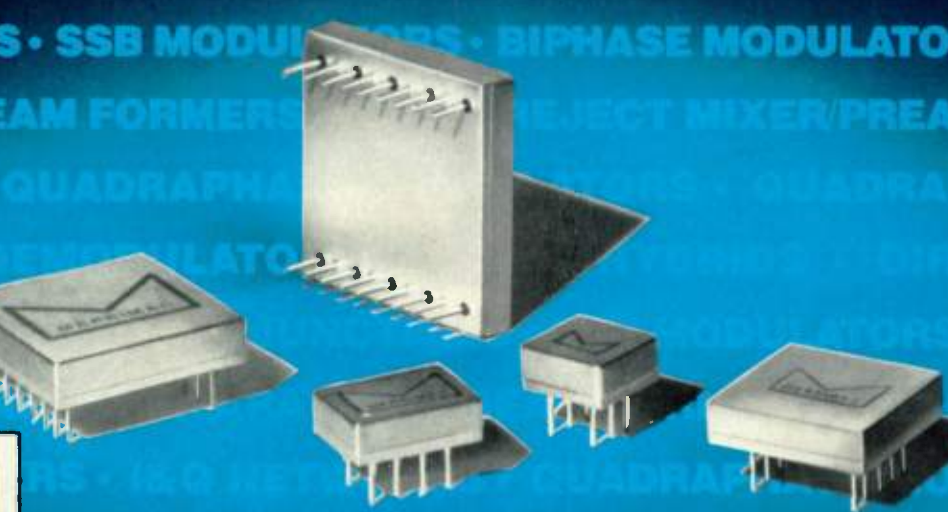


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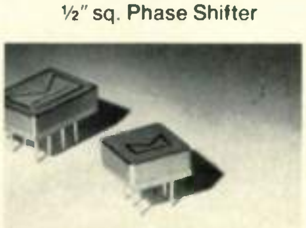
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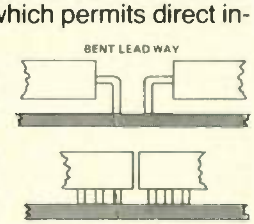

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frequencies approaching 10 GHz at 100 W of peak-pulse output power. Currently, no single device is capable of providing such power levels at that frequency. Such a device is expected to greatly reduce the size, weight, and cost of military equipment calling for these characteristics.

Survey Shows Many Companies Hesitate on CAE

More than one-third of the companies involved in the design of electronic circuitry have made no significant purchase of computer-aided engineering tools, according to a survey conducted for Automated Design & Engineering for Electronics (ADEE).

Thirty-seven percent of the survey respondents reported that their companies have either not started their purchases of CAE or have made "no significant purchase." In addition, 20 percent reported that their companies were less than half-way complete in their purchases; 19 percent said their companies were more than half-way complete; 17 percent said their companies had essentially completed their purchases but were still making supplemental purchases of peripherals and software.

Only 6 percent reported that their purchases of computer-aided engineering tools were "essentially finished."

ADEE, which takes place twice a year, once on each coast, is an exposition and conference devoted entirely to automated systems for the design of electronic circuitry. This circuitry includes logic circuits, integrated circuits and printed circuit boards. ADEE will next take place at the World Trade Center, Commonwealth Pier, Boston, September 30-October 2.

Those companies that have invested in CAE systems reported heavy usage of the CAE workstations. A typical workstation, the survey showed, is shared by an average of 3.9 designers and is used almost 13 hours a day. The average designer, it was reported, uses CAE tools, when they are available, about 3.3 hours each day.

The survey indicated that add-on software for existing systems was likely to be a market segment that should experience rapid growth. A total of 70 pecent of the respondents planned to purchase additional software for hardware they already own. The largest segment, 49 percent, was composed of companies that planned additional purchases of software for personal computers, it was found. Software purchases for large host computers were planned by 12 percent, and 9 percent reported planning software purchases for engineering workstations.

Hughes Outer Space Technology to Tap Subsea Oil Reserves

Outer space technology is being put to work in inner space by Hughes Aircraft Company to help tap oil reserves buried deep beneath the world's oceans.

Hughes' Radar Systems Group, El Segundo, Calif., has applied its aerospace experience to develop a multiplexed telemetry command and control system that will provide the reliability necessary to extract oil economically from wells thousands of feet below the oceans' surfaces. The group will produce the electronic portion of the deepwater oil well control systems being built by Hughes Offshore, part of the Houston-based Hughes Tool Company, for a floating production platform and accompanying subsea oil wells in the Gulf of Mexico.

Hughes Offshore is under contract from Placid Oil Company, an oil producer, to provide the control systems for up to 24 subsea wells. production from the wells, situated in approximately 1,600 feet of water in the Gulf about 100 miles southwest of New Orleans, is scheduled to begin in mid-1987. All equipment will be rated for at least 3,500-foot water depths. When installed in the Gulf, the system will break the world's water depth record for subsea oil production. The current record, 1,253 feet, is held by Hughes Offshore in the South Atlantic Ocean off the coast of Brazil.

"Our work in subsea telemetry command and control system technology is a direct transfer of the expertise acquired in more than 38 years of developing telemetry for a wide range of missile, spacecraft, and aircraft flight test, instrumentation, and data reduction programs," explained James A. Skinner, RSG's subsea project manager.

Multiplexed systems, which use paired wire cable to transmit many bits of information almost simultaneously, have been used by some oil companies for several years to control subsea wells. However, the RSG approach permits economic recovery of oil and gas reserves from greater depths than ever before.

"In researching the market, we discovered the state of the art in subsea telemetry command and control for the oil industry had lagged behind space and airborne applications," Skinner said. "At about the same time, the major oil companies were seeking more efficient ways to automate their offshore operations. There are tremendous capital investments in these operations, as well as enormous operating expenses, so oil companies need the type of reliability we are supplying for the military.

"Our system provides the capability to operate in deeper waters, farther from the surface control points, and to get real-time monitoring of events occurring at the wellhead," he added.

Hughes Aircraft entered the subsea market by developing multiplex control systems for remotely operated submersible vehicles for the British Ministry of Defence and the U.S. Navy. Both of these projects used a direct application of missile telemetry command and control technology.

Worst Case Circuit Analysis Handbooks Available

The first Worst Case Circuit Analysis (WCA) Handbooks have been developed to introduce engineers and managers to the subject and show them how to meet the WCA requirements of MIL-STD-785B.

Design & Evaluation, Inc., Voorhees, N.J., developer of the handbooks, teach a 4-day professional engineering course called "Worst Case Circuit Analysis" under contract with the Reliability Analysis Center, RAC/RADC, Griffiss Air Force Base, New York.

The WCA handbooks are designed to be an everyday working aid for seasoned electronic design engineers. They are also useful as on-the-job training materials for engineers new to worst case circuit analysis. The WCA handbooks contain more than 900 pages (in three volumes) of practical "how-to" material for performing worst case analysis, worst case circuit attributes and operating conditions. Numerous examples and case studies are presented for analog and digital circuits, power supplies, RF circuits and more.

Volume 1 — INTRODUCTION explains the philosophical concepts of WCA and takes the handbook user step by step through the construction of a Worst Case Analysis Report in an organized cost-effective manner.

Volume 2 — DESIGN GUIDELINES provides the circuit designer with operating principles, error sources and critical parameters for major classes of circuits.

Volume 3 — EXTREME VALUES DATA explains how-to develop Worst Case envelopes for electronic components in various environments. Included are Worst Case Data Sheets for popular electronic parts over ranges of −20°C to +80°C, 10-year life and non-radiation environment.

The Complete Worst Case Circuit Handbook is available for $395 from Design & Evaluation, Inc., 1000 White Horse Road, Voorhees, N.J. 08043, (609) 770-0800, or circle INFO/CARD #130.

Mixers: Making the Right Choice

Choosing a mixer requires the RF engineer to remember the Three "P's" — Performance, Price and Packaging.

By Gary A. Breed
Technical Editor

One of the most common elements in RF circuitry, the mixer often represents the "weakest link," making it the major factor determining intermodulation, harmonic and signal-handling performance. The non-linearity required for mixing action guarantees that some unwanted products will appear at the mixer output. The job of the RF engineer is to identify realistic performance criteria for his specific design assignment, then choose the mixer that best meets those requirements, while also considering the price, manufacturing ease, and packaging configuration desired for the system.

It is never an easy job to balance conflicting requirements in an RF design assignment. Choosing a mixer is even harder than usual, because there is no "perfect" mixer available. However, there *are* many different configurations and performance levels available, and one of them represents the best possible compromise for a specific RF design.

The Diode DBM

Easily the most common form of mixer today, the standard diode-ring double-balanced mixer (DBM) offers reasonably good intermodulation and signal handling performance for a very low price. Synergy Microwave and Mini-Circuits are the price leaders in this area, with similar products also available from Merrimac, Solitron and Adams-Russell's Anzac Division. For just a few dollars and very little engineering time, a diode mixer can be put into an RF circuit.

What is traded for this convenience is a fairly high local oscillator (LO) level, and moderate port-to-port isolation of 20-35 dB, depending on frequency. Like nearly all mixers, the diode DBM is also sensitive to termination impedance. If designed for 50 ohms, the intermodulation distortion (IMD) products will increase if the desired output frequency, the image frequency, and to some extent, harmonics of these frequencies see a termination other than the desired 50 ohms.

Beyond price and engineering costs, the other practical advantage of diode DBMs is packaging. These devices are available in every conceivable configuration from connectorized metal cases to 8-pin relay headers to DIP plastic carriers to surface mount (SMD) packages. With this kind of packaging selection, combined with generally adequate performance specifications, it is easy to see why the packaged diode DBM is so popular.

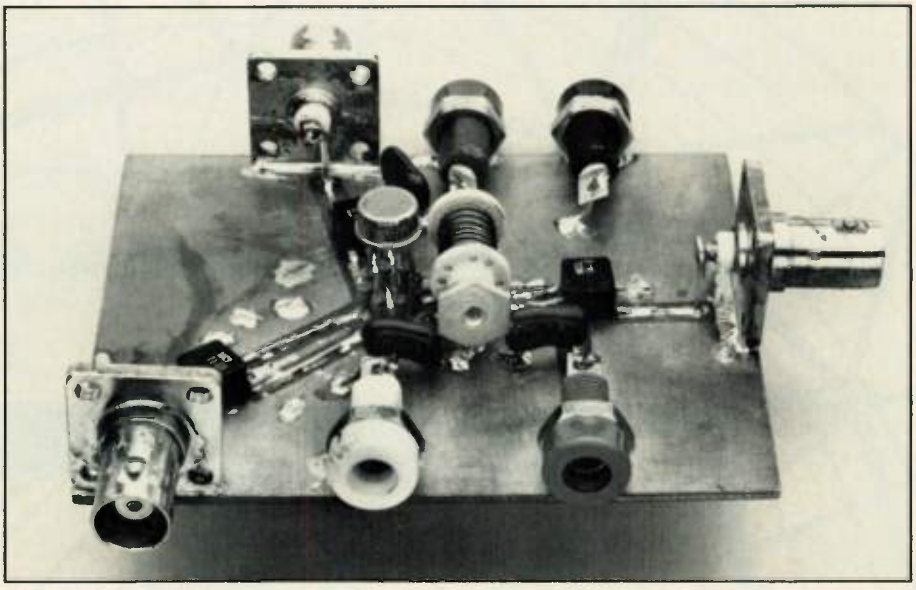
Higher-Performance Passive Mixers

There are several variations on the diode DBM theme that improve IMD, signal-handling and isolation performance. The most straightforward is the use of multiple diodes in each leg of the ring. At the cost of increased LO drive power (up to +23 dBm), a DBM can handle up to about +20 dBm signal (1 dB compression point) with a third-order intercept of +35 dBm or so (specifications will be discussed later on).

Another method is the use of two diode rings, usually in a push-pull arrangement, to increase both signal handling and isolation. These two factors also improve IMD performance. Special transformer design and diode configurations are also used in the "termination insensitive mixer" or TIM. Although mixers are four-port devices (RF, IF, LO and Image), most mixers have only three connections, and the image is reflected internally unless it is specifically terminated at the IF port. The TIM uses coupling and matching transformers to internally terminate reflected products.

IC Mixer Choices

Another low-cost mixer alternative featuring packaging variety and design simplicity is the integrated circuit. The



Prototype commutation mixer uses the Siliconix Si8901 DMOS FET quad ring.

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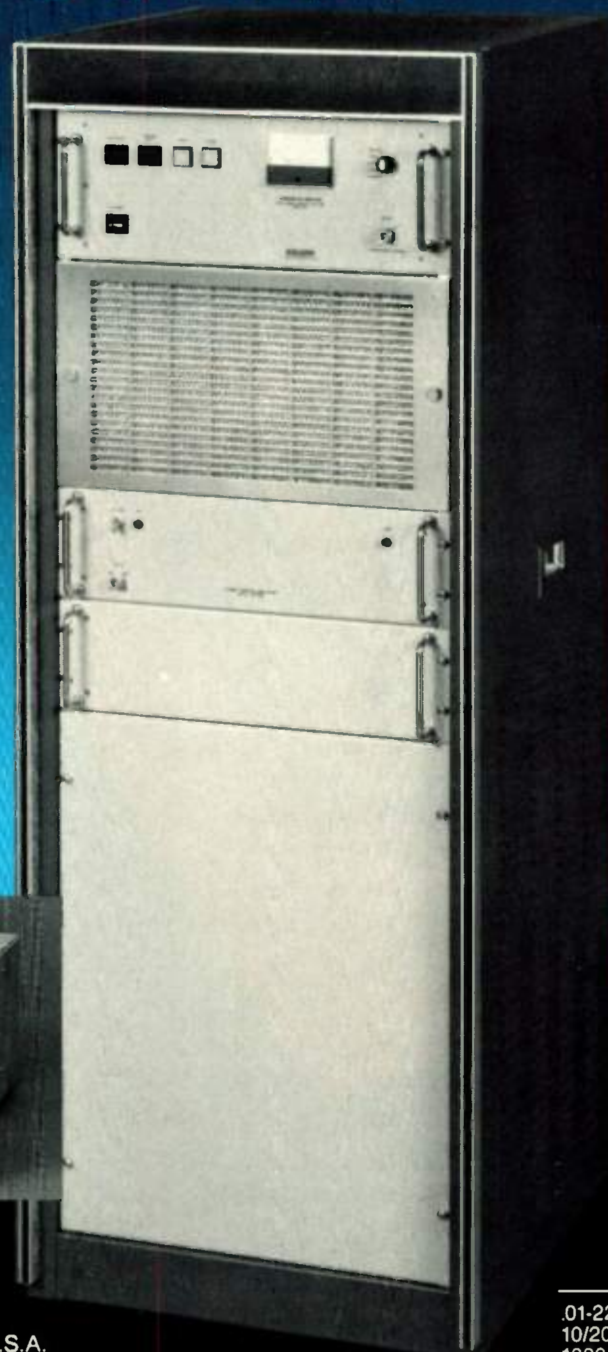

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principal advantages of ICs are those of any active device mixer, low LO drive and conversion gain, rather than the losses inherent to passive designs. Packaging of ICs lends itself well to current manufacturing techniques, and manufacturers have a wealth of applications data available to assist the design engineer.

Plessey, Motorola, Signetics, Texas Instruments, RCA and others make mixer ICs. Single-balanced mixers based on differential amplifiers (e.g., RCA's CA3028A) are available, but the double-balanced "Gilbert cell" type are the principal types currently in use. These include the Plessey SL6440C, Motorola (and other manufacturers) 1496/1596, and the Signetics NE602. Another category includes the "analog multiplier" ICs which can be used as mixers, modulators or attenuators. The new Burr-Brown MPY634 and the Motorola 1495/1595 are examples of analog multipliers, typically used below 10 MHz.

Performance limitations are the principal drawbacks of IC mixers. They can perform extremely well in narrowband applications with fairly constant signal levels, but in the widely variable environment of a receiver front-end only the most inexpensive designs can accept the compromise in performance. One notable exception is the Plessey SL6440C, which is capable of high bias currents and, therefore, higher signal handling capabilities than its lower power counterparts. Zero dBm LO power is all that is needed to obtain IMD and compression levels similar to diode DBMs which need at least +13 dBm LO power. On the negative side is power consumption of 60 mA and a noise figure of 11 dB.

Build Your Own?

Designing a mixer using discrete components is another way to meet the desired price/performance requirement. The simplest and cheapest mixer available is a single diode, bipolar transistor or FET. This can be the choice of an RF designer in low cost consumer electronics, or in a design with a well-controlled signal level and narrow bandwidth. Single-ended mixers of any type are definitely not high performance.

Some designers have chosen to build single- or double-balanced mixers using discrete devices. It probably is no longer effective to build a diode mixer with so much variety commercially available, but certain applications many benefit from a bipolar or FET mixer. Certain power bipolar transistor mixers (using 2N5109 or similar RF transistors) can be used to obtain high signal level performance and accompanying high third order intercept point. However, such designs typically achieve good performance in a narrow bandwidth application. If a specific design requires high performance over a moderate bandwidth, converted to a fixed IF, such a mixer may be the answer to high dynamic range requirements.

It is easier to obtain such performance using FETs, since these devices have the square-law transfer characteristics best suited for mixing. In a transconductance mode, they require little driving power and can provide excellent dynamic range performance. The same bandwidth limitation exists for FET mixers as for bipolars: they will perform optimally only in narrow band applications. The narrow bandwidth is a requirement to avoid reactive components, since proper input and output matching can be achieved over relatively small bandwidths. Broadbanding is possible, but lowers system impedances, resulting in lower conversion efficiency and higher LO drive, creating a mixer which no longer has an advantage over simpler designs.

The Commutation Mixer

Another passive mixer design which has recently gotten renewed attention is the commutation mixer, using the mixing components as switching elements to interrupt the RF signal at the frequency of the LO. One way to accomplish commutation is to drive a diode DBM with a square wave. It has been shown by Walker (1) that a reduction in the rise and fall times of the switching waveform reduces the intermodulation distortion of a mixer. He developed a driving circuit to provide square wave drive at currents appropriate for diode mixers.

JFETs can also be used as switches, and have been used in past experimental mixers that showed promise. Siliconix at one time offered a quad JFET (the U350) for such application. DeMaw developed a mixer using a pair of power VMOS FETs (2) that also showed promise, but did not become widely used.

Ed Oxner of Siliconix re-introduced the commutation mixer this year at the RF Technology Expo '86 (3), with a mixer based on a new part, the Si8901 DMOS FET quad ring. DMOS technology has made possible analog switch devices that operate into the hundreds of MHz, rather than previous CMOS or JFET switches that operated only in tens of MHz. The switching mixer concept put forth by Walker now has better devices to work with. A prototype Si8901 mixer has achieved third order intercept performance beyond +40 dBm; better in narrowband applications. Oxner's design achieved this sort of performance with +17 dBm LO power.

The DMOS commutating mixer is still not the perfect mixer, however. Driving the capacitive gates of a FET is no small problem. A tuned circuit tank can provide high voltage to the gates, as needed, but is a narrowband solution. Otherwise, high LO power is needed for the fast turn-on time and fairly high gate voltage required for top performance.

Wes Hayward at Tektronix has evaluated the mixer, and while generally impressed with its performance, noted a couple of characteristics that are unusual. The most significant was the fact that the slope of the third order IMD products did not follow the classic relationship as the cube of the input signal level. With this variation, the RF engineer cannot predict with certainty that a 1 dB reduction in signal will reduce third order products by 3 dB.

Making Design Decisions

Ulrich Rohde's comparison of different mixer types (4) is a good place to start in the evaluation of options for a new design. His notes are a result of the same process of evaluation every RF engineer must go through, and is one of very few side-by-side comparisons that have been published.

The bottom line of that analysis is that diode DBMs and commutating FET mixers have the most favorable characteristics, while ICs and discrete component designs have a combination of pluses and minuses that must be considered carefully. It is this consideration of the strong and weak points in each mixer's characteristic that is the engineer's job.

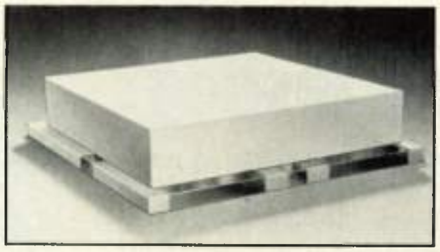
Before establishing specifications for

a mixer, the RF designer has to make sure everyone's specs are defined in the same way. As in every business, each manufacturer wants to make its product appear in the best light, and may define specifications somewhat differently than others. Principal mixer specifications are:

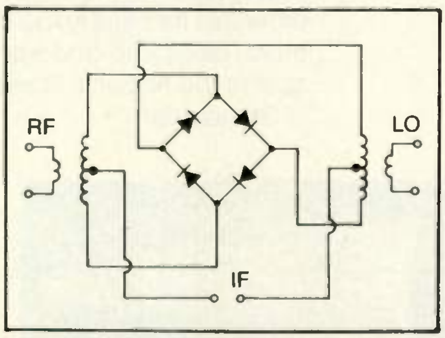
1. *Input compression:* The level of signal at the input that results in an output that deviates *1 dB* from a linear response. Some manufacturers may specify 2 dB compression, or *output* compression.
2. *Third-order intercept (input):* The point at which the input level slope and the third order IMD product level slope intersect on a graph of input vs. output level (using a two-tone test signal). As pointed out by Hayward, if the whole graph is available, possible anomolies in the slopes may be identified. If just a number is given, it may not tell the whole story. Also, some manufacturers may specify an *output* intercept, requiring the conversion loss or gain to be factored into the figure.
3. *Conversion loss (or gain):* While the definition is self-explanatory, the conditions of measurement should be identified by the manufacturer, and should represent normal operation, not a set of parameters that result in the best efficiency at the expense of other performance characteristics.
4. *Local oscillator drive:* Again, normal operating parameters are required, not a minimum specification that does not truly represent the mixer.
5. *Noise figure:* In a passive mixer, the noise figure will be the same as converion loss, with negligible noise contribution from the diodes or transistors. An active mixer may have conversion gain, but also have a noise figure higher than a passive mixer. Don't get the terms confused.
6. *Desensitization level:* This is the level at which a signal removed (typically 20 kHz) from the test signal results in a 1 dB reduction in output. This is related to, but not the same as, input compression.

Once an engineer is "speaking the same language" as the manufacturer, the selection process can begin. Each specification has to have a target value assigned to it, and can then be compared to the available mixer choices.

For example, a receiver operating in the low-VHF range may require signal handling capabilities up to about −10 dBm, with interfering signals of similar levels. Bandwidth needed is about 20 MHz, and no special needs are identified for power consumption, LO drive, or conversion loss. In this example, the signal levels are too high for most ICs, although the Plessey SL6440C could be used. Without special needs, an inexpensive diode DBM would probably fill the design needs adequately.



Packaging options for diode mixers include 8-pin relay headers (top) and surface mount packages by Synergy Microwave (center) and Mini-Circuits (bottom).



Typical circuit design of a standard diode double-balanced mixer. IF port may be DC-coupled as shown, or AC-coupled by a third transformer.

Another possible design task is to identify a second mixer in a double-conversion communications receiver. The unit will be portable and battery operated, and will have AGC applied to the first IF. In this case, the mixer will be narrowband, with controlled signal levels. Power consumption should be minimized for battery operation, and conversion gain would reduce the number of components. Possible choices for this mixer are a bipolar transistor or FET, but better yet would be an IC mixer, offering conversion gain and small size. Further savings might be achieved with a multi-function IC which has a local oscillator transistor on the same chip, and possibly additional IF amplifiers and detectors, as well.

Mixers need special attention by the RF designer, since they represent the limiting factor in system performance. Careful attention to specificiations, performance characteristics, plus the cost and size requirements of manufacturing, is the job of the RF designer who must choose the right mixer for the application.

Note: Attention was not given here to the specialized mixer functions such as the Image-Reject mixer or Quadrature mixer. Readers are invited to submit comments and analysis on these and other mixer types.

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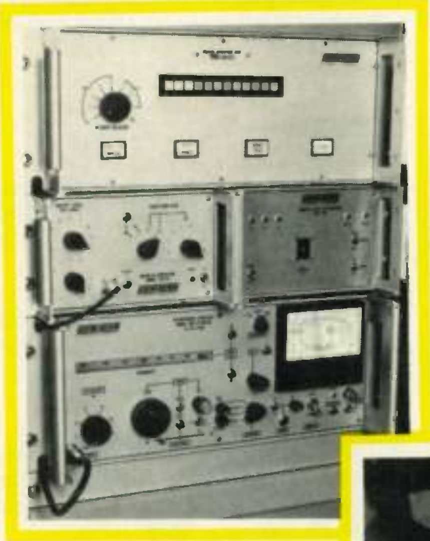

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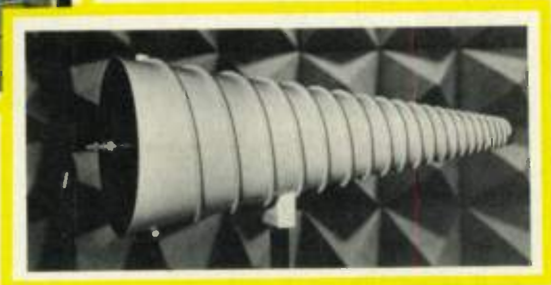

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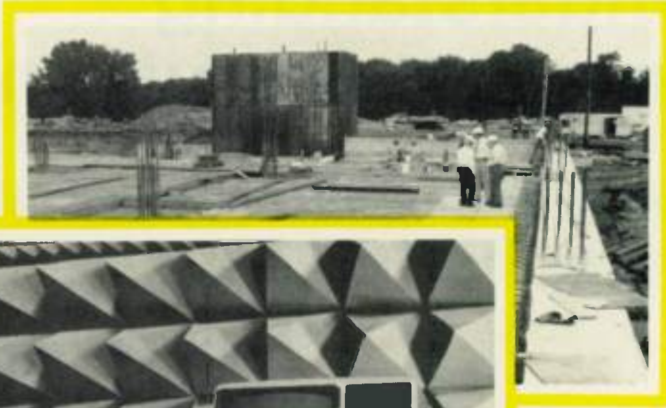

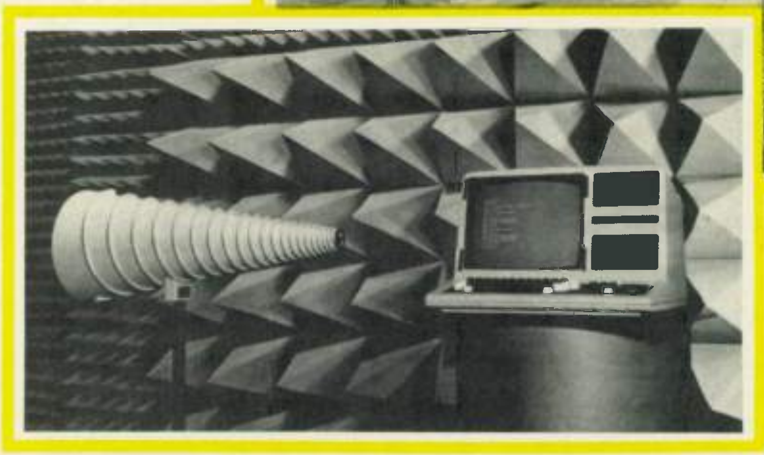

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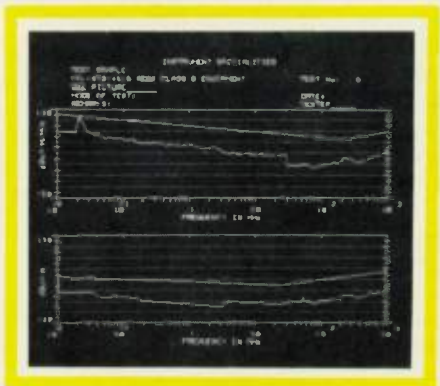

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INFO/CARD 20

Understanding Tempest Requirements

Part II: Design Techniques and Test Considerations

By Michael L. Brooks
Teledyne Systems Company

*The first part of this article (*RF Design, *June 1986) provided information on TEMPEST definitions, security considerations, and the implication of having a TEMPEST requirement imposed on a contract. This information gave us a fundamental understanding of TEMPEST considerations for complying with these constraints. This second part concentrates on general design techniques for satisfying TEMPEST requirements, providing additional insight into the implications of these requirements, especially at the Red/Black interface design level.*

Included in this discussion are the following topics: mechanical partitioning and shielding, grounding configurations, and cabling design. Finally, a brief description of test costs completes this TEMPEST discussion.

Mechanical Partitioning and Shielding

The TEMPEST sub-system example shown in Figure 1 interfaces with both Red and Black I/O signals, and receives Black input power. (As a review; the term "Red" is used to define any plain-text classified signal, its associated circuitry or signal-line, while "Black" is any unclassified signal, associated circuit or signal-line. The junction of Red and Black areas in a design is called "The Red/Black interface.") The TEMPEST engineer's task is to contain Red radiated emanations and to prevent coupling of Red signals onto Black circuits or signal-lines via ground loops or common-impedance grounds. Requiring particular design considerations are the Red/Black interfaces *internal* to the unit or sub-system which involve the electrical/mechanical design of modules and backplanes, the power supply, and the EMI filter assembly. Although power supply and EMI filter design are discussed, primary concentration is on design techniques involving the module and backplane printed-circuit (PC) boards.

Figure 2 illustrates this TEMPEST subsystem divided into Red and Black sections, with the Red/Black interface existing between backplane modules and between the power supply compartment and those modules located in close proximity to the Red I/O connector. The Red section modules, by definition, are the only ones which process classified information, and none of these Red signals intentionally flow into the Black section of the backplane or into the power supply. A mechanical partition, or "wall," may be created at these Red/Black interfaces to shield the Red signals from the Black circuitry and contain them to the Red sections of the unit. This "wall" should be a solid and integral part of the housing rather

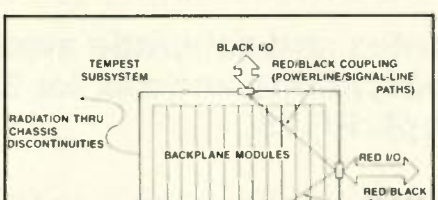

Figure 1. Red Signal radiation/conduction paths.

than a bolted-on addition, to ensure that it will absorb or reflect radiated signals and provide a low-impedance path for ground currents.

Figure 3 is an illustration of a metal Red/Black "wall" shield that is employed to pass Black signals and isolate Red and Black circuits from each other. A feed-thru isolation component is inserted between the two compartments to attenuate Red signal frequencies and prevent them from entering the Black side. This component is bonded to the "wall" barrier, and this barrier is bonded to the equipment housing. The leads of this isolation component are connected to the PC boards located on the respective Red and Black sides of the barrier. This isolation device may be either a discrete filter to attenuate Red signals in a certain frequency range, or it may be an opto-coupler that will transmit only the Black signal information and not Red-related signals. An opto-coupler will also provide isolation of Red and Black current returns (grounds).

It may not be feasible in a particular TEMPEST design to insert isolation components in such a "wall" structure. If this is the case, the Red/Black interface has to be extended into the design of the adjacent Red module. A Red, rather than a Black, module is chosen for control purposes so that all Red signals remain within the Red section.

This module then becomes a Red/Black module and is constructed to contain full-layer PC groundplanes to shield the Red signal traces from Black circuitry. The interconnecting backplane traces must be shielded and isolated accordingly. Figure 4 indicates a simplified layering arrangement for such a Red/Black interface module with its interconnecting back-

plane, and their locations relative to the metal "wall" barrier. Note that the Red/Black interface now extends from the Red/Black module into the associated backplane area, and the "wall" acts only as a shield.

Since the Red/Black module contains the Red/Black interface circuitry and its associated PC traces, the conduction of Red signals must be prevented between the Red signal layer of this module and the Black signal layer via interfacing cir-

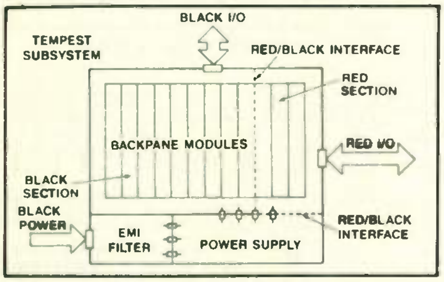

Figure 2. Red and Black compartmentalization.

cuitry (coupling effects). Either isolation devices such as integrated-circuit buffers or filter networks can be employed for this purpose. The isolation circuit techniques should perform as their main function the attenuation of any Red information that has been coupled onto the Black signal-line traces. Figure 5 illustrates how an isolation device would provide interconnection of Black signals between the Black and Red layers of the Red/Black module (layers 2 and 4 of the module, as shown in Figure 4).

The backplane PC traces which connect the Black signals from the Red/Black module to other modules in the Black section, and which connect the Red signals from the Red/Black module to those modules in the Red section, are arranged to provide the needed isolation between Red and Black signal-lines. The backplane area, located at the Red/Black module connector, must provide a continuation of the shielding and isolation designed into the Red/Black module. Whatever degree of Red/Black isolation is found in the Red/Black module has to be maintained in the backplane and in the module connector; i.e., no "weak links." Figure 6 shows a possible backplane trace and connector-pin arrangement for Red/Black signal isolation. (Figure 6 is the backplane-side view of Figure 4). Note that ground pins are utilized to separate the Red and Black signal pins. These pins are plated-thru to the backplane groundplane.

Shielding of the power supply and EMI filter (shown in Figure 2) may be accom-

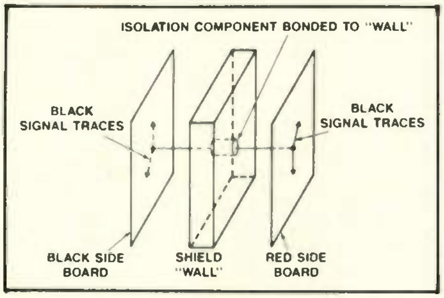

Figure 3. Red/Black shield "wall."

plished by enclosing these sections in a metal compartment isolated from the backplane and modules. The objective is to prevent radiated Red signals in the Red section of the TEMPEST subsystem from entering the power supply and EMI filter compartments. If the power supply cannot be located in a separate compartment, but is designed instead as one module in the backplane, then the shielding techniques illustrated in Figures 4, 5 and 6 may be employed. Nevertheless, the EMI filter must be isolated in a separate compartment with its output terminals shielded from its input terminals and, preferably, constructed integral with the input powerline connector (used exclusively for input power connections).

The Red/Black interface that is developed at the system, sub-system, or unit level must be continued at the module/backplane level and down to the component level. A concentrated effort is required in the early design stages to sufficiently define the Red/Black interfaces. The prompt definition of these interfaces by the cognizant TEMPEST engineer enables module and backplane designers and mechanical engineers to "design-in" the required isolation and shielding. After-the-fact remedial methods are inefficient and poor design techniques that can prove costly in terms of program delivery schedules and budget levels.

Grounding Configurations

A complete grounding configuration for

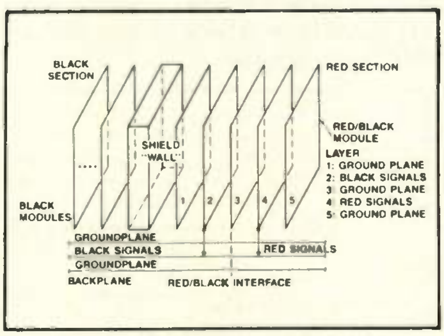

Figure 4. Module and backplane Red/Black interfaces.

the equipment must be developed, as part of the Red/Black interface design, in the early stages of its TEMPEST design. A common ground path must not occur between Red and Black circuits, since the creation of a common impedance between these circuits would cause coupling of Red signals onto Black circuits or signal-lines. Separate current return paths are therefore needed to prevent this TEMPEST problem, and a method of achieving these separate Red and Black grounds is shown in Figure 7. This diagram indicates that the two different grounds are connected together at one point, with no "ground loop" created and thus, no common impedance path for Red-to-Black circuit coupling (assuming that the Red and Black circuits are isolated sufficiently to prevent any high-frequency coupling due to stray capacitance). This single-point chassis ground connection can be ac-

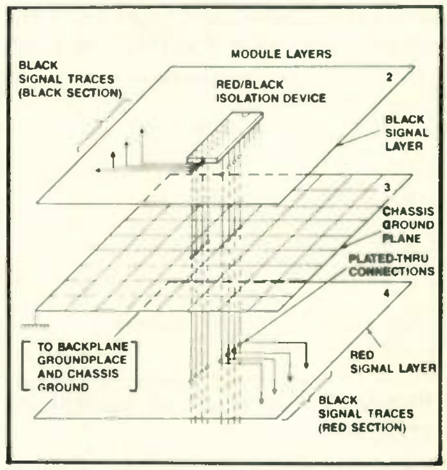

Figure 5. Component-level isolation.

complished with plated-thru holes in a PC board (module or backplane).

The separate and isolated grounds must be continued into the Red/Black interface area and provide the required current return paths for the Red and Black circuits. If the layering configuration of the Red/Black module indicated in Figures 4 and 5 is expanded to include the separate Red and Black groundplanes (with additional circuit and power layers), then the module layering arrangement shown in Figure 8 would be developed. This conceptual eight-layer PC board arrangement provides the separate Red and Black grounds required as well as the single-point chassis ground connection shown in Figure 7. Also, the separation and isolation of Red and Black traces needed to satisfy TEMPEST design constraints can be implemented. If this Red/Black module also had to process both analog and digital signals, then a power or ground plane would consist of four separate sections: Red analog, Red digital, Black analog, and Black digital. Different circuits and component types would then be required to achieve the necessary isolation at the analog and digital Red/Black interfaces.

These groundplanes may also be utilized for shielding purposes (as shown in Figure 4). Each "split" groundplane layer would shield its respective circuits: Red or Black. As many layers as required are employed to isolate Red circuit traces from other Red circuits, as well as from Black PC traces. The Red and Black groundplanes thus serve the dual function of current return and shielding for the Red and Black circuitry. If required, this duality of function could apply to both module and backplane groundplanes.

The use of copper in the PC power or ground planes must be maximized to provide low-impedance paths for current returns (to minimize power losses) and to ensure that these boards are effective as shields. The "cross-hatching" of traces

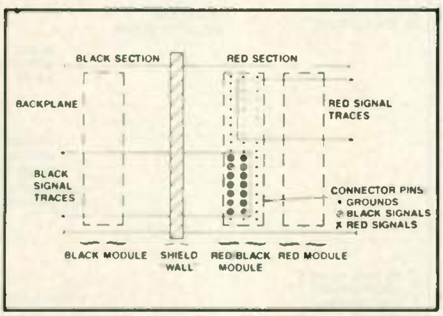

Figure 6. Isolation of backplane traces.

between backplane connector pins or module components is required to form an interconnecting copper grid, permitting only the minimum optical opening (aperture) dimension to remain for connector pins or component leads. Sufficient decoupling capacitors or filter networks are required for powerplanes to attain a high-frequency zero-potential (ground) level for these layers.

Cabling Design

Whatever level of required TEMPEST isolation accomplished by the design of the Red/Black interfaces within the unit must be continued into the design of the internal interconnecting wiring and external cables. Red signal lines must be physically separated from Black lines, including power, control, and signal-lines, to prevent the coupling of Red information onto these Black lines. In addition to this isolation requirement, the Red cables are shielded to contain information within these cables and minimize the creation

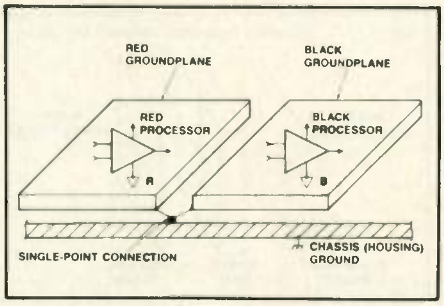

Figure 7. Single-point grounding.

of radiated fields.

The physical space available must be effectively utilized in order to provide the necessary separation and isolation of Red and Black cables (with proper routing and dressing of these lines). As described earlier in the discussion of the Red and Black designated areas, the location of the I/O connectors on the housing must also be arranged to ensure that Red and Black signals are separated. As is shown in Figure 2, the Red I/O connector interfaces with the Red backplane area and associated modules, whereas the Black I/O and power connectors will connect to their respective circuits. Red and Black wire cables (between the I/O connectors and the backplane) must be located in different areas of the housing and shielded to prevent line-to-line coupling.

The effective separation of Red and Black PC wiring requires substantial design forethought to properly route these traces in a backplane or Red/Black module, while considering other constraints for layout of these boards such as power and ground connections, shielding, thermal considerations, component placement, and restrictions on the number of layers. General considerations for the routing of Red and Black PC traces in a backplane are shown in Figure 6, with similar module trace layout used for interconnecting components. Separate sections of the PC board are utilized for the Red and Black signal traces, as is indicated in Figure 8. The use of different Red and Black sections for these respective circuits enables the board to be fabricated with inherent Red/Black isolation.

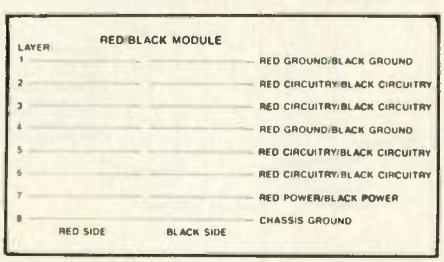

Figure 8. Module layering arrangement.

Shielding is designed as part of the PC boards using ground traces and planes to surround the signal-lines and create a "simulated" shield. Figure 9 illustrates this shielding concept which employs a sufficient number of plated-thru connector ground pins (in a backplane) or component ground pins (in a module) to provide low-impedance grounding paths for the shield. Since the shield is composed of areas of solid copper, adequate protection is provided for the shielded signal-lines. This shielding, combined with the

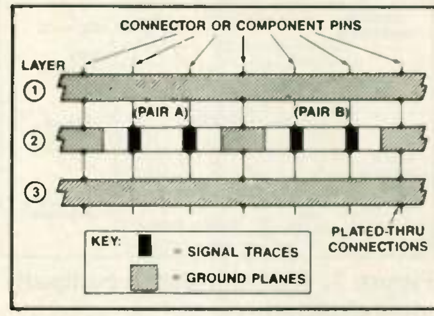

Figure 9. PC board shielding.

proper separation and routing of signals, ensures an adequate TEMPEST design at the PC board level. The specific example of Figure 9 is for a simulated twisted/shielded pair or a twinax, but the construction of other shielding types is also possible. Double-shield configurations may also be obtained with this technique, but would utilize two extra board layers to create the second shield.

Test Costs

Just as the TEMPEST design considerations described in this article have a major impact on the budget and schedule of a program, test costs also have an impact on the budget (non-recurring costs) and schedule. Typically, the following tests will be performed at the equipment level (to NACSIM 5100A requirements):

- Electric-Field Radiated (ER)
- Magnetic-Field Radiated (MR)
- Red Line Conducted (RLC)
- Black Line Conducted (BLC)

The number of different (differing in waveshape) Red signal types will determine the expense of performing ER, MR, or RLC tests. The number of different Red signal types *and* the number of different Black signal types will determine the cost of performing BLC tests. The BLC test costs especially can become high if the equipment interfaces with a large number of different types of Red and Black signals.

In addition to testing, the cost of the required documentation will also have a major impact. The following documents would typically be required for TEMPEST testing:

- Test Plan
- Test Equipment Certification Report
- Test Set-Up Ambient Certification Report
- Test Report

The test plan and the two certification reports are required for submission at least 180 days prior to testing. The test report submittal is usually required 30 days after completion of testing. All TEMPEST documentation requires the approval of the cognizant NSA department, known as the Special Committee on Compromising Emanations (SCOCE).

Conclusion

A requirement for TEMPEST compliance demands total commitment to a design that is optimum in every aspect of Red/Black isolation. The TEMPEST engineer must have both the authority and the initiative to ensure that this commitment is followed-through from the proposal stage to final production of the equipment or system. An in-depth understanding of TEMPEST requirements and their implications to the budget, schedule, and design constraints of a program is a necessity for all mechanical and electrical engineers, the project engineer, and the engineering and program managers.

Although the two parts of this article provide a fundamental background to TEMPEST and some design considerations, these and other design topics may be studied in more detail. In addition to the Air Force Systems Command EMC Design Handbook 1-4, NACSIM 5100A, NACSEM 5201, and NACSIM 5203, the list of unclassified references included below should prove very useful for EMI/EMC/TEMPEST design. rf

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About the Author

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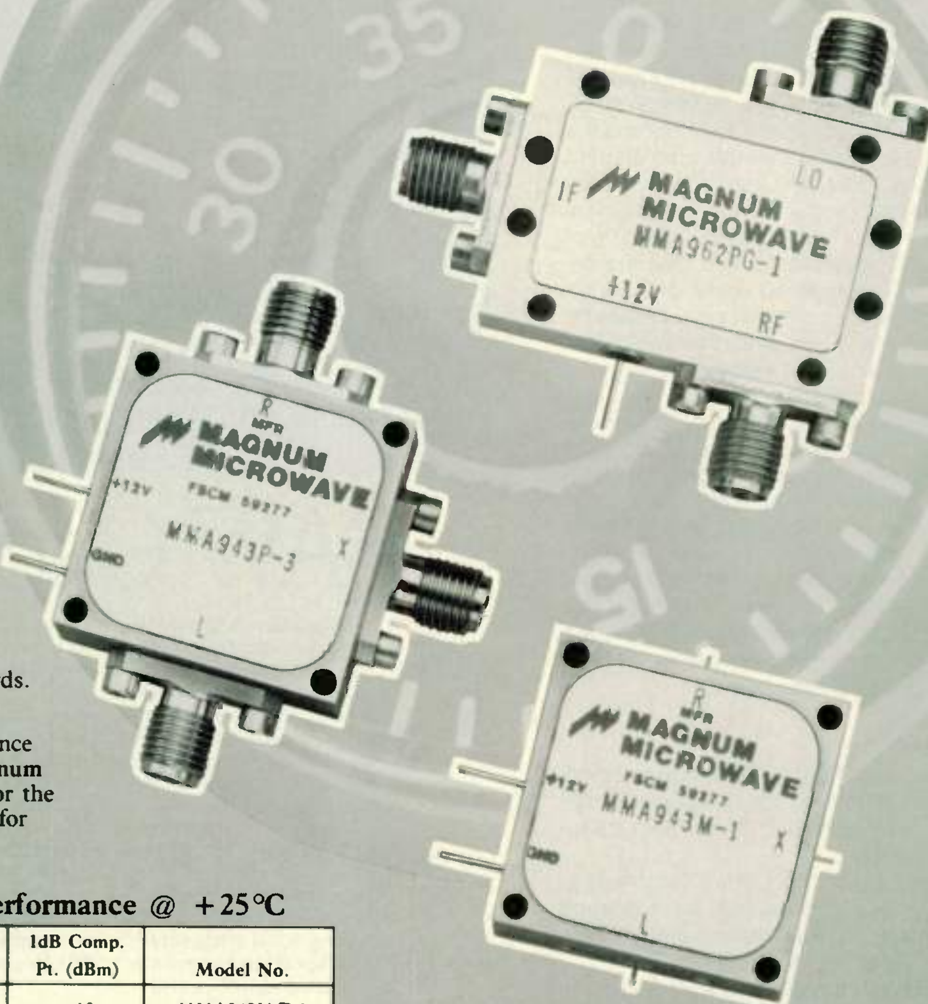

Mixer Preamplifier Typical Performance @ +25°C

Frequency (GHz) Rf, LO	IF	Noise Figure dB	Conversion Gain (dB)	1dB Comp. Pt. (dBm)	Model No.
6-18	.070 ±.020	9.0	12	+10	MMA942M/P-1
6-18	.070 ±.020	9.0	25	+20	MMA945M/P-1
6-18	.160 ±.020	9.5	10	+15	MMA943M/P-1
6-18	.160 ±.020	9.0	22	+15	MMA943M/P-2
6-18	2-6	12.0	10	+10	MMA962MG/PG-1
6-18	2-6	12.0	20	+10	MMA962MG/PG-2
6-18	2-6	12.0	18	+15	MMA963MG/PG-1

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INFO/CARD 23

Interfacing With GaAs Digital ICs

By Don Apte
Harris Microwave Semiconductor

The availability of GaAs SSI and MSI digital ICs has given designers a new way to design high speed digital systems. The inherent speed of GaAs makes it better suited for higher speed and wider bandwidth applications than have been possible with ECL circuits, but moving up to GaAs ICs is not as straightforward as pulling out an ECL device and inserting a GaAs device.

First, the power supply voltages for most GaAs ICs are different than ECL, and they vary from manufacturer to manufacturer. Some companies offer products which have a V_{DD} = +4.0 to +5 V and a V_{SS} = −3.0 to −3.5 V, while others use a V_{EE} = −4.9 to −5.5, a V_{SS} = −3.3 V, and a V_{DDL} = +1 V. Second, GaAs ICs faster edge rates (125 ps) require all input/output signal lines to be treated as 50 ohm microwave transmission lines. Third, the methods for testing and measuring GaAs ICs are different, with operating speed representing a *microwave* environment.

The inputs to most GaAs circuits use BFL, SDFL, DFL or CDFL MESFET configurations and must be protected from static discharge. Power supplies with good voltage regulation are essential for reliable operation. A good design practice is to use decoupling capacitors (0.1 μF) on all power supply lines. Adequate heat sinking and grounding of GaAs ICs is also essential because of the high-power dissipation and high-frequency operation.

There are many other characteristics that distinguish GaAs from ECL devices. Unused GaAs IC MESFET inputs float to a high logic state. In contrast, unused single-ended inputs of ECL devices will assume a low logic state and can be left floating. GaAs devices require a pull-down terminating resistor (R_T) that matches the transmission line characteristic impedance, typically 35 to 65 ohms, preferably 42 to 52 ohms. The GaAs IC terminating resistor must be connected to a negative supply of −2.0 to −3.5 VDC. An ECL terminating resistor is typically 50 to 120 ohms, and must be terminated to −2 VDC for 50 ohm transmission lines. The input impedance of an ECL device is around 50,000 ohms, while the input impedance of a GaAs BFL MESFET input is typically between 100 and 200 ohms. The maximum output current for ECL "10K" series devices is 50 mA, and the output current for military ECL devices is 11 mA. In contrast, the I_{OH} output current of GaAs ICs ranges from 30 to 65 mA. Depending on the output current for a particular device, this means that one GaAs device can drive as many as three other GaAs ICs if R_T terminates the transmission line at only one point.

Any unterminated stub lengths should be kept under 0.25 inches. By keeping stub lengths very short, the reflections and spurious transmission line frequency components are minimized. The fanout capability of a GaAs device is limited by the effective capacitive loading of the transmission line as well as by the load of the GaAs or ECL inputs receiving the signal (Figure 1).

For example, a 125 ps edge rate driving a 1 pF load will degrade to about 500 ps when it must drive a 5 pF load. The rise and fall times (edge rates) of GaAs digital ICs are measured between the 20% and 80% amplitude points on the output signal, but most ECL devices are measured between the 10% and the 90% amplitude points. For applications that require multiple clock distribution, a Harris clock fanout Buffer/Driver can be used to preserve clock edge rates.

When measuring fast rise and fall times of GaAs ICs, you must use a scope probe that has the lowest possible loading capacitance (1 pF or less) and a bandwidth that passes harmonic frequency components above 12 GHz (Figure 2). It is also recommended that the scope probe have an internal DC bias/offset. The use of gigahertz

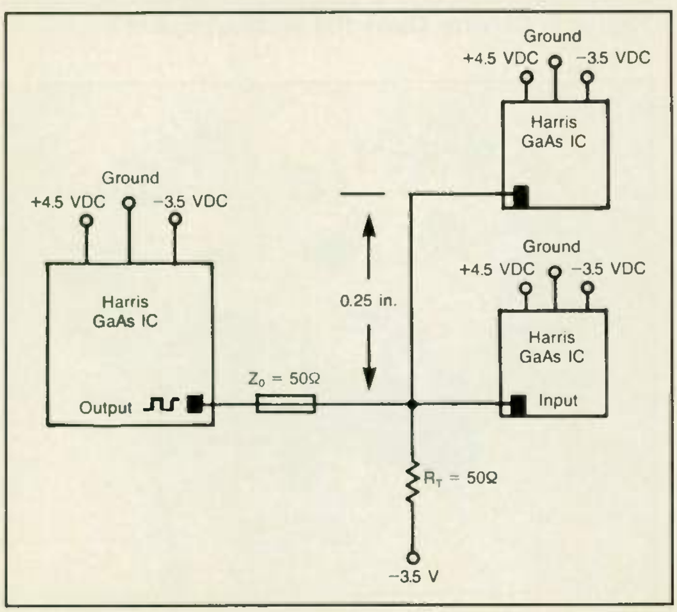

Figure 1. Driving multiple GaAs ICs.

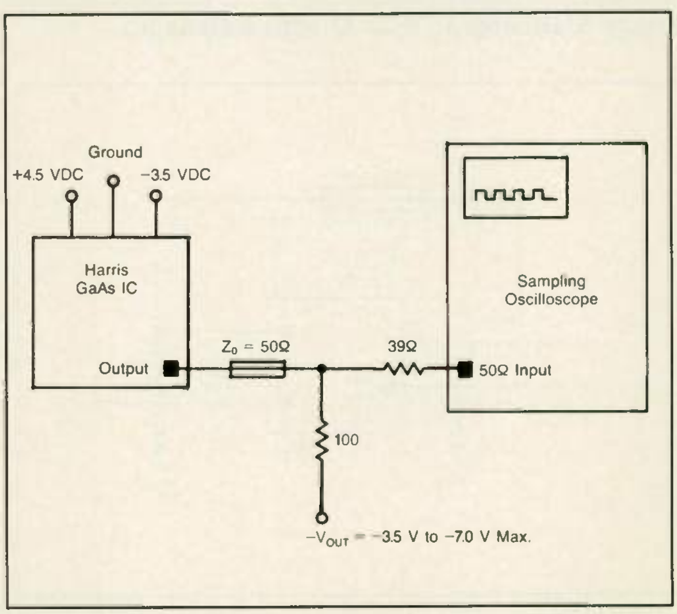

Figure 2. Oscilloscope connection to a GaAs IC.

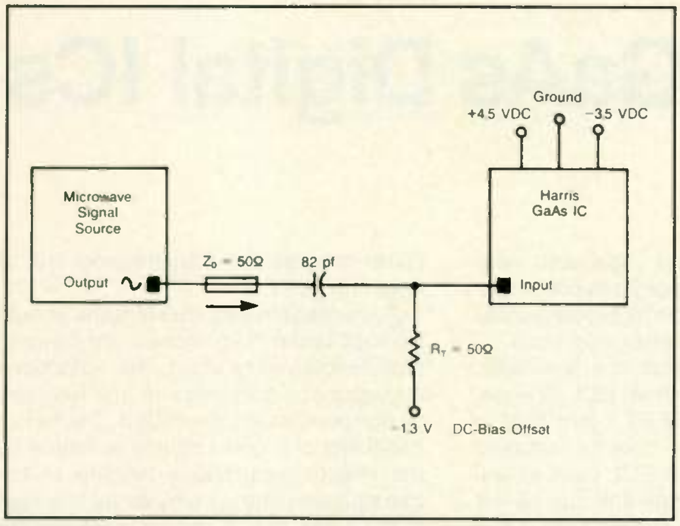

Figure 3. Driving GaAs ICs with an analog signal.

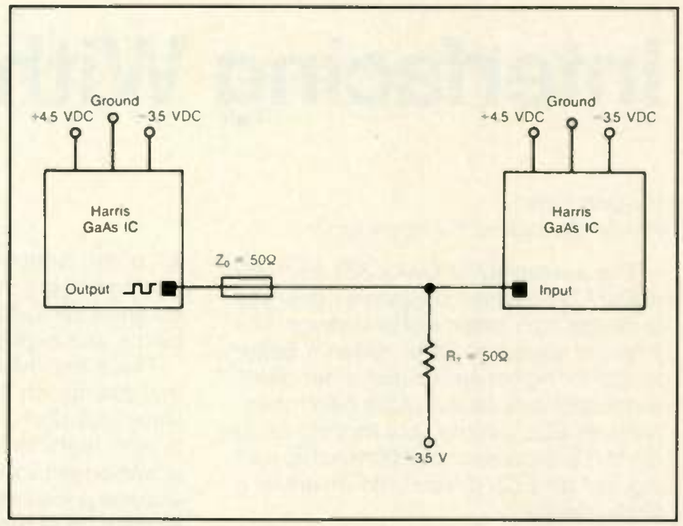

Figure 4. Driving a GaAs IC with a GaAs IC.

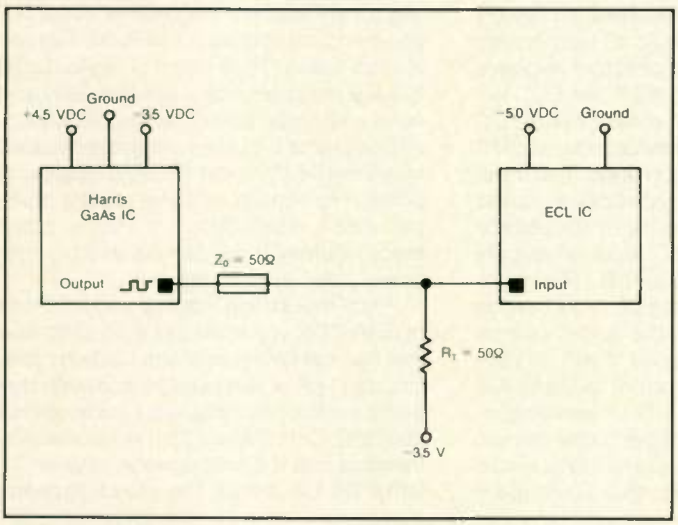

Figure 5. Driving an ECL IC with a GaAs IC.

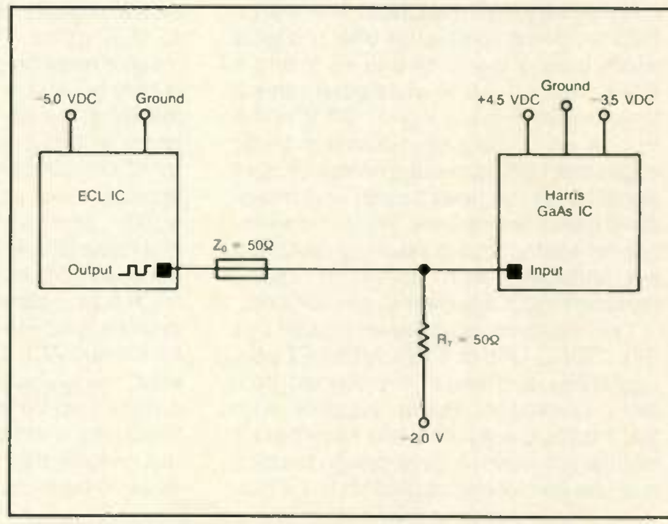

Figure 6. Driving GaAs ICs with an ECL IC.

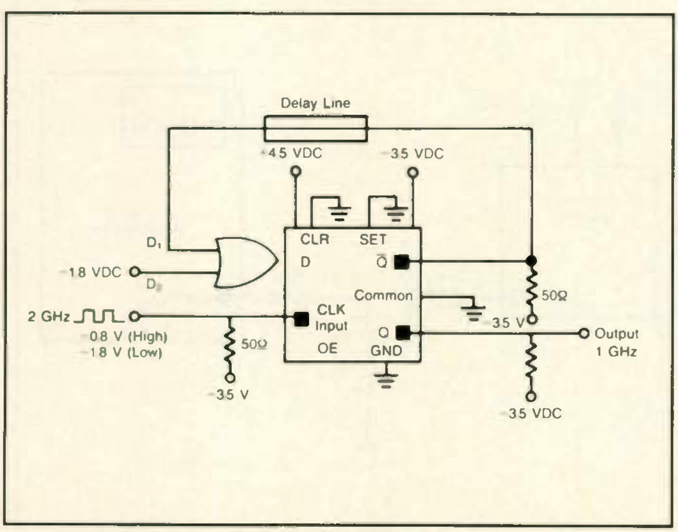

Figure 7. ÷2 Circuit using the HMD-11131-2 Flip-Flop.

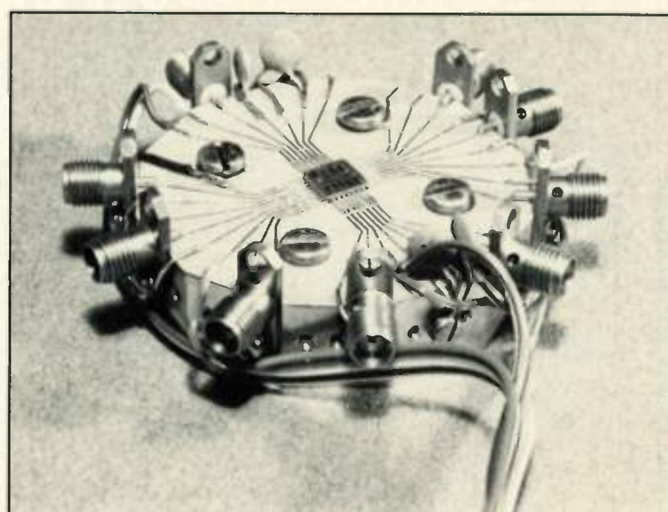

Figure 8. The Harris HMK-11MSI-1 Evaluation Kit.

sampling equipment will provide good measurement results.

The input signal requirements for Harris digital GaAs ICs are standard ECL-compatible levels: −0.8 V Logic High and −1.8V Logic Low, although some other GaAs ICs require higher input levels to achieve faster clock speeds. When applying a sinewave analog signal into a GaAs IC input, it must be AC-coupled and DC-offset to ECL levels (Figure 3). This can be accomplished using a bias "tee" network with a suitable bandwidth. To use an input level other than ECL, certain design conditions must be met. For example, Harris' divider ICs can accept an input swing level as low as 500 mV peak-to-peak if the DC offset voltage is adjusted to a more negative value, typically about −1.6 V. For reliable performance, IC inputs should not be biased at positive potentials above +1 VDC or negative potentials below −2.5 V. Figures 1 through 7 show various bias and drive configurations for Harris GaAs ICs. If an RF signal source is used to drive the IC, the maximum power input should not exceed +13 dBm.

The *outputs* of available GaAs digital ICs are also ECL-level compatible, and require a pull down terminating resistor connected to a negative supply voltage. When driving a Harris GaAs IC with another GaAs IC (Figure 4), the terminating 50 ohm pull down resistor must be connected to a −3.5 V negative supply. When using a GaAs IC to drive an ECL IC (Figure 5), the terminating resistor-bias voltage should also be −3.5 V. When an ECL IC is used to drive a GaAs IC, the bias voltage should be −2.0 V (Figure 6). If a reduced output amplitude is desired, the −3.5 V bias voltage can be adjusted to −2.0 V, lowering GaAs IC output buffer power dissipation by 30 percent.

GaAs ICs with complementary Q and $\overline{Q}$ outputs should have a 50 ohm transmission line for each output to maintain a balanced system. This is best accomplished by placing a 50 ohm pull down resistor on each output to a bias voltage of −3.5 V (Figure 7). For an IC with multiple single ended outputs, connect any unused output through a 50 ohm resistor to ground.

These GaAs ICs are housed in hermetic 50 ohm microwave flatpacks to minimize parasitic and cross talk performance degradation. Standard ECL plastic and ceramic dual inline packages are unusable at microwave frequencies, since the added propagation delay of the package must be minimized. For specific applications, the GaAs IC supplier must understand the customer application and system layout, then configure the device pinout to minimize propagation delay and feedback return path.

To assist designers in learning the basics of working at the speeds now possible with GaAs digital ICs, a number of manufacturers offer evaluation kits such as that shown in Figure 8. The evaluation kits allow "hands-on" use of the devices for prototyping or device characterization by the user. rf

About the Author

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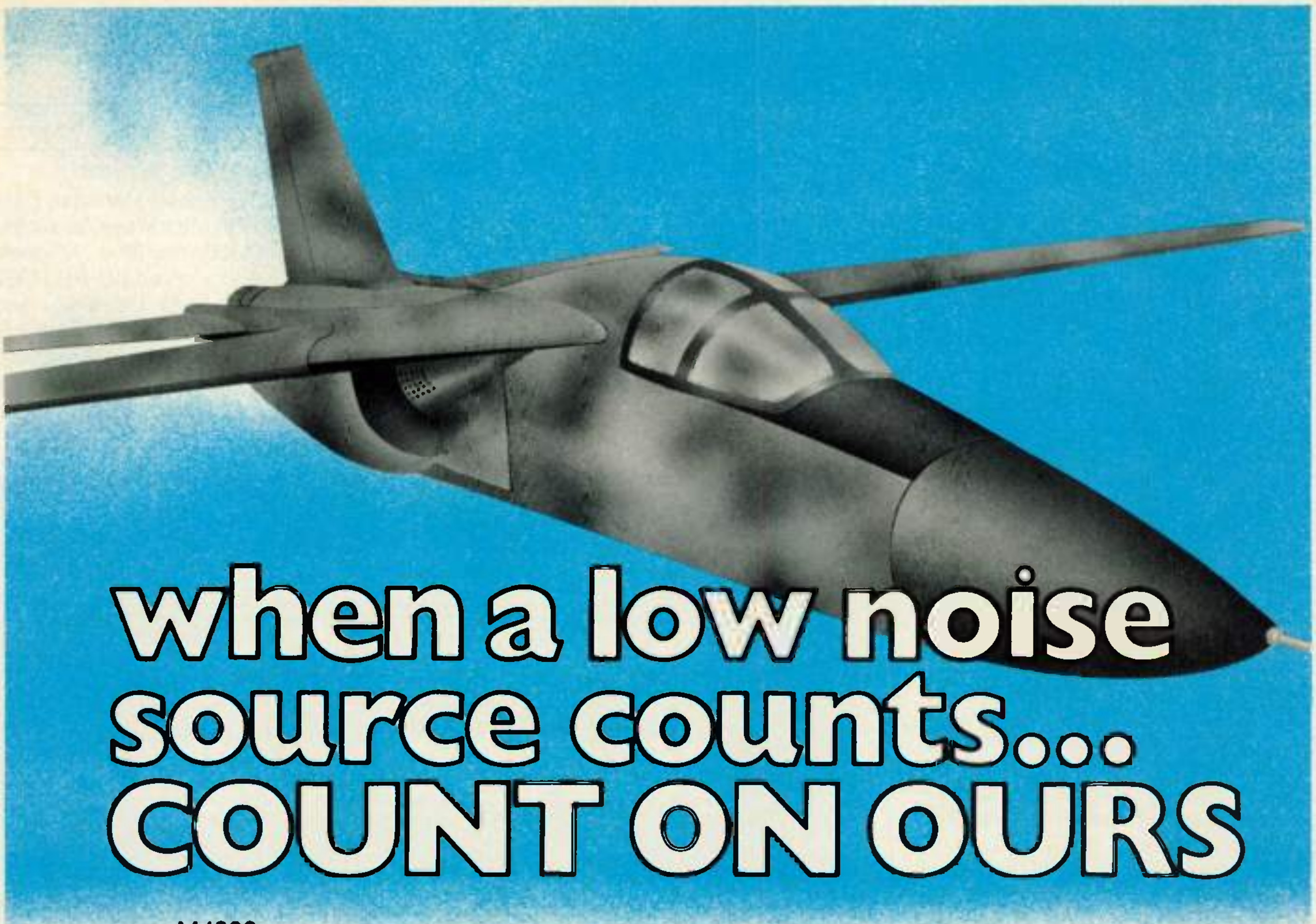

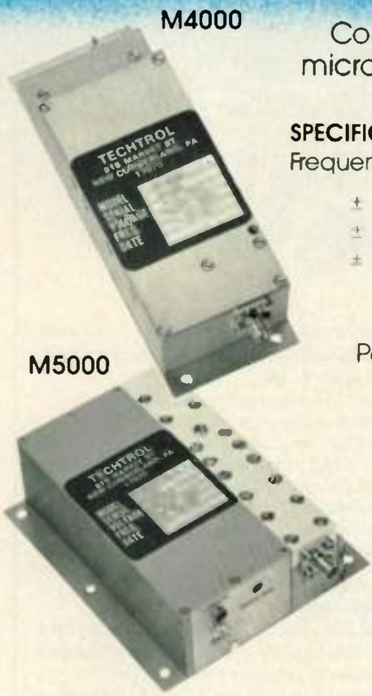

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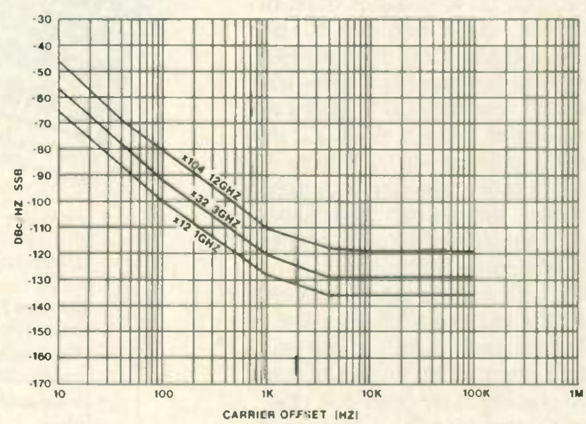

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REACTION INSTRUMENTS

INFO/CARD 26

100 MHz to 3.5 GHz Propagation Curves

Computer Programs for Communications Range Calculations.

By Lynn A. Gerig
and Joseph R. Hennel
Magnavox Electronic Systems

Although the typical RF design engineer is often characterized as being concerned only with transmitter or receiver circuits, actual design tasks are widely varied, including everything from crystal filters to antennas. In recent years the heavy emphasis on energy conservation and total system costs have required engineers to look at the total system. Can the increase in power consumption and cost resulting from increasing transmitter power from 10 watts to 100 watts be justified? Could the same performance be achieved with less money by increasing antenna gain or height? In these times of economic "crunch," contracts are won and lost by the answers to such questions.

Many engineers, aware that free-space propagation loss changes at a 20 log (distance) rate, assume one can always double communications range by increasing transmitter power by 6 dB. However, when working with actual earth curvature, a 25 dB increase in power may yield less than a 10 percent increase in range. This article describes computer programs which predict VHF, UHF and L-Band communications range based upon receiver, transmitter, and antenna parameters. Ground-to-ground, ground-to-air, and air-to-air data are included. Both free space range and range over real earth are given.

Propagation Curves

Although propagation curves have been available for about 40 years, many engineers have not been aware of them or have not known how to use them. The classical curves by Bell Labs (1) cover frequencies from 200 kHz to 600 MHz, distances of .5 to 1000 miles, and are arranged in 6 sections covering propagation over sea water, good soil, and poor soil for vertical and horizontal polarizations. Typical inputs and outputs are: power relative to 1 kW transmitted from a grounded vertical antenna, and field strength units of dB above 1 micro-volt per meter, and one must be wise in the ways of antenna conversions to use them. Predictions are also complicated at HF where antennas are usually located within a few wavelengths of ground, and where actual antenna directivity and efficiency are directly affected by soil conductivity.

Propagation predictions at VHF (and higher frequencies) are more straightforward because antennas at these frequencies are usually mounted many wavelengths above ground. At these frequencies the communications range is essentially independent of polarization and soil type for antenna heights of 100 feet or more. Variations of not more than 3 or 4 dB are to be expected at heights of 25 feet. Based upon these facts (and other assumptions) the ESSA curves (2) are useful at frequencies above 100 MHz.

The computer programs described below utilize data taken from selected curves in the ESSA document. After entering operating frequency, receiver sensitivity, transmitter power, and antenna heights and gains, the programs calculate the expected communications range. The programs have been developed for the Commodore 64 (or 128), the Texas Instruments TI-99/4, as well as the IBM-PC and compatibles. A typical output from the Commodore 64 version is shown in Figure 1.

Program Description

This section describes the program for the Commodore 64 (or 128) since it contains the most features. Adaptations for other computers will be described later. The program begins with line 2, sending you to a subroutine (lines 500-510) where arrays are dimensioned and certain variables are established. The actual program begins with line 10.

In lines 10 through 40 the program title is displayed on the screen and selection can be made by any combination of screen, border, and letter colors that may be pleasing, instead of the Commodore 64 default conditions. In line 50-74 receiver sensitivity and transmitter power is defined either in micro-volts and watts or in dBm (decibels relative to 1 milli-watt). This is for operating convenience, as the program will convert either type input to the other and display both as an output. In lines 100-110 selection is made of either VHF, UHF, or L-Band as the operating band, and the appropriate data is read (VHF data lines 2000-2610, UHF data lines 3000-3810, or L-Band data lines 4000-4610).

Actual program inputs for range calculations begin at line 200 where sequential subroutines are used for selecting frequency, transmitter and receiver parameters, antenna gains, and antenna heights.

The subroutine in lines 600-604 asks for a specific operating frequency within the band you selected. Actual data are for 125 MHz, 300 MHz, and 1.6 GHz, but the program scales to your actual operating frequency by a 20 Log (F/F_{ref}) factor in line 350 to show propagation variations within a given band.

The subroutine in lines 700-740 asks for receiver sensitivity and transmitter power output. The units are either micro-volts and watts or dBm, depending on which was selected in line 74. Input is converted to both units which will be displayed later.

The subroutine in lines 900-906 asks for antenna gains in dBi, the gain in dB relative to an isotropic antenna. If your antenna gain is known relative to a dipole, add 2.15 dB. For example, an antenna with 7.5 dB gain referenced to a dipole (dBd) has a gain of 9.65 dBi. The operator is next asked to enter any system losses, such as coaxial line losses.

Actual antenna heights are selected in the subroutine from lines 800-870. The data tables from lines 2000 to the end of the program contain propagation information for specific antenna heights, so the discrete value closest to actual antenna height must be chosen. For example, if the antenna height is 40 or 60 feet, use menu item "2" which is 50 feet. For selected antenna heights of 50' and 100' (menu items 2 and 3), the program then selects H$(2, 3) data for these heights. The string manipulation in lines 850-858 will be described later.

The actual program output to the screen is performed in lines 300-426 (shown in Figure 1). The operating frequency is printed, followed by XMTR output in dBm and watts and RCVR sensitivity in dBm and uV. The antenna gains and heights selected are then printed followed by the losses selected. The next item printed is the system path margin in dB, followed by the free space path length in miles. This is the distance over which communications could take place if it were not for the earth's curvature, etc., and is useful in predicting satellite communications. Finally, the range over the real earth is printed in both statute and nautical miles. The range given is the expected range for normal conditions; actual range will obviously be affected by atmospheric conditions, terrain, etc.

One of the features of this program is the change in a single parameter without having to re-enter all previous inputs. Note the menu at the bottom of the screen (Figure 1). Would you like to see how much further you could communicate if you raised the ground antenna from 25 feet to 50 feet or changed the aircraft height from 10,000 feet to 40,000 feet? Just press "H" on the keyboard and the program asks for new antenna height (subroutine at line 800 from line 420), then the new range for those heights will be instantly displayed. With a few keystrokes you can easily compare expected improvements in range from changes in antenna height, antenna gain, power output,etc. If you have a printer, just press "P" and lines 430-436 will give you a screen dump to your printer.

```
 ---------------------------------------
UHF PROPAGATION:   FREQ = 312.5 MHZ

TRANSMITTER POWER OUT: 44.8     DBM
                       30       WATTS

RECEIVER SENSITIVITY: -95       DBM
                       4        UV

LOWER ANTENNA :   7.5 DBI @ 50 FT
UPPER ANTENNA :   1.5 DBI @ 40000 FT

COAXIAL LINE LOSSES :   4.2 DB

 144.6 DB PATH
FREE SPACE PATH = 768 MILES

MAXIMUM EXPECTED RANGE:   272 MILES
                          236 (NAUT MI)

 ---------------------------------------
G=MODIFY ANT GAINS        R=RUN AGAIN
H=MODIFY ANT HEIGHTS      P=PRINTER DUMP
X=MODIFY R/T SENS/PWR     Q=QUIT
F=NEW FREQ (SAME BAND)
 ---------------------------------------
```

Figure 1. Typical program output.

Data Format

The data in lines following 2000 are taken from the ESSA Technical Report mentioned earlier. There are about 100 pages of curves with up to 17 curves per page in that document. The programs store selected data points from various curves, and they construct "piece-wise linear" equations fitting the original curve as nearly as possible.

For the curious, the following is a detailed explanation of the data manipulations. Assume the selection of VHF and antenna heights of 50 and 100 feet. Logical breakpoints in the ESSA curves are 10 miles for a 120 dB path, 32 miles for a 150 dB path, 50 miles for a 165 dB path, 105 miles for a 175 dB path, and 310 miles for a 210 dB path. Now refer to line 2085 and note that:

H$(2,3)="120010150032165050175105210310."

The first 3 digits (120) store the first path point, the next 3 digits (010) store the first distance point, the third 3 digits (150) store the second path point, the fourth 3 digits (032) store the second distance point, etc., to the last three digits (310) which represent the last mileage point. After antenna heights are chosen (lines 800-832), the appropriate data line is divided up into 5 path points and 5 distance points by string manipulation in lines 840-858.

After the program calculates system path margin (lines 320 and 350) from the various inputs, the program path is compared to the data points described above. If it is less than the smallest or greater than the largest, a "Range Not In Program" message is printed (lines 352-358). If the path margin falls between the data endpoints, the program calculates expected range by assuming a straight line between the nearest 2 points stored (lines 360-366), and the expected range is printed to the screen.

Using the Programs

The programs must be used with caution. They give ranges over average terrain for which communications can be expected 50 percent of the time. Obviously you won't be able to communicate as far through a dense jungle or over mountainous terrain, etc., so some common sense must be used. However, the programs are very practical for determining relative changes in anticipated range due to modifications of receivers, transmitter, and antenna specifications. When entering receiver and transmitter parameters, use power output (not input) at the transmitting end and sensitivity at the receiving end.

Feel free to contact either of the authors with questions or comments about the programs, but only letters with an SASE will be answered.

Copies of the programs for the Commodore 64 and the IBM-PC are available from the authors. For the C64, send a blank tape (C-30 or longer) or a formatted disk (1541 format), and for the IBM-PC, a formatted disk. These should be sent in a stamped, self-addressed mailer with check or money order for $5.00 to: Lynn A. Gerig, R.R. #1, Monroeville, IN 46773. Two verified copies will be made on the tape or disk. rf

Editor's Note: With over 350 lines of DATA statements, each containing 30 digits of numerical information, it is recommended that interested readers obtain a copy of the program from the authors. However, if only a program listing is desired, one can be obtained by sending a self-addressed stamped business-size envelope to RF Design, *6530 S. Yosemite St., Englewood, CO 80111. Only requests which include a SASE will be accepted.*

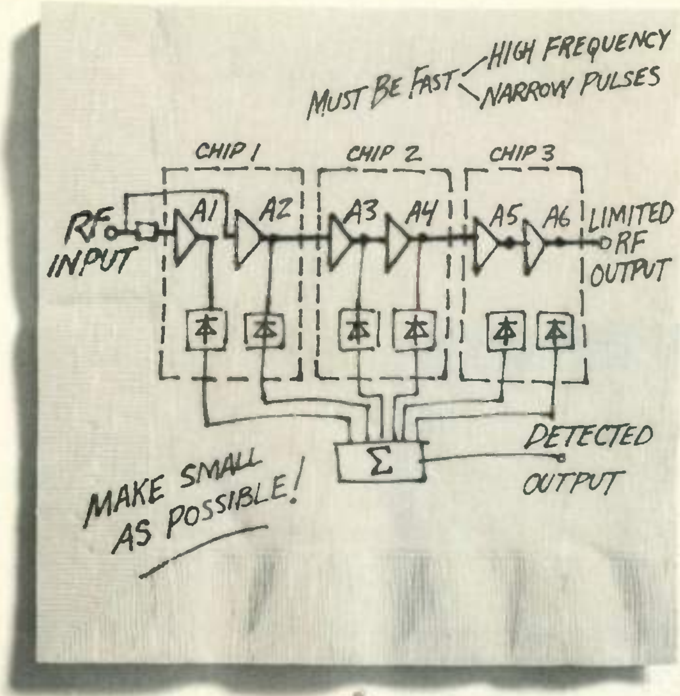
References

1. Report 966-6C, *Propagation Curves,* National Defense Research Committee, Division 15, Bell Telephone Laboratories, Inc., Issue 3, October 1944 (Declassified to OPEN 8 Mar. 1946).

2. *ESSA Technical Report ERL 111-ITS 79,* Transmission Loss Atlas for Select Service Bands from 0.125 to 15.5 GHz, Institute for Telecommunication Sciences, Boulder, Colorado, May 1969. Available for $1.25 from Sup. of Documents, U.S. Govt. Printing Office, Washington, D.C. 20402.

About the Authors

Lynn A Gerig is a project engineer, and Joseph R. Hennel is a section manager with Magnavox Electronic Systems Company, 1313 Production Road, Fort Wayne, IN 46808. They report good correlation between the predictions of this program and measured communications range data. The authors can be reached at the above address or by telephone at (219) 429-6000.



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PLESSEY

INFO/CARD 29

RF-to-Optical Data Link

Patented system uses both RF and fiber optic technologies.

By Gary O. Sandstedt
Commercial Data Processing, Inc.

RF technology must often interface with other technologies within a system, whether it be communications, control or measurements that are required. This article describes a way to interconnect RF and optical transmission modes in a data communications system.

There is another important lesson, too. This system concept is patented (U.S. Patent 4,259,746 and various foreign patents), and illustrates that new arrangements of existing technology can be conceptually unique enough to be patentable.

In recent years the marriage of radio frequency and optical transmission systems has become dramatically more important as a means of moving data cheaply, fast and reliably. Described here is a system where, at some point in the communications link, a change is effected in the method of transmission (from RF to optical or vice versa) while the communications in process retains its integrity. Transmitters and receivers are not merely transmitters and receivers anymore, but support such features as integrated data bases, processors, storage and ancillary peripheral devices including CRTs, tape and disk drives, keyboards, readouts, transponders and other innovations.

RF-to-optical conversion offers many

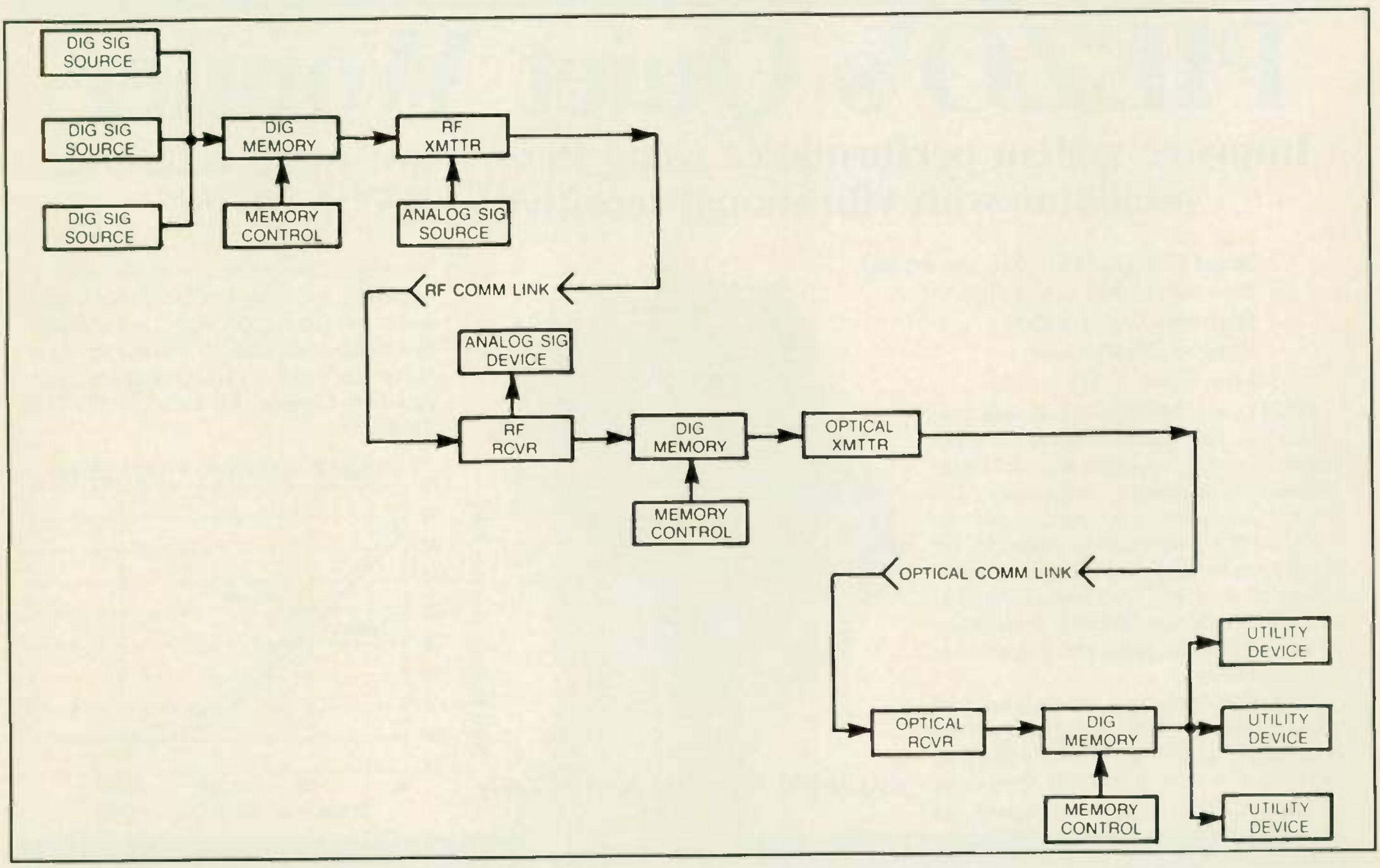

Figure 1. Diagram of the RF-optical data link.

possibilities with the advent of local area networks. One may think of LANs as client computers talking to each other or a central mainframe host in an office environment, but with the advent of factory and campus-wide LANs, distribution of data on a network can be formidable. There are frequently gaps in a system where one technology does not lend itself efficiently to the resolution of all transmission and distribution obstacles. The RF-to-optical link can solve many of these problems.

Figure 1 illustrates the RF-to-optical link's versatility in sourcing digital and/or analog signals, then transmitting them to a distant point and onto utilitarian devices such as host or client computers, terminals, printers, data loggers, instrumentation, etc., by fiber optics.

At the receiving site data is loaded into memory, assembled into some form of protocol and communicated to client devices. The hallmark of both RF and optics is speed, allowing flexibility not found in hard wiring.

Environments where large areas of distribution are needed, such as a recreational theme park, military base, industrial site, a college or corporation campus, provide opportunities for RF-to-optical implementation. Data downlinked from a satellite can be distributed throughout a complex. Obviously a satellite-to-ground link must be by RF means, but from the point of RF demodulation all hardware can be high speed optics.

Office complexes or corporate headquarters situated in a campus environment can communicate through a fiber optic Local Area Network and send their data between buildings via the RF portion of the communications link.

The Military Connection

It has been established within the aircraft industry that an on-board fiber optic communications network is desirable when weight, speed and transmission capacity are considered. One major airframe manufacturer has recently announced that fiber optics control and communications will be part of their new generation of aircraft, making RF-to-optical connection necessary in both commercial and military aircraft. Another military application of the RF-to-optical link is in satellite-to-ship and conventional RF communications-to-ship. Fiber optic communications is becoming increasingly important in battlefield operations where a single strand of fiber can replace many times its weight in copper. A satellite uplink-downlink to a battlefield fiber optic network will find its place in future wars, with the added benefit of reduced RF emanations.

Whenever wired communications is too costly, or becomes saturated with users, the space, weight and cost savings of RF and optical systems will become more and more attractive. rf

About the Author

Gary O. Sandstedt is president of Commercial Data Processing, Inc., 2241 South Grand Blvd., St. Louis, MO 63104. He is an electronics engineer with experience in design of television studio equipment and transmitters, as well as his current work in RF and telecommunications data transmission equipment. Gary can be reached at (314) 776-1130.

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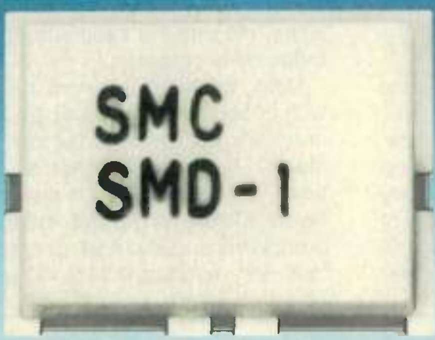

.375 x .500 x .150

.375 x .500 x .140

MODEL	RF/LO MHz	IF MHz	LO POWER dBm
SMD-1	1-1000	DC-1000	+7
SMD-1M	1-1000	DC-1000	+17
SMD-1H	1-1000	DC-1000	+23
SMD-2	20-1500	DC-1500	+7
SMD-2M	20-1500	DC-1500	+17
SMD-2H	20-1500	DC-1500	+23
SMD-3	20-2500	20-600	+7
SMD-3M	20-2500	20-600	+17
SMD-3H	20-2500	20-600	+23

MODEL	RF/LO MHz	IF MHz	LO POWER dBm	PRICE (100 pcs.)
SMD-C1	1-1000	DC-1000	+7	$ 6.50
SMD-C1M	1-1000	DC-1000	+17	7.00
SMD-C1H	1-1000	DC-1000	+23	11.00
SMD-C2	20-1500	DC-1500	+7	7.00
SMD-C2M	20-1500	DC-1500	+17	8.00
SMD-C2H	20-1500	DC-1500	+23	12.00
SMD-C3	20-2500	20-600	+7	8.90
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INFO/CARD 31

Magnetic Core Calculations — A BASIC Program

A Design Aid for Known and Unknown Cores.

By Serg Ticknor
Wide Band Engineering

Magnetic cores using ferrite, powdered iron, or resin-iron materials are used in many applications from audio to microwave. Manufacturers often supply limited or incomplete practical data, or a "mystery" core in an existing circuit may have unknown characteristics. To help in the design of inductors and transformers, this program takes the known parameters and fills in the blanks from a few physical measurements and simple tests. It also provides a flexible design tool for determining optimum geometry and winding data for toroids, sleeves, beads, and binocular cores.

Here are the step-by-step instructions for using the program:

1. To evaluate an existing core, measure the I.D., O.D., and height of the core. Note that some inaccuracies can be expected depending on the degree of corner radii, effectively increasing or decreasing some dimensions.
2. Wrap several turns or wire around the core (the more the better). Each pass through the core counts as one turn.
3. Take an inductance measurement using a Q-meter or series resonance technique using a signal/sweep generator. Note that permeability usually varies with frequency, so make sure the measurement frequency of the meter or signal source is within the proper range.
4. Enter the dimensions, inductance measured, number of turns, RMS voltage and frequency. The other parameters will be displayed by the program.

Designing Inductors and Transformers

After choosing the most applicable core from the manufacturers' data sheets, enter the permeability physical size, number of turns, operating frequency and expected RMS voltage across the primary winding. After studying the display of values, the program may be run again, substituting other numbers of turns, other sizes, etc., until a satisfactory prototype inductor is obtained.

Using the manufacturers' data together with observations of the display, consider changes in: 1) form factor, 2) toroid, sleeve, bead, and binocular configurations, 3) saturating or non-linear flux levels, 4) wire lengths vs. inductance (for broadband applications), 5) reactance (for loss and resonance factors) and 6) sur-

```
PERMABILITY (U)= 850
       FLUX (B)= 341.343263 GAUSS
 INDUCTANCE (L)= 126.640428 UH
 REACTANCE (XL)= 119.355792 OHMS
   IND. 1T (AL)= 1.97875669 UH
    XL IT (XAL)= 1.86493425 OHMS
  COOLING A (AS)= .295506059 SQ.IN.
   WINDOW A (AW)= 1.96349541E-03 SQ.IN.
  CRS SEC A (AE)= .01875 SQ.IN.
   MAG PATH (LE)= .257143659 IN.
   EFF. VOL. (VE)= 4.82144361E-03 CU.IN.
     1T WIRE (W1)= 1.075 IN.
             (B1)= .65 IN.(BIO)
 TOTAL WIRE (WT)= 8.025 IN.
             (BT)= 5.125 IN.(BIO)
 FORM FACT. (FF)= 14.7
             (FB)= 8.9 (BIO)

   AGAIN?    END?    PRINT DATA?
```

Figure 1. Software printout of program computations.

```
10 REM "MAGCOR"
20 REM BY S. TICKNOR (W7ILH) REV.FEB 86          FROM "RF DESIGN" MAGAZINE
30 REM
40 REM ******************************
50 REM * COMPUTES L,U1,B,AL,XL,FF,WL, *
60 REM * ETC. FOR TOROIDAL, SLEEVE    *
70 REM * & BINOCULAR MAGNETIC CORES   *
80 REM ******************************
90 REM
100 REM *** SYMBOLS: LOG(X)=NATURAL LOG X  ""=CURSOR UP  ""=CURSOR DOWN
110 REM ""=CLEAR SCREEN, HOME  ""=REVERSE ON,PRINT BLUE ""=REV. OFF, BLACK
120 PRINT "" TAB(12)" INSTRUCTIONS "
130 PRINT " ENTER EITHER "+CHR$(34)"INITIAL PERMIABILITY"+CHR$(34)
140 PRINT" OR "+CHR$(34)"INDUCTANCE"+CHR$(34)", BUT NOT BOTH. THEN"
150 PRINT " ENTER "CHR$(34) "0" CHR$(34)" FOR THE OTHER VALUE."
160 PRINT " NOTE: RESULTS INDICATED " CHR$(34)"(BINO)" CHR$(34) " ARE    FOR";
170 PRINT " THE SAME CORE, CUT IN HALF BY       HEIGHT, AND REARRANGED IN A ";
180 PRINT "PARALLEL    OR BINOCULAR CONFIGURATION."
190 PRINT " FOR A SPECIFIC BINOCULAR CORE, APPROX."
200 PRINT " THE DIMENSIONS AS IF IT WAS 2 PARALLEL"
210 PRINT " CORES. ENTER THE I.D. AND O. D. OF ONE"
220 PRINT" CORE, AND HT. EQUAL TO 2X ONE CORE.":PRINT" WHEN RUNNING "CHR$(34);
230 PRINT "AGAIN"CHR$(34)", TO ENTER ANY OLD  VALUES, JUST PRESS THE RETURN KEY.
240 PRINT TAB(26)"PRESS RETURN"
250 GET A$:IF A$="" THEN 250
260 PRINT ""
270 INPUT "                 INITIAL PERM  U ";U   REM AT APPROPRIATE FREQ. "F"
280 INPUT "              INDUCTANCE (UH)  L ";L
290 INPUT "              NUMBER OF TURNS  N ";N   REM (PASSES THROUGH CORE)
300 INPUT "   HEIGHT OF CORE (INCHES)  HT ";HT
310 INPUT " OUTSIDE DIAMETER (INCHES)  OD ";OD
320 INPUT "  INSIDE DIAMETER (INCHES)  ID ";ID
330 INPUT "              FREQUENCY (MHZ)  F ";F
340 INPUT "                       V(RMS)  V ";V  REM VOLTS ACROSS PRI. WINDING
350 REM
360 IF U=0 THEN 390
370 L=.0117*U*N*N*HT*LOG(OD/ID)/LOG(10):AL=L/N↑2: REM REF 3, PG 8, REF 1, PG 16
380 GOTO 400
390 U=L/(.0117*N*N*HT*LOG(OD/ID)/LOG(10))     AL=L/N↑2
400 XL=2*π*F*L:X1=XL/N↑2
410 AS=π*HT*(OD+ID)+(π/2)*(OD↑2-ID↑2)
420 AW=π*(ID↑2)/4  REM REF 4, PG 236
430 AE=HT*((OD-ID)/2)
440 LE=((OD-ID)/(LOG(OD/ID)/LOG(10)))*1.36437 : REM REF 3
450 VE=AE*LE : REM REF 4 PG, 198
460 W1=OD-ID+2*HT:      B1=2*(OD-ID)+HT:  REM REF 2 PG 69
470 WT=N*(2*HT+OD-ID)-(OD-ID+HT)
480 BT=N*(2*(OD-ID)+HT)-(OD-ID)
490 FF=W1*2*π/(HT*LOG(OD/ID)):  REM REF 2, PG 68-69
500 FB=B1*2*π/(HT*LOG(OD/ID))
510 B=V/(.28645*F*N*AE):     REM REF 1, PG 15
530 PRINT ""
540 PRINT " CORE OD="OD"IN."TAB(22)"N="N"TURNS"
550 PRINT " CORE ID="ID"IN."TAB(22)"F="F"MHZ"
560 PRINT " CORE HT="HT"IN."TAB(22)"V="V"V RMS"
570 PRINT " ______________________________________ "
580 PRINT " PERMABILITY (U)="U    REM  PERMABILITY AT FREQ "F"
590 PRINT "          FLUX (B)="B"GAUSS"
600 PRINT "   INDUCTANCE (L)="L"UH"    REM  TOTAL INDUCTANCE
610 PRINT "   REACTANCE (XL)="XL"OHMS"   REM  TOTAL REACTANCE
620 PRINT "     IND. 1T (AL)="AL"UH"   REM  INDUCTANCE FOR 1 TURN
630 PRINT "      XL 1T (XAL)="X1"OHMS"  :REM  REACTANCE FOR 1 TURN
640 PRINT "  COOLING A (AS)="AS"SQ.IN."  REM  TOTAL SURFACE AREA FOR COOLING
650 PRINT "   WINDOW A (AW)="AW"SQ.IN."  REM  WINDOW AREA (OF INSIDE DIAMETER)
670 PRINT "  CRS SEC A (AE)="AE"SQ.IN." REM  EFFECTIVE CROSS SECTIONAL AREA
680 PRINT "   MAG PATH (LE)="LE"IN."   : REM  EFFECTIVE MAGNETIC PATH LENGTH
690 PRINT "  EFF. VOL. (VE)="VE"CU.IN.": REM  EFFECTIVE VOLUME
700 PRINT "     1T WIRE (W1)="W1"IN."   :REM LENGTH OF 1 COMPLETE TURN (TOROID)
710 PRINT "             (B1)="B1"IN.(BIO)":REM LENGTH 1 COMP.TURN (BINO. CORE)
720 PRINT " TOTAL WIRE (WT)="WT"IN."    :REM  TOTAL LENGTH OF WIRE ON TOROID
730 PRINT "             (BT)="BT"IN.(BIO)"   REM TOTAL WIRE LENGTH ON BINO. CORE
740 PRINT " FORM FACT. (FF)="INT((FF+.05)*10)/10 :REM  TOROID FORM FACTOR VALUE
750 PRINT "             (FB)="INT((FB+.05)*10)/10"(BIO)": REM BINO. CORE F. FACTOR
755 IF G$="P"THEN 1100  REM GOTO PRINTER-OFF COMMAND IF IN PRINTER ON MODE
760 PRINT "   AGAIN? A   END? E   PRINT DATA? P"
770 GET G$:IF G$=""THEN 770
780 IF G$<>"A"AND G$<>"E" AND G$<>"P" THEN 770
790 IF G$="A"THEN 260:IF G$="E"THEN 810
800 IF G$="P"THEN 1000
810 PRINT"":END
1000 OPEN 1,4:CMD1:GOTO 540    REM ***   COMMAND TO TURN ON PRINTER
1100 PRINT#1:CLOSE 1:GOTO 770   REM *** COMMAND TO TURN OFF PRINTER
```

face area (heat dissipation).

When re-entering data with the "again" option, input values identical to the previous trial need not by typed in. Just re-enter by pressing the return key following the prompt.

In this program all dimensions are in inch units. This seems to be a worthy compromise since data sheets, articles and design data may use either English or Metric (or an unwieldy mixture of both). Conversion is a simple task, if necessary.

The program should be usable on most computers using BASIC. Peeks, pokes, and other non-universal language have been avoided as have superfluous opening formats, menus, graphics, etc. Plenty of space has been left between line numbers for additions and alterations.

Liberal use of REM statements explain terminology and assist start-up. Since the Commodore C64 was used, lines 100 and 110 explain any symbols needed for conversion to other computers. Lines 755, 1000, and 1100 give instructions to the printer which prints data from lines 540-750. Equation source references can be found in REF statements opposite the equations in lines 370-510. To speed copying, all REM statements can be deleted.

Although there has not been any attempt to offer comprehensive grounding in theory, measurements or applications, the references provided are an excellent source of information. The user is encouraged to experiment with the program and gain confidence in its use by cross checking manufacturers' data and comparing this data with the display. The benefits of speed and accuracy will soon be revealed and make this program a useful addition to your circuits library. rf

References

1. DeMaw, "Magnetic Cores in RF Circuits," *RF Design*, April 1980.
2. Nagle, "Use Wideband Autotransformers," *Electronic Design*, Feb. 2, 1976.
3. Stackpole Carbon Company, "Cermag Ferrite Cores," Bulletin 50C.
4. DeMaw, "Ferromagnetic-Core Design and Application Handbook," Prentice-Hall, Inc., 1981.

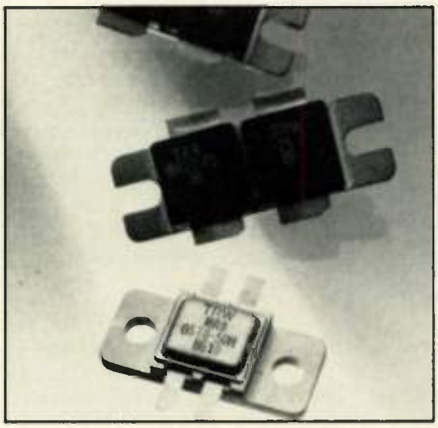
About the Author

Serg Ticknor is president of Wide Band Engineering Company Inc., P.O. Box 21652, Phoenix, AZ 85036. He is a member of IEEE, ARRL and QCWA, and has been head of WBE for 15 years.

rf products

UHF Power Transistors Use Push-Pull Design

TRW RF Devices Division has introduced new broadband, push-pull, high power, class "AB" bipolar RF amplifiers for military communications and ECM applications. The MRA0510-50H device provides 50 watts of CW linear power in broadband applications. Gain is 7 dB minimum at 1000 MHz and 28 volts, and is usable over a 500 to 1000 MHz frequency range. The MRT0105-75 device provides 75 watts of CW linear power. Gain



is 7.5 dB minimum at 500 MHz and 28 volts, usable over a 100 to 500 MHz frequency range. The MRT0105-75V device provides 75 watts of CW linear power with gain of 7 dB minimum at 500 MHz. The MRT0105-75V can withstand a ∞:1 VSWR load pull at 100 MHz. In 100 piece quantities, the MRA0510-50H is priced at $146.50, the MRT0105-75 is $111.00 and the MRT0105-75V is $114.00. **TRW RF Devices Division, Lawndale, Calif. INFO/CARD #158.**

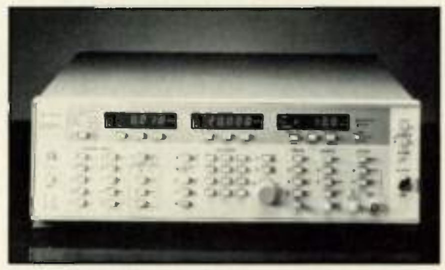
Oscillator Available as Phase Noise Standard

Brightline's Model 1039 oscillator features stability better than 3×10^{-13} from 0.1 s to 1 s, ultimate aging less than 5×10^{-11}/day, and phase noise perfor-

mance (−166 dBc floor) unique in its class. Output is nominally +13 dBm in 50 ohms. Linear electric tuning permits recalibration at 3 years or more in atomic clock or other phaselock applications. The 1039 is also available on special order in calibrated pairs for phase noise standard service. **Brightline Corporation, Cedar Park, Texas. INFO/CARD #157.**

Sweep Generator Series Has Been Updated

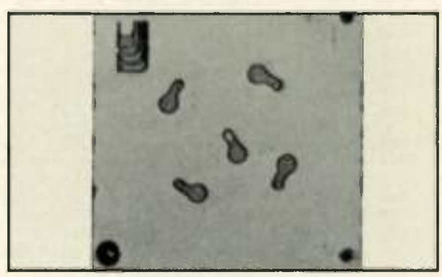
A new series of sweep generators enhances the performance and convenience of earlier instruments, including units significantly reduced in price. Covering the 10 MHz to 60 GHz range in 36 models, the Wiltron 6600B Series includes units that sweep from 10 MHz to



20 GHz with 40 mW leveled output power. Several new features reduce test times and simplify operation: nine stored front panel setups, eight markers, 15 dB power sweep, front panel security, and ten-year nonvolatile memory. An example of pricing is the Model 6647B, 10 Mhz to 20 GHz, 40 mW; $27,000. **Wiltron Company, Morgan Hill, Calif. INFO/CARD #156.**

Back Diodes (Tunnel Diodes) for Detectors

Metelics introduces the MBD 100 Planar Back (Tunnel) Diodes for detector applications. The planar germanium back



diodes feature wide band RF match, very wide video bandwidth (fast pulse response), and low I/F noise. No DC bias is required; junction capacitance is .3pF maximum and peak currents range from 100-600μ amps. **Metelics Corporation, Sunnyvale, Calif. INFO/CARD #155.**

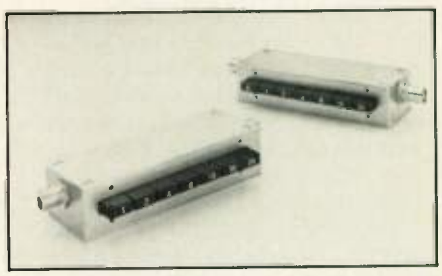
Zero Loss Probe for 100 kHz-1.25 GHz

A new high-impedance FET active probe has been designed by Marconi Instruments. The Model 2388 Zero Loss Probe has a patented design that eliminates the need for clip-on voltage dividers as a means of varying attenuation. With the 2388, attenuation levels are continuously varied over 40 dB by simple rotation of an integral barrel attenuator.

The 2388 has a wide frequency range of 100 kHz to 1.25 GHz covering HF to UHF. The probe is priced at $1195 and is supplied with its own carrying case, spring grounding pin, square probe tip and terminated 50 ohm Type N adapter. When used with the 2382 Spectrum Analyzer, the adapter enables the probe to be connected to the tracking generator output. Optional power supply is available for use with non-Marconi products. **Marconi Instruments, Allendale, N.J. Please circle INFO/CARD #154.**

Low Cost Pushbutton Attenuators

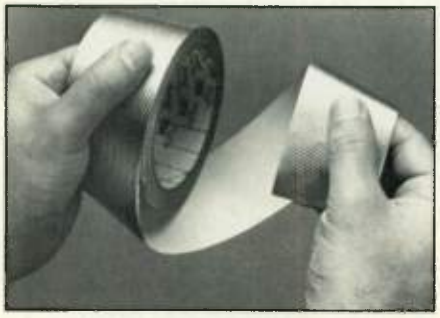
JFW announces their new pushbutton attenuators available in both 50 ohm and 75 ohm. Standard attenuation range for the attenuators include 0-65 dB in 1 dB steps or 0-45.5 in .5 dB steps. The 50 ohm



version has a frequency range of DC-750 MHz and is available with BNC or TNC connectors. The 75 ohm version has a frequency range of DC-500 MHz and is available with BNC, TNC or F connectors. These units are priced at $95.00 each. JFW also has a make before break pushbutton available. **JFW Industries, Inc., Indianapolis, Ind. INFO/CARD #153.**

Shielding Tape Features Plated Copper Construction

A premium-quality, embossed, tin-plated copper foil shielding tape has been introduced by 3M's Electrical Products Division. Scotch brand Embossed Shielding Tape No. 99 is applied via pressure-sensitive adhesive and has a tin-alloy



coating for corrosion control and easy soldering. It is ideal for sealing seams and penetrations in portable or permanent shielded rooms faced with copper, steel or aluminum where electromagnetic shielding is required. The 4.2-mil-thick tape is available in widths up to 8 inches. **3M Electrical Products Division, St. Paul, Minn. INFO/CARD #152.**

GaAs FET LNAs for L- and S-Band

JCA Technology has expanded its line of GaAs FET amplifiers to include a series of low-noise feedback amplifiers to cover L-Band and S-Band. These amplifiers feature a noise figure of less than 1.0 dB over a 100 to 200 MHz bandwidth and less than 1.2 dB over bandwidths of 500 MHz. The amplifiers can be used as "drop-in" units by removing the SMA connectors and exposing the pin input and output. **JCA Technology, Inc., Newbury Park, Calif. INFO/CARD #151.**

Attenuator Kits Include Documented Calibration

Alan Industries has announced a line of fixed attenuators in kit form. Each kit contains four attenuators of the same

series, the Alan 50SP, MP or HP. The 50SP series is a small, general purpose pad for DC-2 GHz and 1-20 dB. The MP series covers up to 18 GHz with attenuation of 1 to 40 dB. For 10 and 25 watt average power in a frequency range of DC-2 GHz specify series HP. The user selects the series and dB values. Each attenuator is furnished with documented calibration traceable to NBS. Each kit is supplied in a hardwood enclosure. Prices are: SP Kit, $150 (all connectors); MP Kit, $250 with SMA and $425 with N connectors; HP Kit, $700 for 10 watt and $750 for 25 watt kits. **Alan Industries, Inc., Columbus, Ind. INFO/CARD #150.**

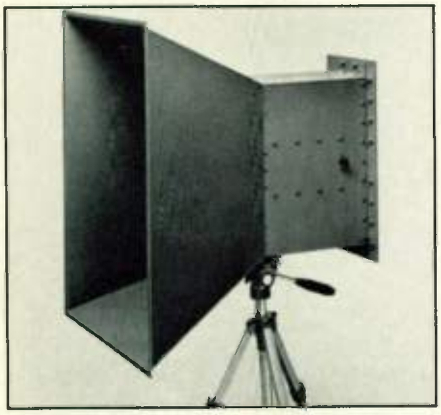
Isolated BNC Jack Mounts on PCB

A series of isolated BNC and TNC chassis and PC board mounted jacks is being introduced by AVA Electronics. Isolation can often be useful in reducing

RFI from computers and peripherals. They are also finding increasing use in testing and communications equipment. The body is nickel plated brass. Center contact is silver plated for reduced electrical resistance. Nominal impedance is 50 ohms, at 500 volts RMS max., designed for operation to 4 Ghz. **AVA Electronics Corp., Drexel Hill, Pa. Please circle INFO/CARD #149.**

Horn Antenna for 400-1000 MHz EMC Testing

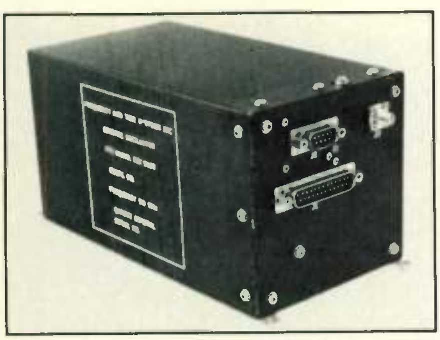
This high-gain, high-power horn antenna by Amplifier Research, for shielded-room or open-space RFI susceptibility and emissions testing, reduces the problem of field-strength loss at high frequencies. The Model AT4001 antenna operates within the frequency range of 400 to 1000 MHz, with power-handling capability to 1000 watts. Its minimum 10-dB gain, at



400 MHz, increases almost linearly to beyond 15 dB at 1000 MHz. Field strength measured at one meter from the horn exceeds 300 V/m at 400 MHz with a 300-watt input. Price is $2,000 with delivery in 60 days. **Amplifier Research, Souderton, Pa. INFO/CARD #148.**

Precision Oscillator is Space Qualified

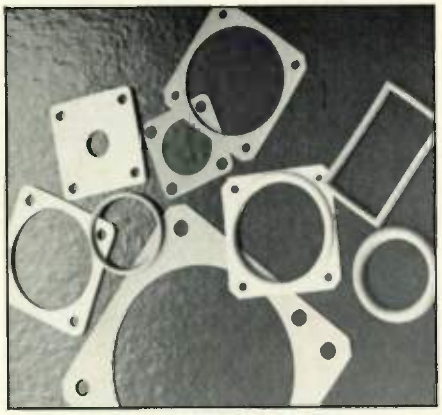
Available from Frequency and Time Systems, Inc. (FTS) is a remotely controlled, digitally tuned space qualified precision oscillator, the FTS 9125. The 9125 features a low phase noise floor of −157 dB at 1000 Hz, radiation hardening,



and remote frequency adjustment via a 12-bit serial word command. Instability attributable to temperature and aging is very low at 5 × 10^{-12}/°C and below 10^{-10}/day. The oscillator is available for any frequency in the range of 4 to 6 MHz. **Frequency and Time Systems, Inc., Beverly, Mass. INFO/CARD #147.**

EMI/RFI Gasketing Functions at 200°C

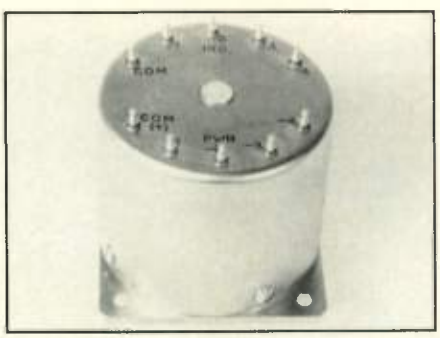
Multi-Point VI, a line of particle filled composite materials that provide EMI/RFI shielding plus environmental protection at operating temperatures to 200°C and beyond, is now available from Conductive Systems, Inc. The conductive particles used are pure silver, silver-plated nickel, silver-plated copper, silver-plated inert, nickel and carbon. They provide shielding



effectiveness to 70 dB or more over a frequency range of 10 kHz to 12.4 GHz. Flourosilicone compounds are available for applications involving contact with chemical solutions, organic or inorganic oils or fluids. **Conductive Systems, Inc., East Hanover, N.J. INFO/CARD #146.**

Coaxial Switches for Space Applications

A line of space-qualified hi-rel microwave coaxial switches is now available from the Wavecom division of the Loral Corporation. The lineup offers a DC-to-26 GHz frequency range and includes both SPDT and multiposition models, with



or without indicator circuits. RF performance features a VSWR of less than 1.5:1 and insertion loss under 0.5 dB. These new switches satisfy all requirements of MIL-S-3928. As with others in the Wavecom line, the 7XXX series swtiches are guaranteed for 1 million cycles per position. **Wavecom, Northridge, Calif. INFO/CARD #145.**

Tunnel Diodes Available in Die Form

The Planar Tunnel diode is now available in die form for detector applications which require their unique characteristics. Some of these characteristics are zero bias, low temperature sensitivity, low input and output impedance (50 to 150 ohms) and fast pulse response. Epoxy die attach and wire bonding up to 160°C may

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MIL-M-28837 mixers are available in two levels: screened and nonscreened.

DoD's Defense Electronics Supply Center has approved the listing of certain Watkins-Johnson Company mixers on its qualified products list (QPL).

TYPICAL SPECIFICATIONS

MIL-M-28837	W-J Model	RF Frequency	LO Power Nominal dBm	Conversion Loss (Noise Figure) Typ. dB	IF Frequency	f_R Level at 1 dB Compression Point Typ. dBm	Isolation Typ. dB L-R	Isolation Typ. dB L-I	Input Intercept Point Typ. dBm	Package Type	Outline Drawing	Hermetic Seal
1-01S	M6D-100	0.05-200	7	6.5	DC-200	0	45	40	13	PC	298572	Yes
1-01N	M6D-101	0.05-200	7	6.5	DC-200	0	45	40	13	PC	298572	Yes
1-02S	M6E-100	5-500	7	7.0	DC-500	0	45	40	13	PC	298572	Yes
1-02N	M6E-101	5-500	7	7.0	DC-500	0	45	40	13	PC	298572	Yes
2-02S	M4A-100	10-1500	7	7.0	DC-1000	0	30	30	13	Flatpack	298509	Yes
2-02N	M4A-101	10-1500	7	7.0	DC-1000	0	30	30	13	Flatpack	298509	Yes
7-01S	M6T-100	10-500	7	7.0	DC-500	0	40	35	13	TO-5	298642	Yes
7-01N	M6T-101	10-500	7	7.0	DC-500	0	40	35	13	TO-5	298642	Yes
7-03S	M6V-100	4-500	7	6.5	DC-500	0	45	30	13	TO-5	298643	Yes
7-03N	M6V-101	4-500	7	6.5	DC-500	0	45	30	13	TO-5	298643	Yes
1-04S	M9D-100	2-400	20	6.5	DC-800	15	40	40	30	PC	298500	Yes
1-04N	M9D-101	2-400	20	6.5	DC-800	15	40	40	30	PC	298500	Yes
1-05S	M9AC-100	0.05-200	13	7.5	DC-200	10	45	40	23	PC	298640	Yes
1-05N	M9AC-101	0.05-200	13	7.5	DC-200	10	45	40	23	PC	298640	Yes
1-06S	M9BC-100	0.5-500	17	7.0	DC-500	8	55	45	23	PC	298640	Yes
1-06N	M9BC-101	0.5-500	17	7.0	DC-500	8	55	45	23	PC	298640	Yes
1-10S	M9C-100	0.4-500	13	7.5	DC-500	10	45	40	23	PC	298640	Yes
1-10N	M9C-101	0.4-500	13	7.5	DC-500	10	45	40	23	PC	298640	Yes

WATKINS-JOHNSON

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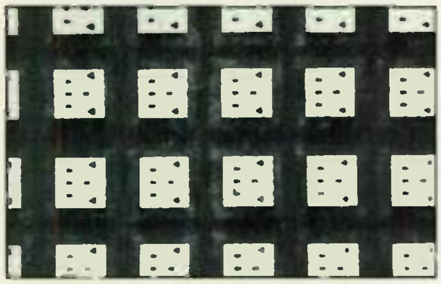
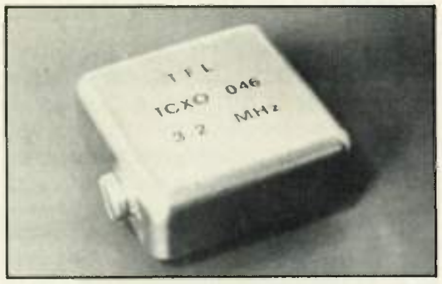




be utilized. Junction capacitance for the V100 series range from 0.7 pF up to 2 GHz, 0.18 to 0.3 for the V2000 series up to 18 GHz. Price of the V1000 Series (100 pcs) is $6 to $12; the V2000 series (100 pcs) is $12 to $24. **Virtech Microwave, Inc., Los Gatos, Calif. INFO/CARD #144.**

TCXO Features Low Power Consumption

Time & Frequency Ltd. has announced a new low power TCXO for frequency hopping portable military radios or for any battery powered application. Designated the 046 Series, the unit features small size, low power (3.5 mW @ 5.0 Vdc), and a wide frequency range of 3 to 10 MHz (50 Hz to 10 MHz with internal divider). 3.2 MHz model is in stock; for other frequencies allow 12 weeks delivery. **Time & Frequency Ltd., Mitchel Field, N.Y. Please circle INFO/CARD #143.**

MIL-STD 45662 Calibration Service is Available

U.S. MIL-STD 45662 calibration services are available from Hewlett-Packard Company to assist customers in passing the government-compliance audit. Services offered are: MIL-STD calibration agreement, MIL-STD full-service agreement, per-incident MIL-STD calibration, and per-incident repair plus MIL-STD calibration. These services are available from seven regional H-P customer service centers in the United States. The service facilities are available for customer inspection. **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #141.**

Signal Generator Features Spectral Purity

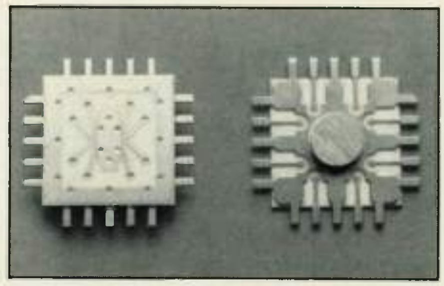
Comstron Corporation has announced a new Signal Generator Model 742 A. It features spectral purity close to the carrier, quality of modulation, and low residual FM. Specifications include 100 kHz-2400 MHz range, 1×10^{-7}/day or 5×10^{-9}/day (optional) stability, 20 ms switching time, SSB phase noise at 500 MHz of −120 dBc/Hz at 20 kHz offset, plus AM-FM and Pulse (optional) modulation. **Comstron Corporation, Freeport, N.Y. INFO/CARD #142.**

140 MHz IF Noise Test Set

Scientific-Atlanta, Inc. has introduced the Model 4648 IF noise test set for noise stress testing of 140 MHz digital radios and satellite modems. The noise test set is designed for insertion into the IF section of a communications systems to add calibrated levels of white noise in a band from 100 to 180 MHz. The Model 4648 greatly simplifies bit-error-rate threshold tests, satellite modem tests, AGC curve measurements and FM threshold measurements. **Scientific-Atlanta, Inc., Atlanta, Ga. INFO/CARD #140.**

Surface Mount Package for GaAs MMICs

Tektronix has introduced a GaAs MMIC package for external sale. Part number 812-0012-00 is an eight port, hermetic, surface mount package with a VSWR of less than 1.2:1 from DC to 12 GHz, less than 2:1 from DC to 18 GHz; and has a mounting footprint of .410 by .410 inches. Designed to accept MMICs up to 1.37 mm (.054") square and two bypass capacitors, the package has eight signal lines and twelve grounds arranged in a ground-signal-ground format. An evaluation kit



consisting of three packages, two RT/duroid evaluation boards, connectors and mounting hardware is available for $300. **Tektronix, Inc., Beaverton, Ore. Please circle INFO/CARD #138.**

10 dB Directional Coupler Covers 10-400 MHz

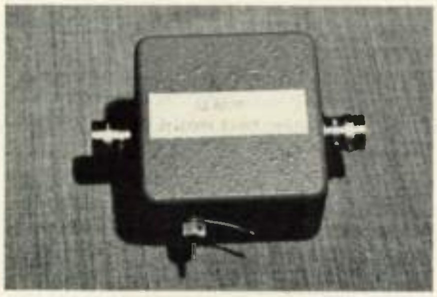
Mini-Circuits' new TODC-10-1 directional coupler features 10 to 400 MHz bandwidth, low mainline insertion loss (only 1.2 dB including theoretical loss at coupled port), and 30 dB typical directivity. Coupling is 10 dB± 1.0 dB, with ±0.5 dB flatness. The TODC-10-1 is packaged in a hermetically-sealed 0.6 in. diameter, 0.25 in. high case and is suited for such applications as signal sampling, signal injection, signal generator/oscillator leveling, and measurement of incident and reflected power. The TODC-10-1 is priced at $15.95 (5-49 qty). **Mini-Circuits Labs, Brooklyn, N.Y. INFO/CARD #137.**

16-Channel Multiplexer has 300 MHz Bandwidth

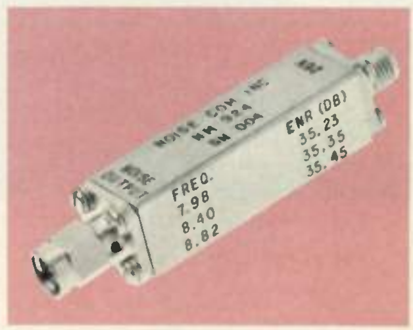
Siliconix has introduced its new ultra-wideband DG536 16-channel multiplexer for a broad range of audio, video, and telecommunications applications. While most multiplexers operate up to about 5 MHz, the DG536 has a 300 MHz bandwidth. Wideband DMOS switches fabricated on this monolithic device are connected in a "T" configuration, and each signal line is fully isolated from adjacent signal lines. These features combined with the low on-resistance (55 ohms typical) and low drain capacitance (12 pF maximum) contribute to the device's superior performance: −92 dB crosstalk and 70 dB off-isolation at 5 MHz. All control inputs are latched internally and are fully CMOS-compatible from microprocessor control. Price of the DG536 is $19.20 (100s). **Silconix, Inc., Santa Clara, Calif. INFO/CARD #136.**

5-950 MHz Amplifier Has 11 dB Gain, 4 dB NF

A wideband general purpose preamplifier covering the frequency range from 5 MHz to 950 MHz has been announced by Wi-Comm Electronics Inc.



The unit features a 4 dB noise figure, gain of 11 dB, and a 1 dB gain compression level of typically 11 dBm. Other parameters are: third order intercept point of 26 dBm, input and output VSWR of 1.8:1 and standard power of 15 VDC, 40 mA. The preamplifier is housed in a diecast aluminum case with BNC female connectors. **Wi-Comm Electronics, Inc., Massena, N.Y. INFO/CARD #139.**



rf software

Super-Compact Update Released

Compact Software announces the release of its new Version 1.81 of Super-Compact. The new version offers improvements in user interface and accuracy over the earlier 1.7 release, and includes new elements such as stripline discontinuities, thru-holes and wraparounds. Version 1.9, to be released at the end of 1986, will offer new functions beyond those already contained in 1.81. **Compact Software, Inc., Paterson, N.J. INFO/CARD #176.**

Public Domain Software Catalog

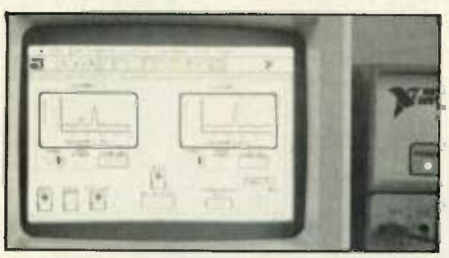
Multipath, Inc. announces availability of the latest edition of its catalog which now lists 1,200 public domain programs for computers running the MS-DOS, PC-DOS, CP/M-80 or CP/M-86 operating system. All programs listed in the catalog are available on 3½", 5¼" and 8" floppy disks. A table in the catalog shows 200 DOS and CP/M disk formats supported by the company. Public domain programs require no royalty or license fees. **Multipath, Inc., Montville, N.J. Please circle INFO/CARD #175.**

MMIC Foundry Design Package

EEsof, Inc. and TriQuint Semiconductor, Inc. have teamed together to incorporate TriQuint's GaAs (gallium arsenide) custom MMIC foundry models into Touchstone®, EEsof's program for the design, analysis, and optimization of linear microwave circuits. The companies have developed a GaAs MMIC element library that allows Touchstone users to simulate microwave integrated circuits using components that precisely model the actual components available from TriQuint's custom MMIC foundry facility. TriQuint will license the library to EEsof, who in turn will incorporate the models into Touchstone and license the enhanced program to its customers. **EEsof, Inc., Westlake Village, Calif. INFO/CARD #174.**

Graphical Programming for Engineering Applications

National Instruments Corporation announces a new programming technology which it calls "graphical diagramming" and a new product for that technology that runs on the Macintosh computer. Lab-



VIEW™ (Laboratory Virtual Instrument Engineering Workbench) provides an environment for developing scientific applications that integrate instrument control, data acquisition, data analysis, data entry, data management and report generation. The user views the application as a model virtual instrument and then creates a *front panel* for interacting with it. Next, he or she designs a block diagram that shows the flow of data from inputs through internal processing functions to output display terminals. First deliveries are scheduled for August. Price is $1,995. **National Instruments Corporation, Austin, Texas. INFO/CARD #173.**

Digital-Radio Teaching Tool

I-Q Tutor, Hewlett-Packard's interactive training program for learning the principles of digital communications, now runs on the HP Vectra personal computer. This also opens up the training course to owners of the IBM PC/AT computers. HP 11736B models a modern digital-communications-system signal chain, from analog input through baseband, modulation, transmission, demodulation and back to analog. The program presents graphic displays of the interactions of S/N ratio, bit-error rates, system bandwidths and filter characteristics. HP 11736B for HP Vectra PC is priced at $95. **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #172.**

DSP Development System

Analog Devices has introduced a development system for its new ADSP-2100 digital signal processor (DSP) microprocessor. Software tools include; a System Builder, Assembler, Linker, Simulator and PROM Splitter. An ADSP-2100 Emulator provides the necessary hardware to debug user-developed programs in their target system. The emulator functions exactly as the ADSP-2100 and runs at the full 8 MHz speed. The software tools run on an IBM-PC/DOS or a multi-user Digital Equipment VAX/VMS. **Analog Devices Inc., Norwood, Mass. INFO/CARD #171.**

Software Catalog for Scientific Computers and Array Processors

Floating Point Systems, Inc. announces the availability of a 74-page publication entitled "Third-Party Software for Scientific Computers and Array Processors." Each program in the catalog is identified by product name, industry focus, application, computers supported, environment, services, marketing, product abstract and developer contact name and address. **Floating Point Systems, Portland, Ore. INFO/CARD #170.**

rf literature

Brochure Describes Power Meter and Sensors

A brochure describing the Model 6960 Automatic RF Power Meter has been released by Marconi Instruments, describing its features and detailing calibration, memory, cables, duty-cycles, analog outputs, GPIB, self test and service. The Model 6960 offers a dynamic range (depending upon sensor) of +20 dBm (100 mW) to –70 dBm (0.1 nW) extendable to +37 dBm (5 W) and a combined frequency range of 30 kHz to 26.5 GHz. Control is via the simple keyboard or GPIB.

The brochure also details the full line of RF Power Sensors. **Marconi Instruments, Allendale, N.J. INFO/CARD #169.**

Fact File Features Silicone Resins and Coatings

Revised and updated information on five silicone resins for the electrical industry is available in a new fact file published by General Electric Silicone Products Division. Included in the GE silicone electrical resins line are an improved flexible insulating varnish for wire and cable applications where resistance to temperature extremes is important. Other silicone resins described include an insulating varnish for glass cloth coating, for mica tape binder, for impregnating motor windings, as a vehicle in aluminum leafing coatings, and for high temperature and moisture resistant coatings for printed circuit boards. **General Electric Company, Silicone Products Division, Waterford, N.Y. INFO/CARD #168.**

Brochure Features RF Inductors

A 4-page brochure describing low cost RF chokes and adjustable RF coils for 10-450 MHz applications is now available from J.W. Miller Division of Bell Industries. Low cost encapsulated radial lead RF chokes are available with inductance values from 1.0 to 4700 uH, in addition to epoxy coated shielded RF chokes from 0.10 to 120 uH. Adjustable and fixed RF coils, shielded and unshielded, with inductance values from .046 to 1000 uH are available for equipment operating in the 10-450 MHz range. **J.W. Miller Division, Bell Industries, Rancho Dominguez, Calif. INFO/CARD #167.**

RF and Microwave Signal Sources

Three new brochures are available, describing Sanders' RF and microwave sources. The Digitally Tuned Oscillator brochure offers various DTOs with a wide range of options available for customizing. The Dielectric Resonator Oscillator brochure describes DROs, Switched DROs and Phase Locked DROs which utilize MIC hybrid techniques to minimize size. The Stabilized Master Oscillator brochure offers oscillators that exceed the environmental requirements of MIL-E-5400 Class 2 and MIL-E-16400. **Sanders Microwave Division, Manchester, N.H. INFO/CARD #166.**

RF Hybrid Circuits and Subassemblies

Standard and custom RF amplifiers up to 2 GHz, voltage-controlled attenuators and switches are covered in a new catalog just published by Aydin Vector Division. Custom cascaded amplifiers are also described in the catalog. Vector features in-house facilities for designing and manufacturing custom and RF hybrid microelectronic circuits to meet the requirements of MIL-STD-883 and MIL-Q-9858A. **Aydin Vector Division, Newtown, Pa. INFO/CARD #165.**

rf literature *Continued*

Brochure Describes Crystal Oscillators

A newly revised brochure covers oscillators ranging from 1 Hz through 1 GHz with stabilities from ±.01% to 1×10^{-10}. The catalog details clock oscillators (TTL, CMOS, HCMOS and ECL), low phase noise oven control crystal oscillators, TCXOs, VCXOs, VCOs and frequency standards. **Vectron Laboratories, Inc., Norwalk, Conn. INFO/CARD #164.**

Transmission Lines for Land Mobile Radio Systems

Andrew Corporation offers a bulletin describing its HELIAX® coaxial cables for land mobile radio systems, providing details on both foam-dielectric and air-dielectric cable and featuring a selector chart based on frequency and feeder length. In addition, Bulletin 1381 provides detailed information and charts on cable connectors, accessories, adaptors and electrical and mechanical characteristics. Sizes range from 3/8" to 1-5/8". Included in this series is the new LDF6-50 at 1-1/4". **Andrew Corporation, Orland Park, Ill. INFO/CARD #163.**

EMI Facility Filters

A new data sheet has been produced by Puroflow Marine Corporation giving details on the company's series of EMI Facility Filters. These products are designed to protect solid-state telecommunications and computer-based systems from the harmful effects of conducted electromagnetic interference (EMI) in power lines. Puroflow offers a complete line of EMI filters and surge suppression devices, for applications ranging from individual items of electronics to large mainframe computers and complete telecommunications suites. **Puroflow Marine Corporation, Newport News, Va. Please circle INFO/CARD #162.**

LC Filters Catalog

Allen Avionics Catalog 21F presents the firm's extensive line of custom-built and stocked LC filters in frequencies from 20 Hz to 1000 MHz. Included are bandpass, band reject, linear phase, highpass and lowpass filters, and video filters consisting of NTSC lowpass, reject and bandpass types. Also covered are subminiature filters. Allen Avionics also specializes in fast prototypes. **Allen Avionics, Inc., Mineola, N.Y. INFO/CARD #161.**

Power Amplifiers and Communications Systems

Milcom International, Inc. offers informational brochures on the following product lines: FM power amplifiers for fixed station use up to 150 watts in frequency ranges from 30-900 MHz; FM mobile power amplifiers in the same frequency range; TB100 Series transportable base stations for public safety, military, temporary airfield, and civil defense applications; AM/FM power generators; and laboratory amplifiers from 2-1000 MHz for linear or non-linear applications. **Milcom International Inc., Los Alamitos, Calif. INFO/CARD #160.**

Noise Brochure

A 12-page brochure provides information on noise products such as chips, diodes, sources, modules and instruments, including the line of Programmable Noise Instruments, NC7100 Series. Specific product examples are shown with their block diagrams. Featured are white Gaussian, symmetrical, broadband, audio, VHF-UHF, microwave and millimeter products. **Noise Com, Inc., Hackensack, N.J. INFO/CARD #159.**

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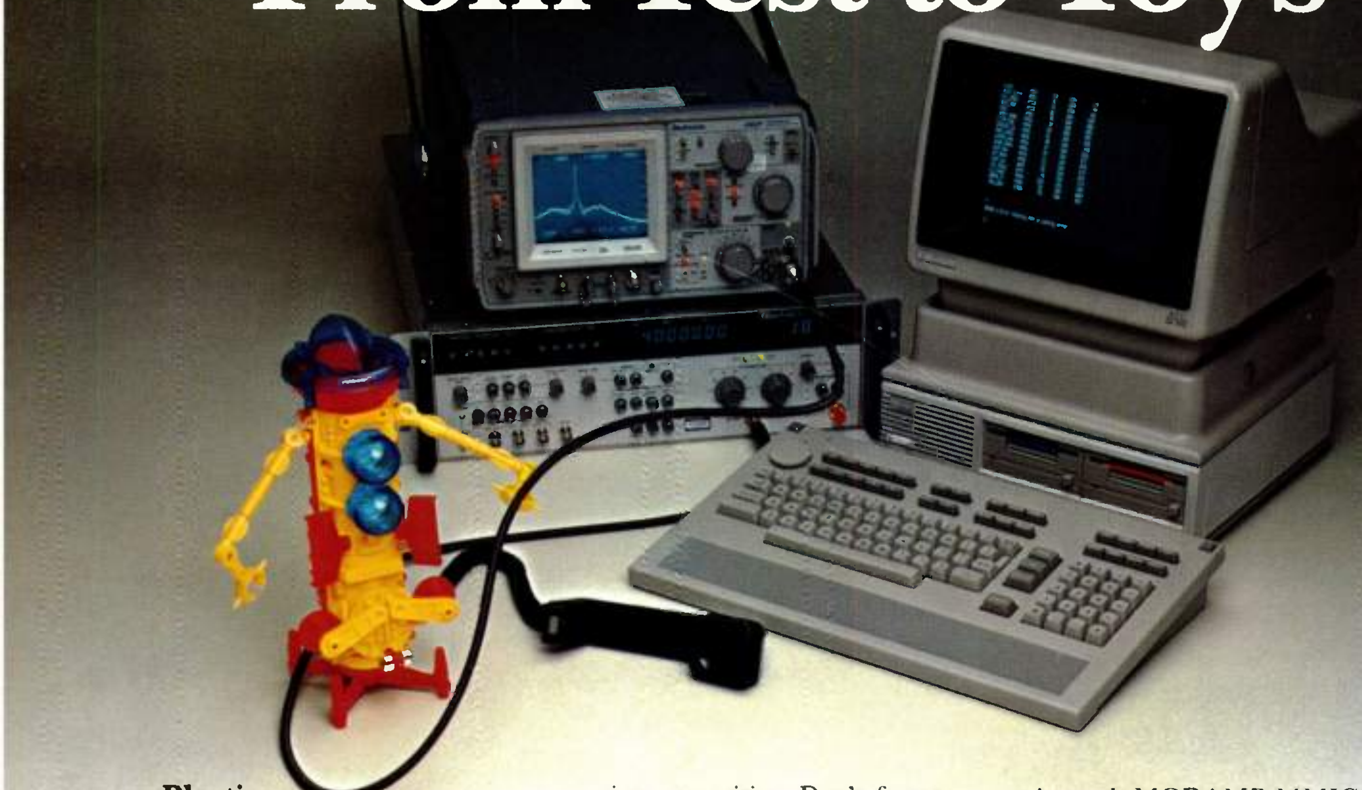
Advertiser's Index

From Test to Toys



Plastic MMIC gain blocks. Avantek 4-Pac amplifiers. $1.80 each*.

Avantek's series of MODAMP™ silicon monolithic microwave integrated circuit amplifiers are ready to drop into your 50-ohm circuit, with no design problems — virtually no concern for what comes before or after. These MMICs are unconditionally stable and provide cascadable gain blocks at any frequency up to 2 GHz.

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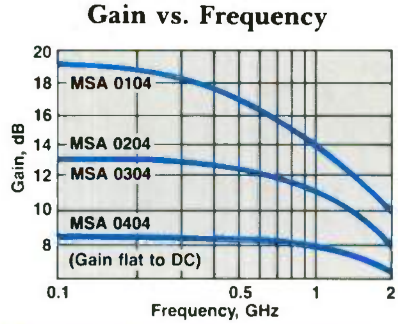
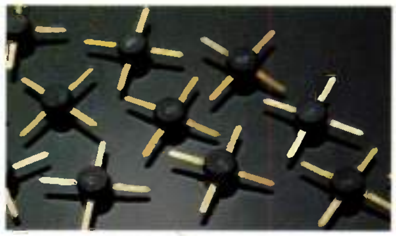
Gain vs. Frequency





*price in 10,000 piece quantities.

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