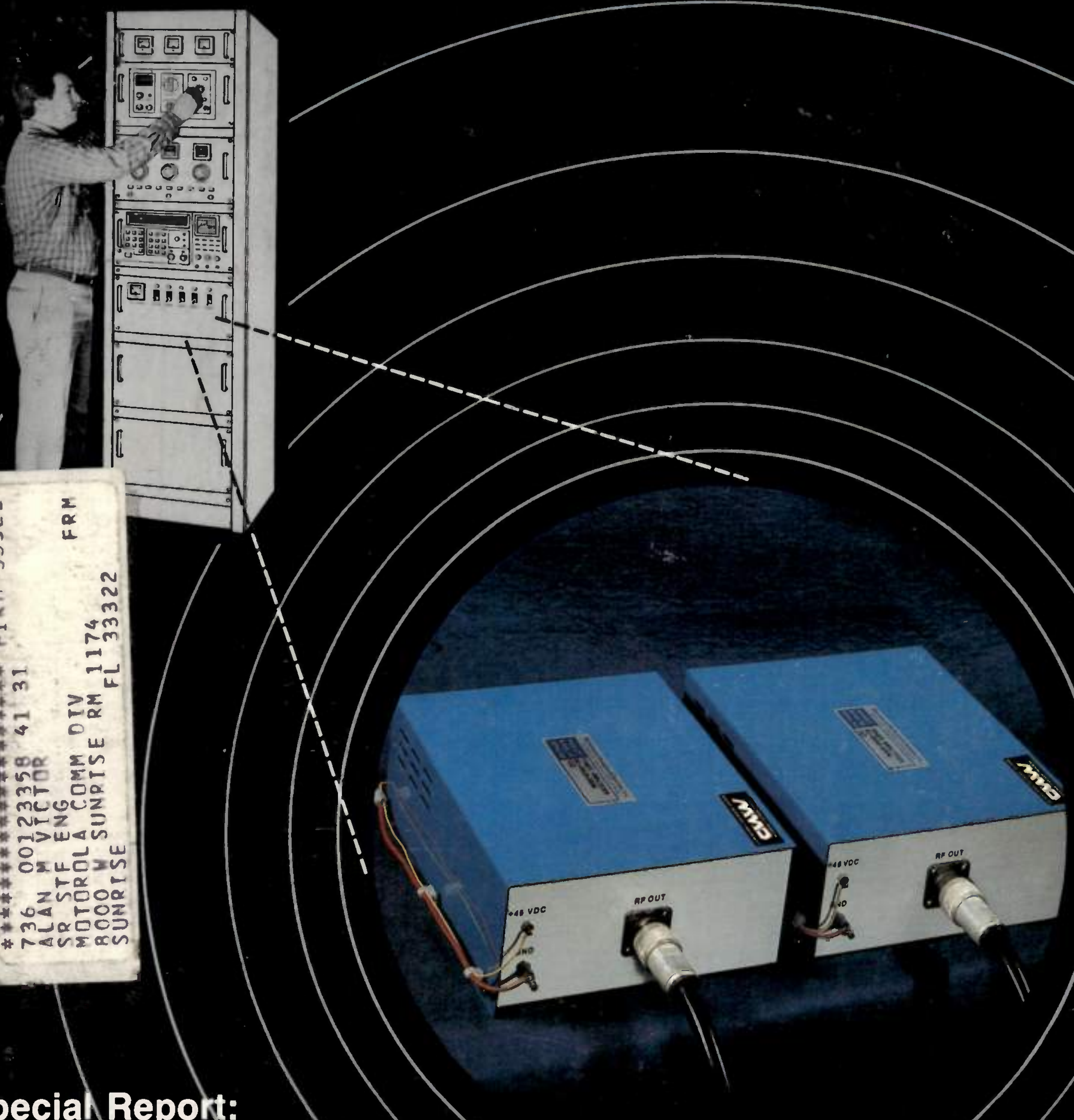
rf design
ideas for engineers
April 1985



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INFO/CARD 1

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INFO/CARD 2

GOING THE DISTANCE

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ACRIAN
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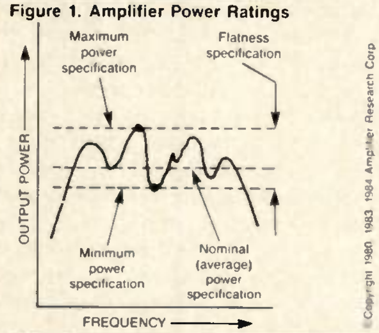
rf design

April 1985

Cover

This month's cover features Microwave Modules and Devices' new 500-watt wideband power amplifier, the AC-0003-500W. This modular HF Class AB linear amplifier features wideband, high power 90 degree quadrature combiners on the input and output impedance and 1.5:1 input and output VSWR. It is a "drop-in" 50-ohm building block suitable for multi-kilowatt transmitters.

Figure 1. Amplifier Power Ratings



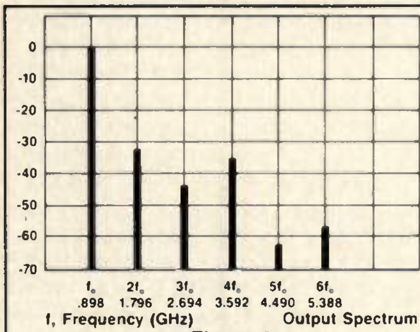
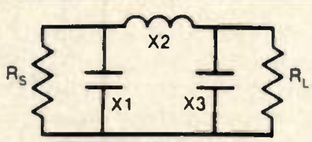


Figure 9



$$X1 = -R_S \sqrt{\frac{R_L/R_S}{Q^2 + 1 - (R_L/R_S)}}$$

$$X2 = \frac{Q\ R_L - (R_S\ R_L/X1)}{Q^2 + 1}$$

$$X3 = -\frac{R_L}{Q}$$

Features

Departments

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rf editorial

About That $600 Toilet Seat . . .

Every once in a while a story breaks in the press about some common item purchased by the military at exorbitant cost. The best stories are about items that could be purchased at a fraction of the cost at the local hardware store. Columnists scream and congressmen investigate until some new scandal forces the old one out of the newspapers. The story fades, leaving readers with a memory of military purchasing officers approving bills from conniving businessmen and probably receiving a kickback. Unfortunately, the truth is far less exciting.

Many *RF Design* readers produce and sell components and equipment to the military. To them it is no surprise that a coffee pot for a military aircraft can cost $400 or a toilet seat can cost $600. They know about the incredibly expensive and time-consuming process of meeting military contract requirements.

Let us look at how the process works.

Suppose an engineer develops a superior op amp and sets up a company to manufacture it. After testing the op amp a contractor decides to include it in a computer it is building for a Navy aircraft. The engineer thinks his future is secure with a government contract. Then he learns about the Specification Control Drawing (SCD) and the volumes of related paperwork the Navy requires on every phase of the manufacture and testing of that op amp.

The SCD describes in painstaking detail every step of the manufacturing process, every test that must be performed and even the materials that must be used to make that op amp. It does not matter that this component is already being manufactured and has been on the market for some time, or that it was chosen in the first place because it was so good. The engineer now must hire people to study the paperwork and respond to the requests for documentation, in addition to those building the op amps.

Next come the government inspectors to look at his operation and discuss the steps he needs to take to conform to military specifications. Whenever they come, he must postpone his other activities and spend the time with them. This calls for more staff to carry on the regular business while he negotiates with the inspectors.

The process of establishing procedures to meet military specifications and documenting his progress with paper might take a year or longer. During this time he receives no money and is probably borrowing to keep his business going. Eventually, he will have to pay that interest.

Finally, he is approved. Now he can begin to make op amps for the Navy contractor, but every unit must be tested according to specifications and test records kept. If the Navy aircraft falls out of the sky 10 years from now, the government can demand to see the test record for the particular op amp in the computer in that plane.

If the order is a small one, as it often is, the engineer must charge many times the normal cost of that op amp. He has incurred enormous expense to manufacture the military units, and it is a fact of life that businessmen who do not recover their costs do not stay in business.

Most *RF Design* readers are not shocked by high prices for common items sold to the military. They have seen the military procurement process in action.

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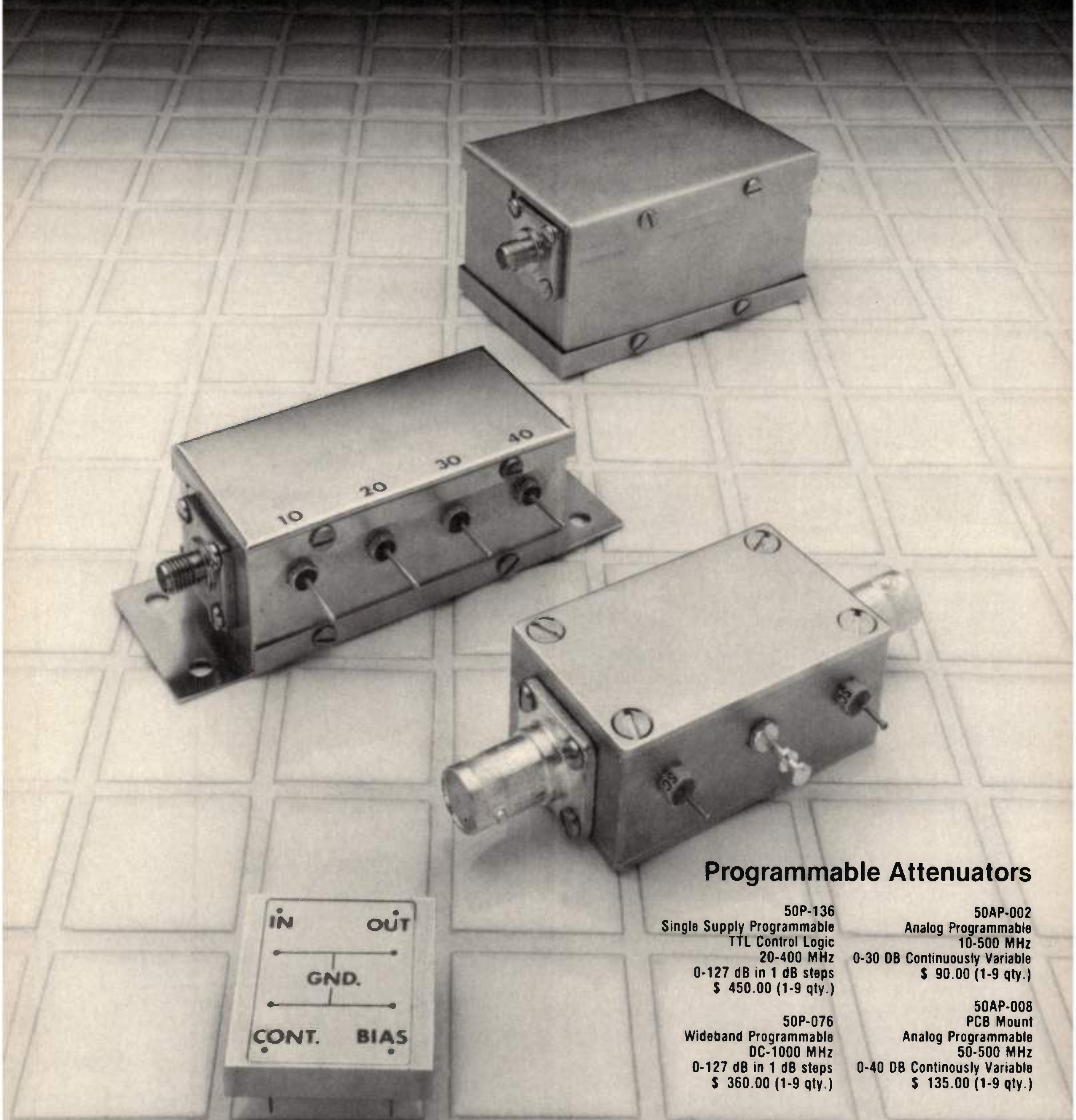

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INFO/CARD 5

rf publisher's note

AND NOW: RF TECHNOLOGY EXPO 86

Keith Aldrich
Publisher

Whatever else happened in Anaheim in January during RF TECHNOLOGY EXPO 85, one thing was established beyond any shadow of doubt. An annual technical conference of the first importance came into being, one which will be a part of the engineering landscape for many years to come.

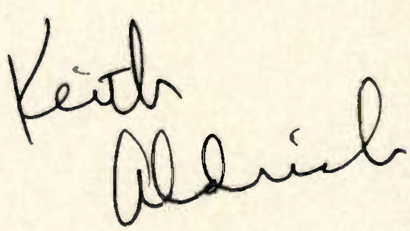
So it is with great pleasure indeed that we announce RF TECHNOLOGY EXPO 86. It will be held at the Anaheim Hilton and Towers in California from January 30 to February 1, 1986. It will pursue and expand the kinds of sessions that were most useful to attendees and, of course, eliminate the few bugs that marred the first RF TECHNOLOGY EXPO (overcrowding at the "Fundamentals" course, for instance, due to success beyond our modest expectation).

The success of the first EXPO, we realize, was due to you *RF Design* readers who attended the event and to those of you who presented papers there. How do we know that? Because if you didn't read *RF Design* you would have had a hard time hearing about the EXPO: the electronic press outside our own magazine largely ignored it.

I want to thank you personally for the faith that brought so many of you out and assure the rest of you, who waited to see if it was going to "go," that RF TECHNOLOGY EXPO will more than repay the time and money you might invest by attending it. It's a success, created by the RF community itself, and no one will ignore it again.

I can even predict, now, with some basis in experience, what you will find when you come to EXPO 86. You will be joined there by at least 2,000 and perhaps as many as 4,000 RF engineer/compatriots (two to three times as many as in 1985). You will be able to survey the product offerings of about 100 leading manufacturers, occupying more than 150 booth spaces (about twice the numbers recorded in 1985). You will be able to pick and choose among more than 80 technical papers offered by senior RF engineers in maker and user companies around the world. The day-long "Fundamentals of RF Design" course will be offered again, under the direction of Les Besser, President of Microwave Educational Programs.

And, if you want it badly enough, the program will include a distinguished, eminently helpful paper from you. In this issue you'll find a "Call for Papers" from Editor Jim MacDonald, who is serving as Program Chairman for RF TECHNOLOGY EXPO 86. Please respond to this call now, even though the EXPO is a good nine months off. This year we want to have the sessions in place and publicize them in advance, so there'll be no last-minute changes or confusions. We want to maximize the usefulness and convenience of RF TECHNOLOGY EXPO 86 to the community it was borns to serve. . . and which in fact came together around EXPO 85. Let's put it this way, *compadre:* we're in this thing together. Let's work together to make it go. . .and grow.



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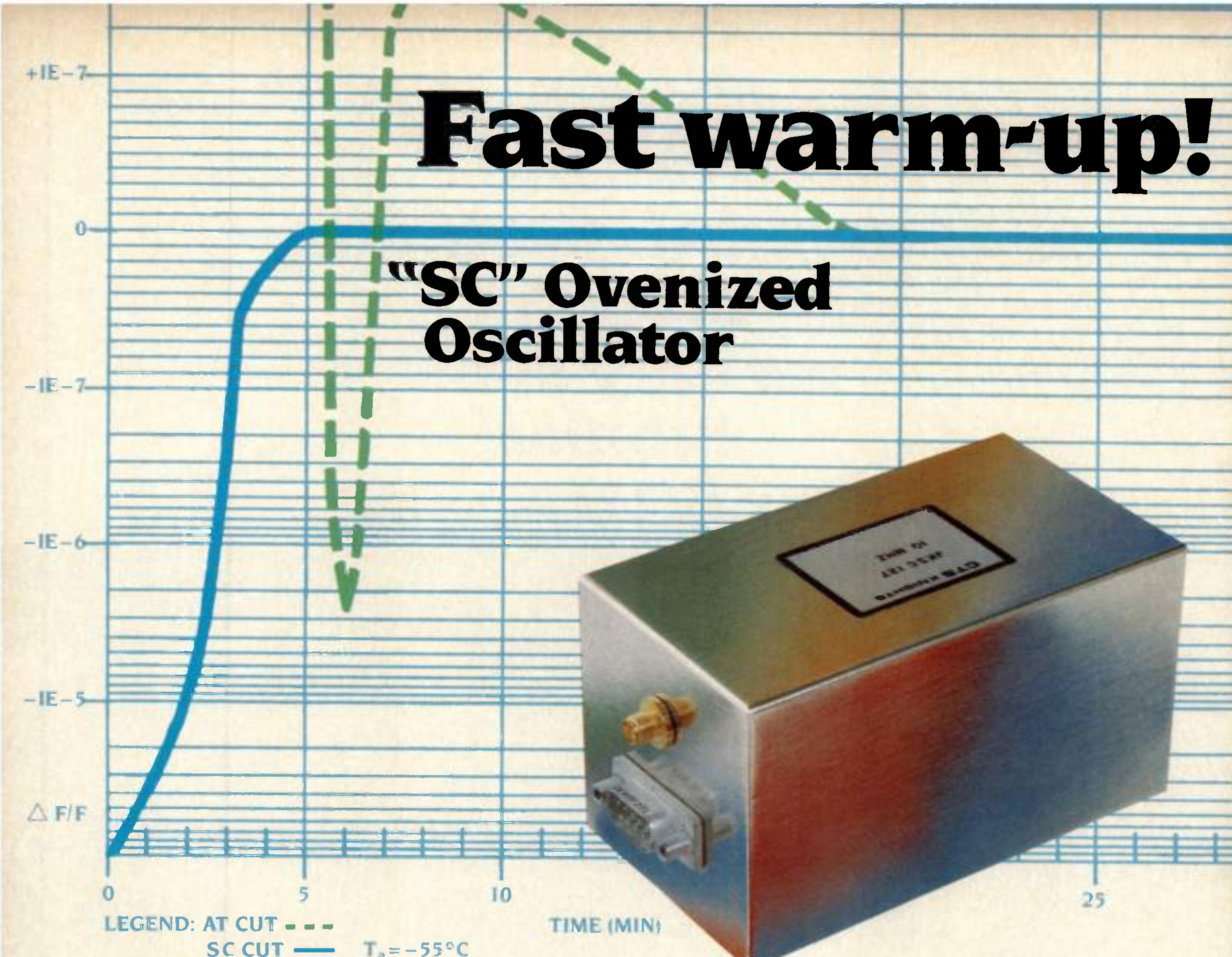

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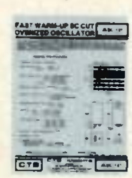

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Frequency Stability Vs. Temperature	±5 x 10^{-9} from −55°C to +71°C
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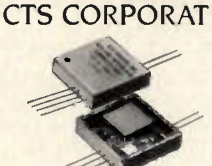

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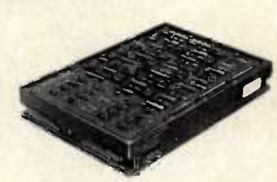

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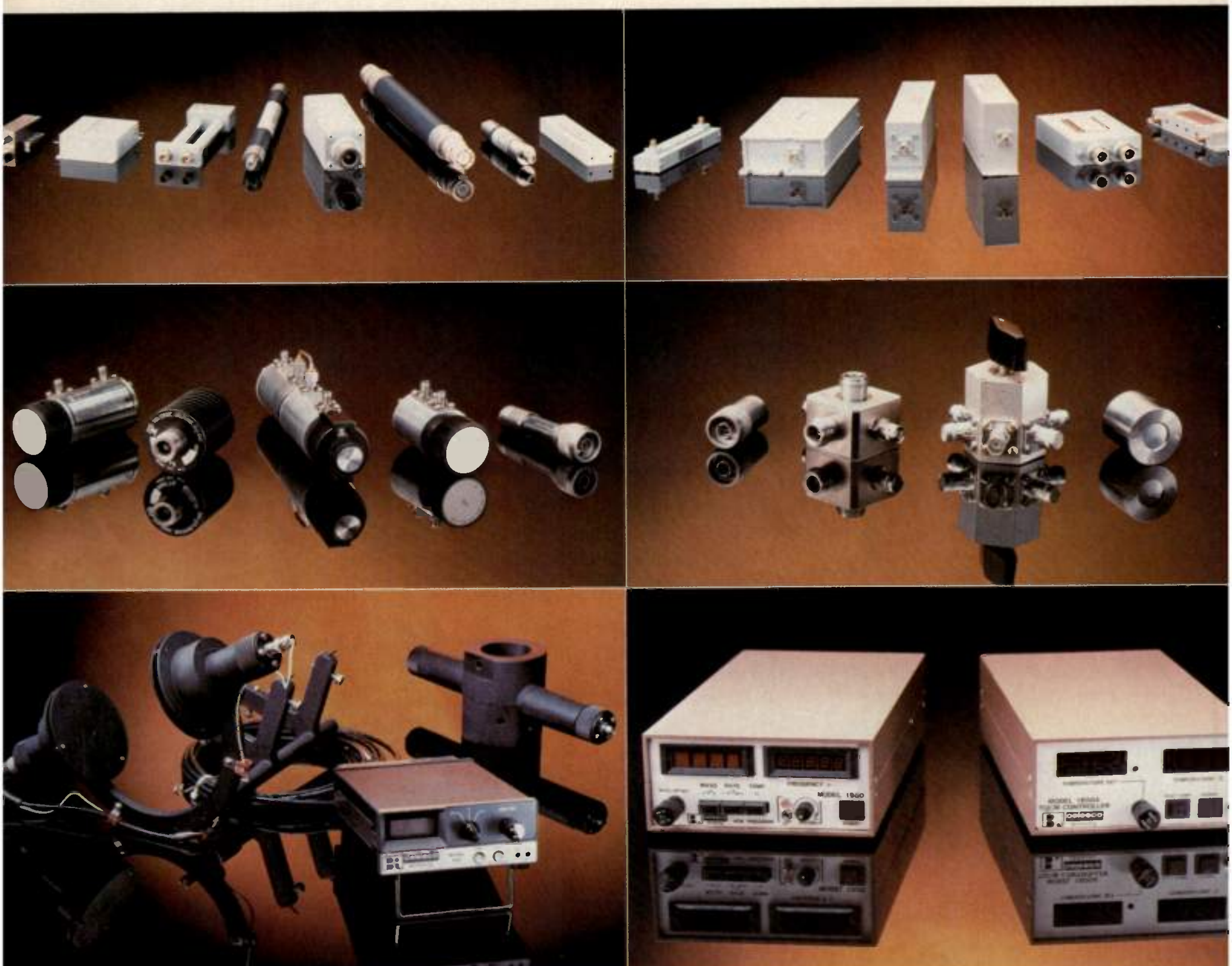

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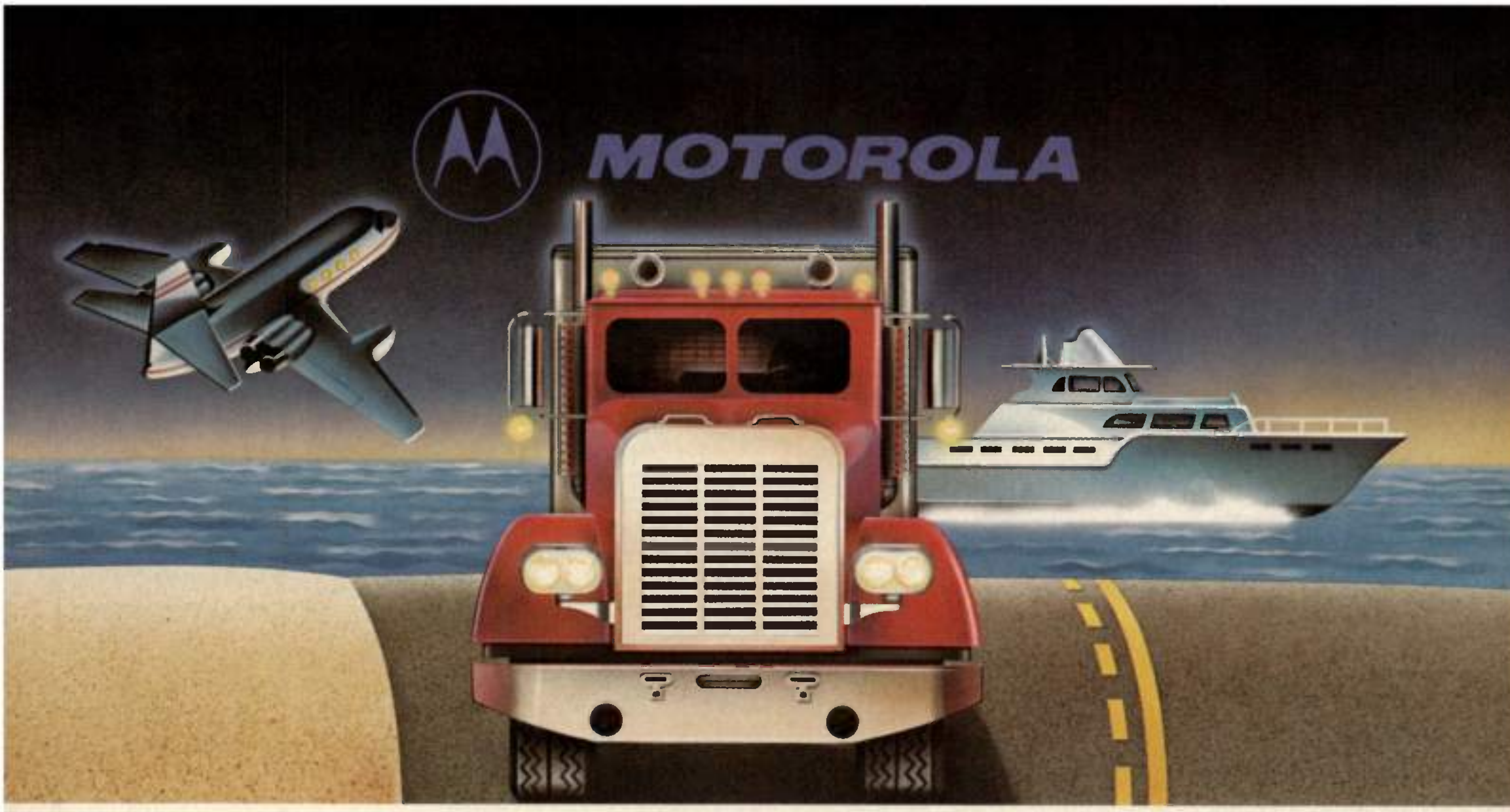

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Editor:

I recently had the opportunity to start a series of open seminars for RF design Engineers. I am looking for some self-explanatory articles I could use as documentation in my lessons.

Reading Steve Smith's letter in your November/December issue I had the idea to ask you for copies of articles such as the one Steve Smith mentions in his letter, (14 basic impedance-matching networks) and other documents about basics in RF design. Would you be so kind as to send me some?

I would also like to tell you how much your publication is appreciated here in Belgium, where the need for such a tool is tremendous. Your work is known to be (at least) one of the best in the field.

Jacques Casier
Broadcast Equipment
rue Emile Wauters, 52
1020 Bruxelles

So many readers have asked for information from previously printed articles that we are giving serious consideration to the idea of gathering articles from past issues and printing them as volumes. Each volume would contain articles about a specific subject. We invite suggestions from readers about what subjects would be most useful. — editor

Editor:

I would like to point out the following typographical errors in my article, "Theory of Operation of the DRO," published in the January issue. On page 27 the angle associated with α (alpha) is Θ (theta). The angle associated with β (beta) is Φ (phi). The same associated angles should be corrected in figure 4d.

Equation (7) variable was published as Q_1. It should be Q_L (the loaded Q calculated in equation 6).

Readers with further questions may contact the author.

Jim Walworth
10406 Lake Grove Dr.
Odessa, FL 33556
813-920-4008

Dear Mr. Aldrich:

As I mentioned to you last Friday, the show was a real success from our viewpoint and it certainly is our intent to participate in and support it next year.

I believe a real need exists for us and the RF Industry for exactly the kind of function which you put together at Disneyland. Based on this year's success, my guess is that next year's expo will be significantly larger in booth space, presentations and participants.

As you know, many of us participated this year on an "experimental" basis; Avantek did commit to support the show to help make it a success and are glad we did. Our thanks to you and your staff, and our best wishes for the continuance and success of your RF Technology Expos.

John P. Moore
Director Business Development
Microwave Products Group.

We appreciate Mr. Moore's support and good wishes and predictions, and thank him and the many other companies which participated in the first RF TECHNOLOGY EXPO. — publisher.

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Orange County Convention Center
Orlando, FL

Information: Cahners Exposition Group, Cahners Plaza, 1350 E. Touhy Ave., Des Plaines, IL 60018; Tel: (312) 299-9311.

April 23-25
Electro/85

New York Coliseum
New York, New York

Information: Tim Parrott, Electro/85, 8110 Airport Blvd., Los Angeles, CA; Tel: (213) 772-2965.

April 26-28
Dayton Hamvention

Hara Arena and Exhibition Center
Dayton, OH;

Information: Tel: (513) 443-7720

April 28-30
Intelligent Vision Systems

Holiday Inn
Monterey, CA

Information: Richard D. Murray, Institute for Graphic Communication, Inc., 375 Commonwealth Ave., Boston, MA 02115; Tel: (617) 267-9425.

May 14-16
Test & Measurement World Expo

San Jose Convention Center
San Jose, CA

Information: Meg Bowen, Conference Director, 215 Brighton Ave., Boston, MA; Tel: (617) 254-1445.

May 20-22
Electronic Components Conference

Capital Hilton Hotel
Washington, DC

Information: Tom Pilcher, Electronic Components Conference, Washington, DC; Tel: (317) 261-1592.

June 4-6
MTT-S

St. Louis, MO

Information: Fred Rosenbaum, Central Microwave, 12180 Prichard Farm Rd., Maryland Heights, MO;
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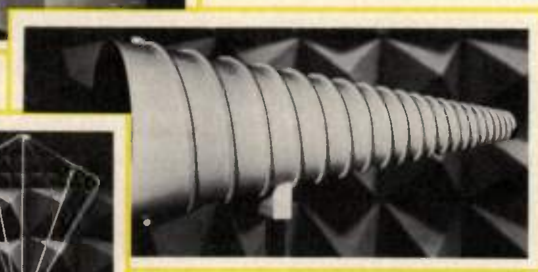

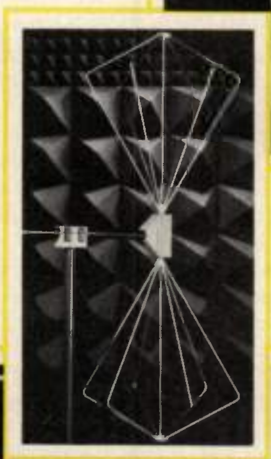

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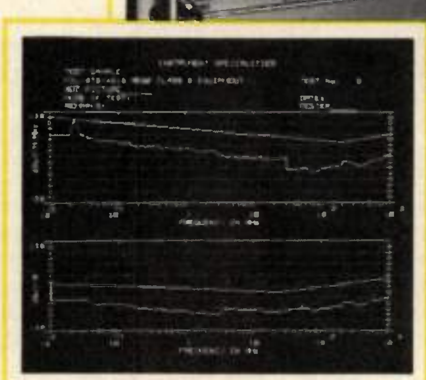
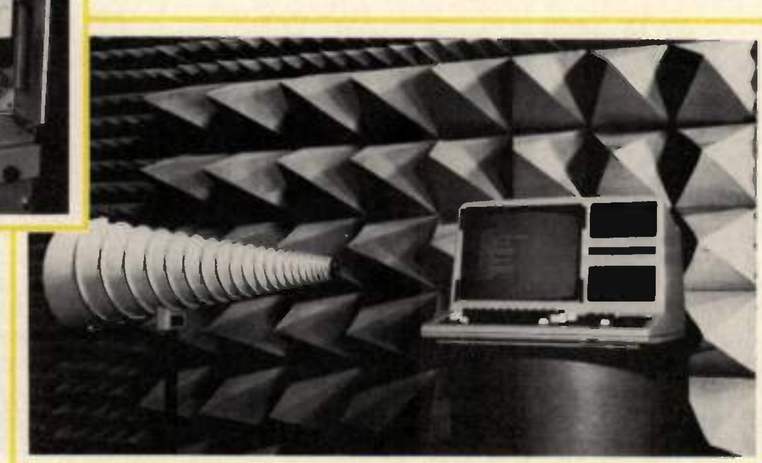




INFO/CARD 15

Digital Ionosonde System Helps Long-Range HF Radio

A digital ionosonde system produced by Australia's KEL Aerospace Pty. Ltd. is attracting increasing attention from HF radio and communications research groups throughout North America.

The IPS/DBD system is used for standard worldwide ionospheric monitoring and provides both interchange of information and central collation for evaluation and distribution. The system determines the most suitable high frequency wavelength for long-range HF radio communications at a given time and also easily identifies short-term variations in the earth's ionosphere.

Managing Director Terry Kelly said more than 60 KEL Aerospace ionosondes have been installed by governmental and educational institutions worldwide, even in remote tropical locations and the Antarctic. All are serviced by KEL specialists, Kelly said, and training also is offered.

The compact IPS/DBD system weighs less than 220 pounds and is transportable for field use. It "sounds" the ionosphere at regular intervals using high powered vertical radio frequency pulses. Echo pulses are used to plot ionograms, showing the relationship between virtual height and frequency.

The basic IPS/DBD package consists of a radar system, field-sited digital control system with 20 megabyte digital tape storage and a video scaling system. Accessories for field sites include an antenna, high resolution printer and telecommunications modem.

Additional information is available from The Office of the Australian Trade Commissioner, 636 Fifth Avenue, New York, NY 10011.

Ian Crossley is Senior Scientist at Alpha Industries

Dr. Ian Crossley has been promoted to Senior Scientist at Alpha Industries' Advanced Technology Division. Robert E. Goldwasser, corporate vice president, said Dr. Crossley is responsible for the development and production of GaAs microwave devices and monolithic microwave intergrated circuits.

Dr. Crossley spent five years at the Plessey Research Centre at Caswell in England before joining Alpha in 1977. He holds a Ph.D. from Brighton Polytechnic for research in GaAs/GaAlAs technology.

Alpha Industries, Inc. is a major manufacturer of microwave semiconductor devices, components, and subsystems for the defense electronics, commercial telecommunications, and other commercial markets. Alpha's Advanced Technology Division develops and produces GaAs FET-based MMICs, diode-based millimeter wave monolithic circuits, and GaAs semiconductor diodes.

Bruno O. Weinschel

Weinschel Recognized for Significant Contributions

Dr. Bruno O. Weinschel, President and Founder of Weinschel Engineering, recently received an award from the Automated Radio Frequency and Technology Group (ARFTG). The award, presented only on rare occasions, recognizes individuals who have consistently "enhanced the RF measurement discipline through the development of hardware, software and/or measurement techniques." Dr. Weinschel received the award in recognition of a long career of significant contributions to the RF and Microwave Industry.

Dr. Weinschel produced the first commercial coaxial attenuator in 1948 and in 1952 founded Weinschel Engineering, a company which has received over 40 patents and is well-known as an innovative designer of precision products.

ARFTG is an independent organization affiliated with the Institute of Electrical and Electronic Engineers (IEEE) and the Microwave Theory and Techniques Society (MTTS). The only other recipients of the award have been: Stephen Adam of Hewlett Packard, Robert Beatty of the National Bureau of Standards and Algie Lance of TRW.

Kyocera Gives $3 Million For Ceramics Professorships

Kyocera Corporation has awarded a $3 million grant to three U.S. universities for endowed professorships in ceramics, the largest corporate grant for ceramics professorships in the U.S.

Massachusetts Institute of Technology, Cambridge, Massachusetts, Case Western Reserve, Cleveland, Ohio and the University of Washington, Seattle, Washington, will receive $1 million each to establish Kyocera chairs in ceramics. The professorships are permanently endowed, meaning the professor's salary will be paid from the interest earned from the fund rather than the fund itself.

The three universities are leaders in research in ceramics, which is receiving increased attention as a high-technology material. Ceramic materials that are super-hard, super-strong and super-resistant to heat are being developed for use in industries as diverse as electronics, aerospace, energy and medicine.

Allied Corporation Acquires King Radio

Allied Corporation has completed acquisition of King Radio Corporation of Olathe, Kansas. The Bendix Corporation agreed to acquire King Radio for $40.50 a share or approximately $110 million. King Radio operations include principally the design, manufacture and marketing of aircraft communications, navigation and flight control systems.

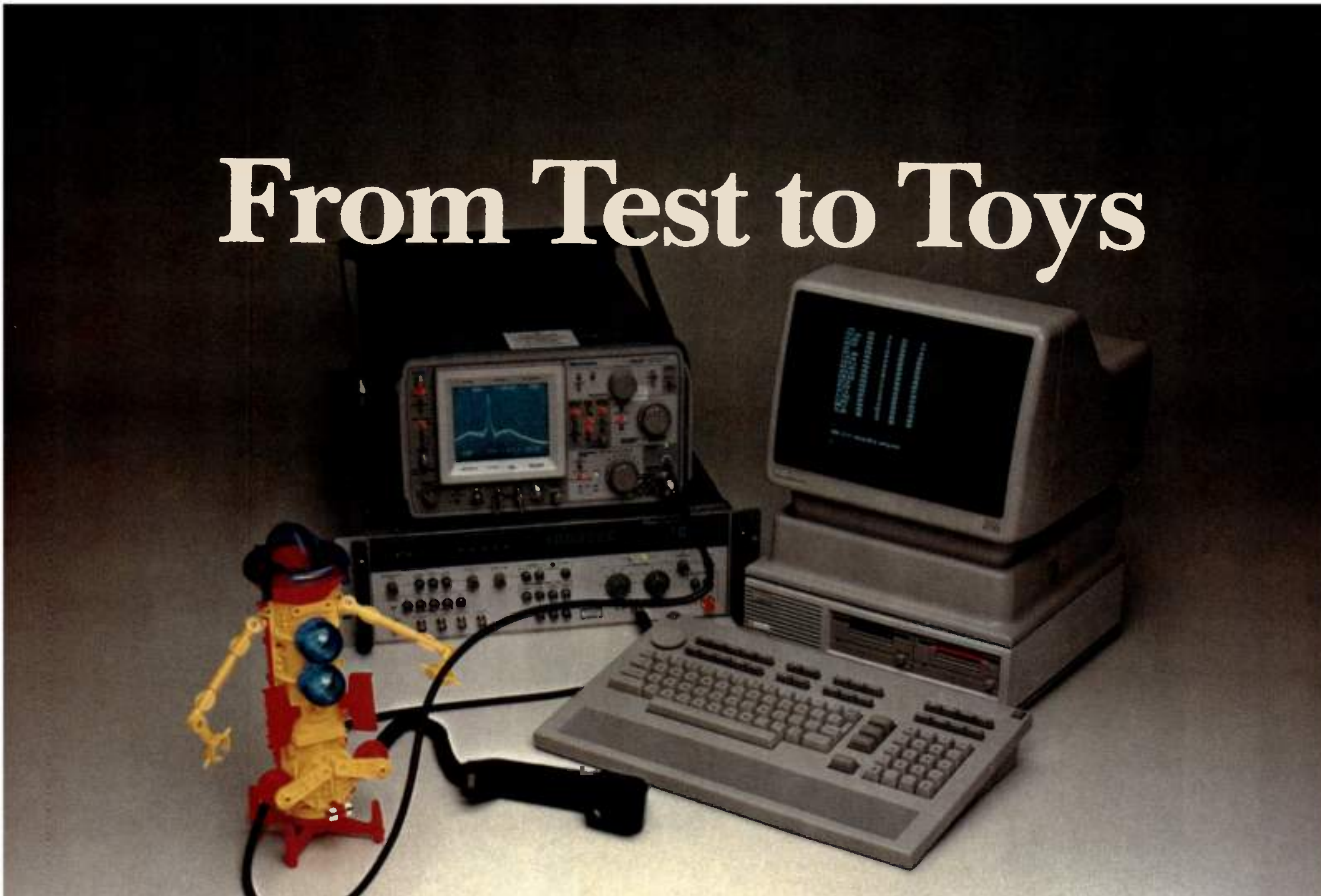
As part of the transaction, King Radio has entered into an agreement to sell to Narco Avionics, Inc. of Fort Washington, Pennsylvania, King's airborne weather radar systems. The sale will follow final approval of the Federal Trade Commission.

King Radio Corporation will operate as a wholly owned subsidiary within the Aerospace Sector of Allied Corporation.

Teledyne Microwave Will Develop Switch Matrix WRA

Teledyne Microwave was recently awarded a multi-million dollar contract by Litton Amecom for the design and development of switch matrix WRAs (weapons replaceable assemblies). The program, the EA-6B ADVCAP (Advanced Capabili-

From Test to Toys



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

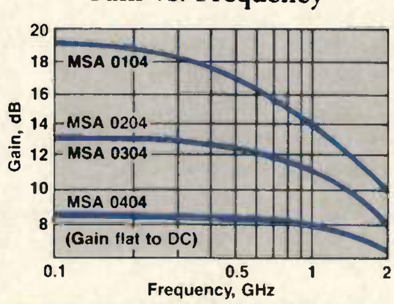
Avantek's series of MODAMP™ silicon monolithic microwave integrated circuit amplifiers are ready to drop into your 50-ohm circuit, with no design problems — virtually no concern for what comes before or after. These MMICs are unconditionally stable and provide cascadable gain blocks at any frequency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

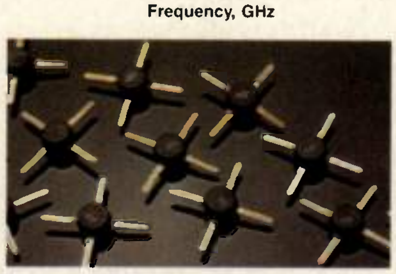
4-Pacs are small (140 mil) plastic packages suitable for PC board or stripline applications in products ranging from instrumentation to toys, from fiber optic systems to mobile communications. They're simple to use and readily available.

Available in volume.

Avantek 4-Pac MODAMP MMICs are available today from your nearest distributor. Prices start at $2.75 and go to $1.80 in 10,000 piece quantities. Don't forget — because of their very wide operating range, the same amplifier can work from DC through video all the way up to 2 GHz. And you can stack them like building blocks to add whatever gain you need. Avantek innovation — designed to make your design job easier.

Gain vs. Frequency





*price in 10,000 piece quantities.

INFO/CARD 16

Avantek MODAMP MMICs are the most universal low-cost RF amplifiers available. Try some today. Contact your nearest Avantek distributor or call us for complete details.

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(617) 862-5100

Technical Marketing Asso.
Hackensack, NJ
(201) 342-4008

CENTRAL
Component Dist.
Ft. Lauderdale, FL
(305) 971-4950

Peak Distributors
Arlington Heights, IL
(312) 255-0707

Thorson Dist.
Dallas, TX
(214) 233-5744

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Pen Stock, Inc.
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Sertek, Inc.
Los Angeles, CA
(213) 477-9051

Spirit Electronics
Scottsdale, AZ
(602) 998-1533

AVANTEK

3175 Bowers Avenue
Santa Clara, California 95051
Sales: (408) 496-6710

ty), will replace the current AN/ALQ-99 countermeasures suite. These matrices will be integrated into Litton's electronic warfare system to be provided to Grumman for Navy Prowler aircraft.

The Litton contract represents a major step into larger component assemblies to be designed and built by the subsystems group at Teledyne Microwave. Using MIC thin film technology, the unit will be integrated with products currently manufactured by the company, including diode switches, BAW delay devices and FET amplifiers. This highly complex assembly will meet demanding requirements for reliability, maintainability and performance.

Flight test systems are scheduled for delivery in 1987, with full production turn-on planned for 1989.

New Company Second-Sources Mixers For Less

Synergy Microwave, a three-year-old Paterson, N.J., manufacturer of mixers, dividers and other signal-processing components has begun to gain a reputation for its ability to turn out duplicates of other makers' devices at a lower cost, and often with a faster delivery, than the original maker's.

According to Meta Rohde, SM's president, this capability applies even when speaking of Mini-Circuits, the Brooklyn manufacturer which has been known for the lowest-cost RF components in the market. She maintains that the capability is due to very high quality-control standards in production, which minimizes costly rejects.

Ironically, Rohde insists, 60% of SM's output has nothing to do with such second-sourcing but comprises original, custom designs to customer specs. She prides herself on a 4-week turnaround time from design to delivery.

For more information contact Synergy Microwave Sales Manager Howard Levine at (201) 881-8800.

Meta Rohde

Tektronix to Acquire CAE Systems, Inc.

Tektronix, Inc. and CAE Systems, Inc. have agreed in principle to a corporate acquisition in which CAE Systems will become a wholly owned subsidiary of Tektronix. Under the terms of the proposed transaction, Tektronix will issue common stock valued at $75 million to CAE's shareholders. The proposal is subject to a number of conditions, including the negotiation of a definitive agreement and formal approval by both companies. rf

CALL FOR PAPERS

RF TECHNOLOGY EXPO 86

January 30-February 1
Hilton Hotel and Towers
Anaheim, Calif.

Proposals are now being accepted for papers to be presented at the second annual RF TECHNOLOGY EXPO, the conference and exhibit for RF engineers sponsored by *RF Design* magazine. More than 60 papers are needed for the 3-day event. Presenters will receive free conference registration and a copy of the Proceedings.

Papers dealing with practical, design-oriented information are preferred. They can be instructional, aimed at new RF engineers and those working in unfamiliar fields, or more advanced analysis for senior engineers. Descriptions of new commercial products are acceptable if the presentation features a new design concept or a significant development of general interest. All papers should be about 30 to 40 minutes in length.

Suggested topics include, but are not limited to, RF circuit design, design techniques, components, computer aided design, EMC/EMI, digital interfacing, component mounting, antennas and testing.

Hurry to submit your proposal for a paper in outline form to James MacDonald, Editor of *RF Design*. The proposal should be stated in one page and should specify what audio-visual aids and working materials would be needed for presentation.

Your proposal must be received by July 26, 1985. Selection of speakers and papers will be announced by August 30.

James MacDonald
R.F. Design
6530 S. Yosemite St.
Englewood, CO 80111

Broadband, High Power RF Amplifiers

By James N. MacDonald

A satellite is a beautiful thing, speeding silently through the cold blackness of space, relaying signals from one part of the earth to another. Shiny and delicate, it draws the smallest current possible from its batteries to amplify and retransmit signals between microwave transmitters and receivers — and therein lies its weakness.

From atmospheric tests conducted in the 1950s, physicists learned that a nuclear explosion releases an electromagnetic pulse of astonishing magnitude that can travel great distances. This has had military planners concerned for some time. They fear that a nuclear explosion in the upper atmosphere could silence many of the communications satellites upon which they now depend, their delicate circuitry fried by a current far beyond design limits.

In recent years military strategists have been looking more and more toward long range HF communications as a backup, if not a primary system. At the same time, physicists have been learning more and more about the properties of the ionosphere, which, by reflecting and refracting radio waves, makes over-the-horizon propagation possible. Engineers now can predict appropriate frequencies for long range communications with much greater accuracy.

For long range communications, electronic warfare and other applications the military is looking for high power transmitters. Along with high power goes a requirement for wide bandwidth, since military communications cannot be confined to a narrow spectrum. Modern frequency-hopping and spread spectrum transmission techniques for secure communications require transmitters and receivers capable of operating over a wide bandwidth with little loss of gain. Although the primary application of wideband high power amplifiers today is military, they also are finding civilian uses, such as EMI susceptibility testing and magnetic resonance applications.

This special report examines some of the specifications of high power, broadband amplifiers currently on the market.

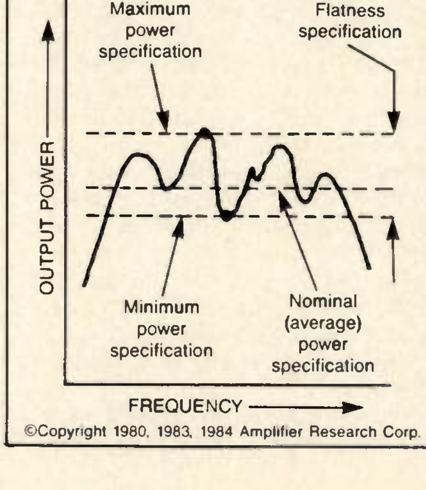
Broad bandwidth and high power are conflicting parameters in an amplifier. Generally, gain decreases as frequency increases. The amplifier designer faces a limit in the gain-bandwidth product and the power capabilities of the device. Furthermore, high-gain, untuned amplifiers tend to oscillate. To be useful for the purposes just stated, broadband amplifiers must be stable over the entire bandwidth and under conditions of severe load mismatch.

Since output power usually varies with frequency, amplifiers can be described in terms of maximum power at a given frequency, nominal power over the amplifier bandwidth or minimum power available at any frequency within the bandwidth. Figure 1, produced by Amplifier Research Corporation, shows the differences that can exist in power claims for a given amplifier.

In addition to rated power, flatness specification can be an important amplifier characteristic for the designer. Amplifiers rated with nominal power and flatness specification should always deliver power greater than the rated power minus the flatness specification. Amplifiers rated with maximum power usually will deliver less power over most of the bandwidth.

Linearity is the ability of the amplifier to deliver output power in exact proportion to input power. When the output is driven to a point near saturation, gain compresses and linearity is lost. Linearity is usually specified as the output level where gain compresses by a given amount.

Figure 1. Amplifier Power Ratings



Following are some descriptions of recently developed RF power amplifiers and specifications provided by the manufacturers. *RF Design* has made no attempt to verify the manufacturers' descriptions of their products. The information is furnished here to illustrate what characteristics amplifier manufacturers are seeking to improve.

A new Amplifier Research RF power amplifier, model 80W100M1, produces 80 watts minimum output throughout a 200 to 900 MHz bandwidth, with 70 watts minimum to 1000 MHz. The bandwidth is available instantly without bandswitching or tuning, and it performs with unconditional stability into an open cable, dead short or any VSWR, without damage, oscillation or shutdown.

The minimum CW linear output of this model (less than 1 dB gain compression into 50 ohms) is 50 watts from 200 MHz to 1000 MHz. Maximum power output is 150 watts. Harmonic distortion is no less than 20 dB below fundamental at 50 watts output, and intermodulation distortion, specified by the third-order intercept, is 59 dB typical.

Another new Amplifier Research amplifier produces saturated CW output rated at 1600 watts nominal, 1400 watts pulse over an operating bandwidth of 10 kHz to 220 MHz. The model 1500L produces 600 watts minimum linear output (less than 1 dB compression) over this bandwidth.

Designed for laboratory applications requiring instantly available bandwidth and high gain, the Model 1500L is fully compatible for use with swept-frequency RF signal sources. It is also equipped for pulsed output at duty cycles of up to 25%. In this mode, the 1500L output is rated at 4000 watts minimum from 10 kHz to 150 MHz and 2000 watts minimum from 150 kHz to 250 MHz.

The full bandwidth, available instantly, requires no bandswitching or tuning.

Flatness is ±1.5 dB typical. Gain at maximum setting is 63 dB minimum. All harmonic products occur more than 15 dB below fundamental power at 1400 watt output. The 1500L is unconditionally stable. It will not shut down or sustain damage while driving any load impedance, inductive or capacitive, including infinite VSWR.

M/A-Com Microwave Power Devices, Inc., has a series of solid-state, Class A power amplifiers employing a unique combination of microstripline, low loss hybrid combiners and the latest available silicon bipolar and GaAs FET devices. The LWA series has more than 60 standard models in octave, decade and specific bands from 1 MHz to 8.4 GHz with linear power outputs from 0.5 watts to 120 watts and saturated power levels up to 180 watts. The power input level for power output at 1 dB compression is typically 1 mW for most models. Noteworthy performance features include low noise figure and wide dynamic range.

Series LWA Class A amplifiers are particularly recommended for those applications requiring exceptional linearity and dynamic range. Their low noise figure and high power output capability allow low distortion amplification of one or more amplitude, frequency and/or pulse-modulated carriers.

Abnormal operating conditions that could ordinarily result in a failure include poor load VSWR caused by an inadvertant open or short circuit at the RF output port, excessive operating temperature due to fan failure or inadequate heat sinking, RF input overdrive and accidental application of reverse DC voltage. MPD Series LWA amplifiers feature DC reverse voltage protection, automatic thermal protection (on models with power outputs above 10 watts), RF input overdrive protection up to 10 dB over the nominal input level required for 1 dB compression at the RF output connector and infinite load VSWR protection. (All models can operate at saturated output levels indefinitely into a 3:1 load VSWR without damage.)

Load VSWR protection is accomplished by a unique electronic turndown circuit. The electronic power output turndown system senses the reflected power and automatically adjusts the amplifier's forward power as a function of load VSWR to the maximum safe level. Response time is less than 100 microseconds.

All active circuits are modularized. In the event of failure of a transisitor, that particular module can be field-replaced without the need for special RF test equipment. The modules are tuned at the factory for low interface VSWR and common gain and phase transmission characteristics. Modular design allows the packaging and fabrication of various power output amplifiers as a function of the number of modules in parallel.

Series EWAL/PWAL solid state, air cooled, kilowatt power amplifiers from M/A-Com MPD represent a significant advance in state-of-the-art design of linear, wideband power amplifiers. They operate in the Class AB mode, which allows amplification of AM signals as well as CW, FM, pulse and phase modulated signals. Available for frequencies from 1.5 MHz to over 1450 MHz, with electronic (EWAL) or circulator (PWAL) load VSWR protection, these amplifiers are used in applications requiring a wide dynamic range, such as communication booster amplifiers and ECM/EW jammers.

In most applications, the ability to amplify signals without alternation of basic signal characteristics is of paramount importance. Series EWAL and PWAL both provide this high degree of linearity. Class A operating low level stages are coupled with Class AB linear intermediate and high power output stages to provide the best possible combination of operating efficiency and linearity. The Class A low level modules, which are inherently linear (and inefficient), draw full power supply current at all times, whether a signal is present or not. This results in significant amounts of wasted energy. While a relatively small amount of current is required for the low level stages, this inefficiency becomes intolerable in the higher output power stages due to thermal considerations, size, weight and overall DC power requirements. Therefore, Class AB stages, which offer good linearity and much higher efficiency, are used in the higher output stages.

Anzac Division of Adams-Russell Company has a series of cascadable thin film amplifiers in TO-8 housings. The AM-171 is a 5-500 MHz device with a 2.3 dB typical midband noise figure, 1.2:1 typical midband output VSWR and a nominal 15 dB gain. The amplifier offers a +12 dB typical third order intercept.

The AM-175 provides a 3 dB typical midband noise figure, +8.5 dBm typical 1 dB compression and 15 dB gain, nominal. It affords a typical +22 dBm third order intercept.

The AM-180 is a 10-2000 MHz amplifier that provides a 5 dB typical midband noise figure, +14 dBm typical 1 dB compression and 1.4:1 typical VSWR. It offers a +30 dBm third order intercept point.

Featured on the cover is Microwave Modules and Devices' new AC-0003-500W, a modular wideband HF Class AB linear power amplifier that provides 500 watts of output power at an intermodulation distortion level of better than -35 dB (IMD_3). The module incorporates wideband 90° quadrature combiners resulting in predictable 50 ohm system interfaces and superior performance into imperfect loads. The unit also contains internal voltage regulation and reverse voltage protection.

A single AC-0003-500W can be used as the final stage in a 500 watt system or modules can be combined to construct multi-kilowatt transmitters.

Intech, Inc., has developed a 1000 watt, solid state, linear, MOSFET power amplifier suitable for RFI/EMI testing, HF transmitters, linear accelerators, NMR scanning, plasma equipment and medical diathermy. With a frequency range of 1.6 to 30 MHz, the COM 1000B has 60 dB linear gain and third order IM products typically 25 dB below rated PEP. Gain flatness is 0.7 dB over the bandwidth. The unit is composed of four interchangeable 300 watt modules. It can operate into a 5:1 VSWR at reduced output and can survive intermittent shorted and open load.

These are a few of the RF power amplifiers on the market today. Looking at these specifications, the RF designer can see the direction amplifier manufacturers are taking. Along with wide bandwidths and high power go the standard requirements of linearity and stability, more difficult to achieve together with the first two parameters. Modern uses require that the full bandwidth be available instantly and that the amplifier not shut down under severe load mismatch. Modular design with isolation so the amplifier will operate under partial failure and can be field-repaired is another consideration, especially important to the military.

Satellite communication is here to stay, of course, and satellite manufacturers are no doubt hardening their products against electromagnetic pulse. Nevertheless, military and commercial users are directing their attention once more to HF communications and other RF applications.

Future special reports will describe the miniaturization of amplifiers and other RF devices and the new materials and packaging techniques developed to meet the modern uses of RF technology.

330 OSER AVENUE
HAUPPAUGE, N.Y. 11788
(516) 231-1400
TWX 510-227-6239

M/A-COM

M/A-COM MICROWAVE POWER DEVICES, INC.

UPDATE: RF/MICROWAVE POWER

To: The RF/Microwave Technical Community

From: Dan Mazziota

Re: Present and Future State-Of-The-Art in Solid State Power Amplifiers

Back in 1967, we made our first state-of-the-art breakthrough, with the successful development of a 5-watt amplifier operating at a frequency of 1 GHz. Since then, we've been committed to a corporate-wide program of technological progress in the design and production of transistorized amplifier systems for higher and higher output power levels -- operating at higher and higher frequencies -- with higher and higher standards of performance and reliability.

Thanks in great part to the challenging demands of your application requirements, together with the fine support and technical cooperation you've given us, we've made tremendous progress -- and I'd like to update you in four important areas:

1. The frequency ranges we work in.
2. The power levels of amplifier hardware we've actually built and delivered for operational service in the field.
3. Our current and near-future power levels, including present development work and/or projects now under contract.
4. Our longer-term future targets, represented by advanced R&D and/or proposal stage projects for upcoming requirements.

	POWER OUTPUT		
FREQUENCY	HARDWARE DELIVERED	CURRENT DEVELOPMENT/CONTRACT	FUTURE DEVELOPMENT/PROPOSAL
1.5-30 MHz	2.6 KW	20 KW	100 KW
20-150 MHz	2 KW	5 KW	10 KW
20-500 MHz	50 W	1 KW	5 KW
100-500 MHz	1 KW	2 KW	10 KW
500-1000 MHz	500 W	1 KW	5 KW
850-1450 MHz	1 KW	2 KW	5 KW
1750-1850 MHz	1.25 KW	2.1 KW	2.5 KW
1-2 GHz	30 W	50 W	100 W
2-4 GHz	5 W	10 W	50 W
2-8 GHz	--	2 W	10 W
4-8 GHz	2 W	10 W	20 W
4.4-5.0 GHz	10 W	50 W	200 W
7.9-8.4 GHz	8 W	15 W	50 W
12-13 GHz	1 W	5 W	5 W
13.5-14.5 GHz	4 W	8 W	10 W
14-14.5 GHz	3 W	5 W	10 W

Our amplifiers and subsystems are produced for industrial and military environments, utilizing both air and liquid cooling technology, with microprocessor control, and are available in either instrumentation or military system configurations.

We would certainly welcome any inquiries you may have, and invite you to contact us to discuss your present or future needs in RF/Microwave power amplification.

Once again, my most sincere thanks for your past support, and more power to you !

Cordially,

Daniel R. Mazziota

Daniel R. Mazziota, President
M/A-COM Microwave Power Devices, Inc.

These Numbers Mean Business

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

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

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

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

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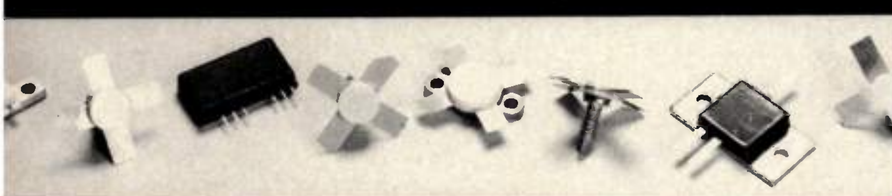

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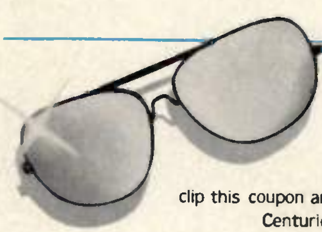

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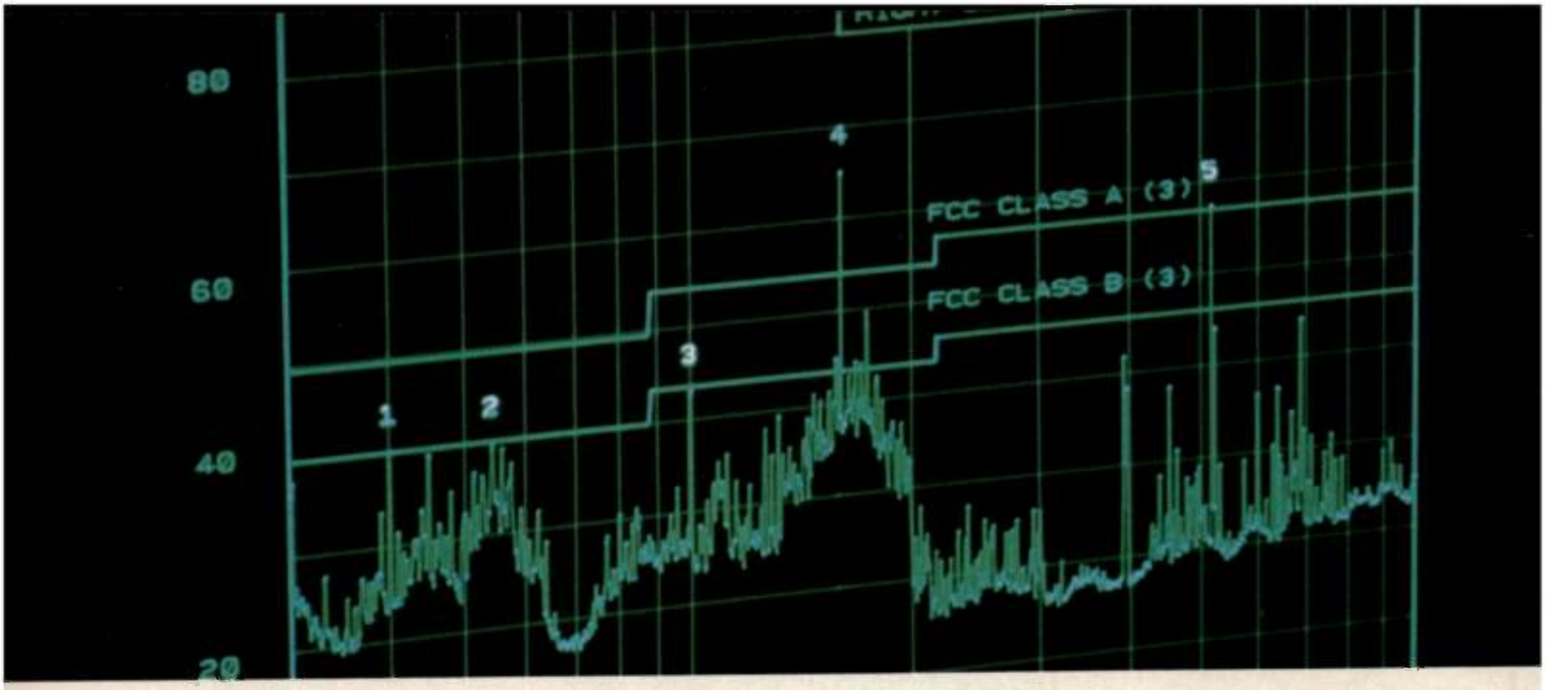

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A 14 Watt, 900-950 MHz Low Cost Amplifier Design

By David Miller
RF Land Mobile, Motorola Inc.

Two high performance 800 MHz parts (MRF839, MRF843) are used to produce a 14 watt, 900-950 MHz amplifier. The MRF839 is an inexpensive, 3 watt device that serves as an excellent driver for the MRF843. Its double emitter bonding, fine line (2 micron) die geometry and isolated collector construction make it superior to other similar devices. The MRF843 is a new 800 MHz 15 watt transistor. Like the MRF839, it is inexpensive, yet possesses excellent performance. Strong points of the MRF843 include good gain, high efficiency and internal input matching for broadband capabilities. This article describes the design, construction and performance of a two stage amplifier constructed with these devices.

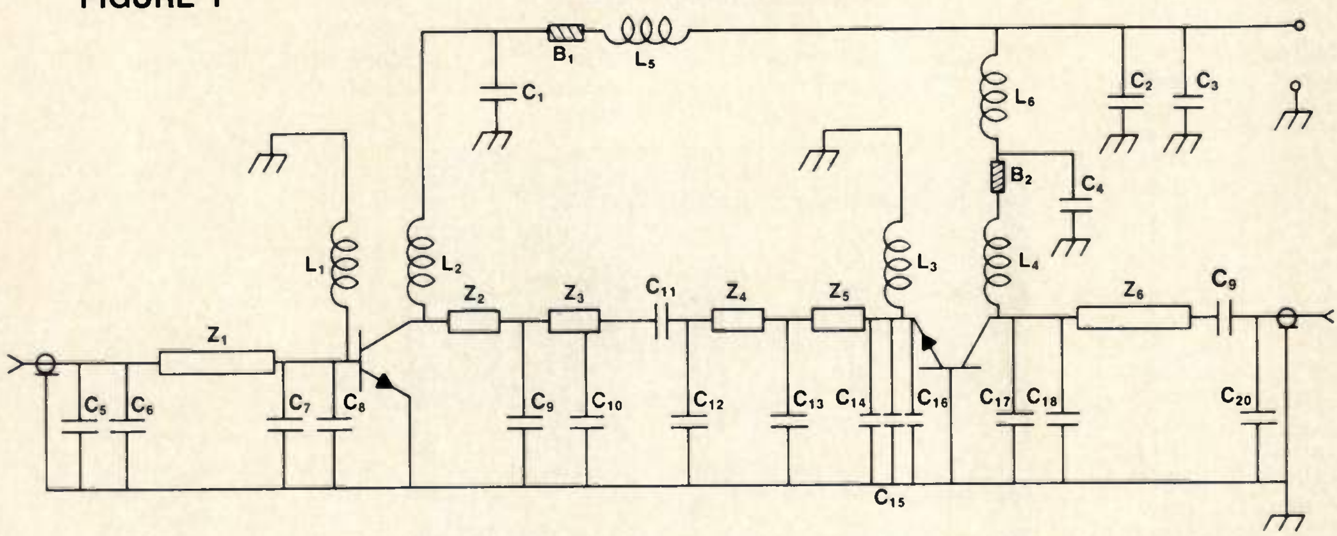
To be considered viable an amplifier must be capable of meeting certain design criteria, regardless of the application. First, the amplifier must possess good RF performance; i.e. good gain, high efficiency and stability. Next, it must be rugged under a variety of adverse operating conditions. Third, it should be easily constructed, tuned and reproduced. Finally, in today's world of "smaller is better" it must be compact. This amplifier has been designed and developed based upon the above described design criteria (see Table 1).

Table 1
Design Criteria

Power Out	14 Watts (Typ.)
Gain	14.5 dB (Typ.)
Efficiency	≥45% 50% (Typ.)
Ruggedness 20:1 VSWR	V_{cc} = 15.5 Vds
	P_{in} = 750 mW
Stability 3:1	V_{cc} = 6-15.5 Vdc
VSWR	Freq. = 900-950 MHz
	P_{in} = 300-750 mW

FIGURE 1

900 MHz 14W 2 STAGE AMPLFIER



C_5, C_{20}	**1.0 pF, ATC, Chip cap, 50 Mil**
C_6, C_{15}	2.2 pF ATC, Chip Cap, 50 Mil
C_{12}	4.7 pF ATC, Chip cap, 50 Mil
C_{10}	7.5 pF ATC, Chip cap, 50 Mil
C_{13}	10.0 pF ATC, Chip cap, 50 Mil
C_7, C_9, C_{16}, C_{18}	12.0 pF ATC, Chip cap, 50 Mil
C_8, C_{14}, C_{18}	15.0 pF ATC, Chip cap, 50 Mil
C_{17}	18.0 pF ATC, Chip cap, 50 Mil
C_{11}	39.0 pF ATC, Chip cap, 50 Mil
C_{19}	39 pF ATC, Chip cap, 50 Mil
C_1, C_4,	68 pF Miniunderwood mica
C_2	2 x 470 pF ATC, Chip cap, 250 Mil
C_3	10μF Tantalum Electroytic
L_1	4 Turns on 10 ohm ½W Resistor
L_5, L_6	10 Turns on 10 ohm ½W Resistor
L_2, L_3, L_4	4 Turns 0.20" I.D. 24 AWG
B_1, B_2	Bead, Ferroxcube 56-590-65/313
Z_1-Z_6	Refer to circuit photomask*
PCB	1/32" G-10 Er = 4.1

*Photomask copies available from Motorola Inc.

Circuit Design

Although two stages of amplification comprise a single amplifier, each stage is designed to stand alone. Such a design scheme allows the designer to independently tune and test each stage. This provides the necessary feedback to ascertain how well each stage is functioning. This ability is particularly important when one considers the number of variables introduced by the matching and biasing of the circuit.

The independent amplifier approach is accomplished by splitting the inter-stage matching network midway and establishing a 50 ohm intermediate impedance level. At the 50 ohm location the two stages are combined via a series coupling capacitor. Independent testing of the stages is accomplished simply by breaking the circuit in two at this point.

A more direct matching scheme might produce a simpler inter-stage match. The added flexibility of the independent amplifier approach is, however, of great advantage to the initial tuning and testing of the circuit. The circuit is shown schematically in Figure 1.

Considering the two stages as independent amplifiers allows one to identify the desirable attributes of each stage. The driver stage has primarily three responsibilities: to contribute to the overall gain, to present a minimal input VSWR and to level the frequency response of the second stage. The output stage has two major responsibilities. It must be matched to provide good gain across the operating band while maintaining a high collector efficiency.

The First Stage. The currents and voltages of the driver stage are relatively low, and parasitic losses, i.e. I^2R losses, are generally considered negligible. Performance in the low power driver stage thus becomes for the most part a function of correct impedance matching (impedance matching will be covered in a later section of this article).

The input VSWR of the amplifier is determined by how well the input impedance of the first stage device is matched. Enough internal transistor feedback exists in all RF power transistors that changes to the transistor's output operating conditions will have an effect on the input impedance of the device. Therefore, attention must be given to both the input and output impedance matching of the transistor when attempting to minimize the input VSWR.

To level the frequency response of the amplifier the first stage is used to compensate for the gain slope of the second stage. This is accomplished as shown in Figure 2. In the figure, curve A shows the typical frequency response of the output stage. Curve B shows an intentionally mismatched (skewed) response for the driver stage. The net idealized gain slope of the amplifier is shown as curve C and is simply the composite sum of the two stages (curves A & B). The intentional skewing of the driver stage is realized by designing the output match to be optimum at 950 MHz instead of at the mid-band frequency. The device thus sees its maximum mismatch at the high gain 900 MHz band edge. The degree of required band edge mismatching can be determined empirically and depends entirely on the gain slope of the output stage. The greater the roll off, the greater the mismatch that will be required to level the amplifier.

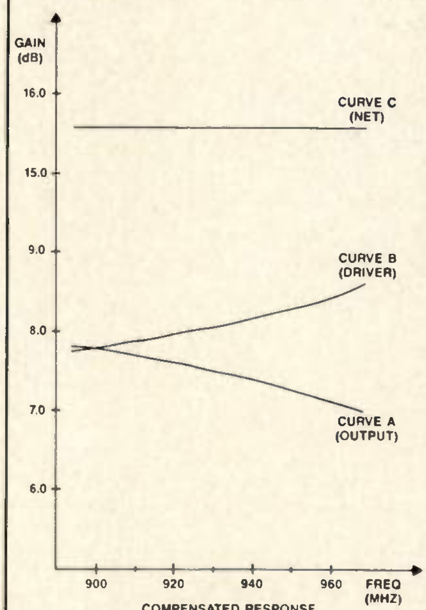


Figure 2

The Second Stage. The second stage, although it does not necessarily provide the majority of the gain, does exhibit the highest current and power levels associated with the amplifier. For this reason the design must not only provide good impedance matching to achieve optimum power transfer, it must also insure low loss conduction paths to minimize parasitic losses. Minimizing the transmission line lengths is the most effective way to reduce losses associated with both the resistance of the conductor and the dielectric substrate.

The output stage of the amplifier is the major determiner of overall efficiency. Equation (1) shows the total collector efficiency of the amplifier to be dependent upon the collector currents drawn by both stages, as well as V_{cc} and P_{out}.

$$\text{Eff total} = P_{out}/V_{cc}\,(I_c \text{ first} + I_c \text{ second}) \quad (1)$$

The second stage draws over 80% of the total supply current. For example, with both stages operating independently at about 60% efficiency the collector currents are 373 mA and 2.0 amp, respectively. Thus, with V_{cc} = 13.8 Vdc and P_{out} = 14 watts the net efficiency is about 50%.

To insure good collector efficiency (whether it be the driver stage or the output stage) it is not only important to have proper impedance matching and to minimize the transmission line losses; losses due to low Q chip capacitors must also be considered. Due to the physical construction of chip capacitors there is a parasitic series resistance and inductance. The inductance reduces the reactance of the capacitor, increasing the effective capacitance. The series resistance may be determined from the equation $R_s = X_s/Q_s$ and manifests itself as a power loss.

Impedance Matching. Low pass filter design techniques are employed throughout the circuit to achieve impedance matching. Chip capacitors and microstrip transmission lines are used to generate the matching sections. Selecting a suitable length transmission line creates the inductive reactance needed to generate the matching sections and eliminates the need for discrete inductors. This not only helps simplify the circuit design but also adds to the reproducibility of the circuit.

The first step in synthesizing a matching network is to determine the number and configuration of the matching sections necessary to achieve the desired response. Strictly speaking, the bandwidth of a ladder network is only limited by the number of sections used. It follows that the overall bandwidth of the amplifier, without feedback, is theoretically limited by the Q_s of the transistor devices. However, because of the lossy nature of the elements used to formulate each matching section, i.e. transmission lines and chip capacitors, the insertion losses limit the maximum number of usable sections. The design consideration at this juncture becomes one of optimizing the bandwidth of the amplifier while minimizing the losses of circuit. A graphical Smith chart design method is used to accomplish this optimization.

As an example of this method, the impedance matching design for the input of

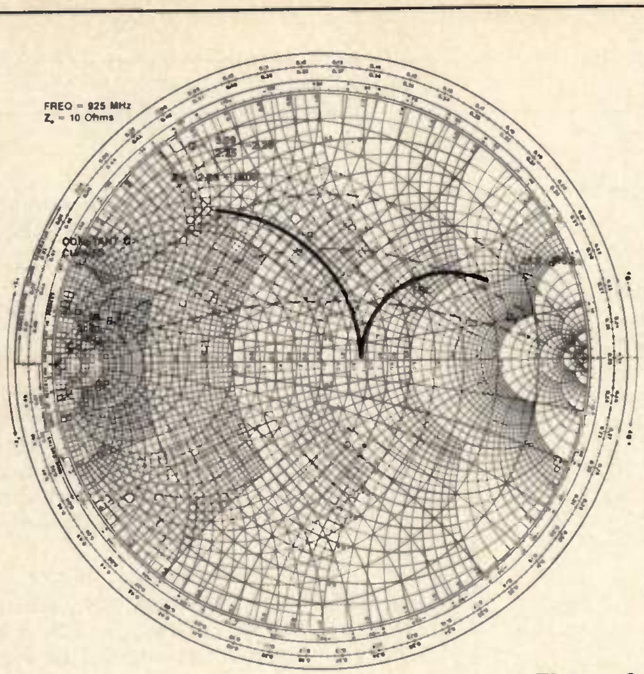


Figure 3

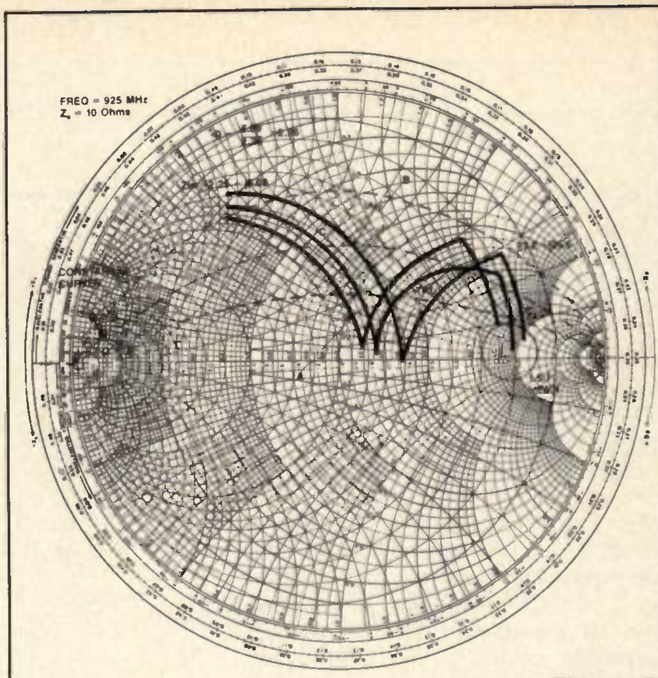


Figure 5

the MRF839 is shown in Figure 3. The midband (925 MHz) input impedance of the device is first plotted on the Smith chart, establishing a starting point (the manufacturer's impedance data for the MRF839 and MRF843 are reproduced in Table 2). The Q_s of the device is computed to be 2.26. To maintain a maximum bandwidth, no portion of the matching network should exceed this Q_s. Shunt capacitance is next used to rotate the impedance along a constant admittance circle to achieve a maximum impedance of 13 ohms. The value of this shunt capacitance (C_1) is computed in Figure 4a to be 28.39 pF. Care should be taken when selecting the actual capacitors to account for the parasitic inductance of the capacitors.[1]

Table 2
Device Impedance Data

MFR 839

Freq.	Z_{in}	Z_{ol}*
806 MHz	3.1 + j4.0	9.6-j6.5
870 MHz	2.8 + j4.6	8.5-j5.6
960 MHz	1.9 + j5.4	8.1-j4.8

P_{out} = 3 Watts
V_{cc} = 12.5 Vdc
*Z_{ol} = Conjugate of Optimum Lead Impedance.

MRF 843
Series Equivalent
Input and Output Impedance

Freq. MHz	Z_{in} Ohms	Z_{ol} Ohms
800	1.23 + j6.14	1.98 + j2.62
870	2.09 + j5.91	2.24 + j3.49
960	2.58 + j5.46	2.51 +j3.92

NOTE: Circuit tuning and input power adjusted to maintain output power of 15W and 65% efficiency.

a.) $b_{c^1} = 1.65 \qquad X_{c^1} = \frac{1}{b_{c^1}} = .6061$ $\qquad W = 2\pi f_o = 5.8119 \times 10^9$ rad/sec

F_o =925 MHz
Z_o = 10 Ohms

$X_{c^1} = x \bullet Z = 6.061$ Ohm

$X_{c^1} = \frac{1}{WC^1} \qquad C^1 = \frac{1}{WX_{c^1}} = 28.39$ pF

b.) $b_{c_2} = 0.215 \qquad X_{c_2} = \frac{1}{b_{c_2}} = 4.65$ $\qquad W = 2\pi f_o = 5.8119 \times 10^9$ rad/sec

F_o = 925 MHz
Z_o = 10 ohms

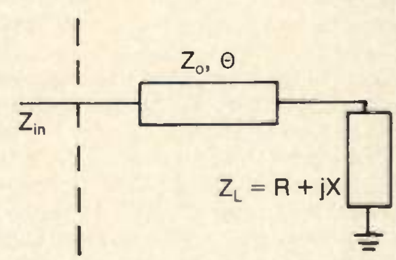
$X_{c_2} = x \bullet Z = 45.5$ Ohm

$X_{c_2} = \frac{1}{WC_2} \qquad C^2 = \frac{1}{WXC^2} = 3.69$ pF

c.) $$Z_{in} = Z_o \left[\frac{Z_L + j\,Z_o \tan\Theta}{Z_o + jZ_L \tan\Theta}\right]$$

$$Z_o = \sqrt{(Z_{in}\ R)1 - \frac{(X)^2}{R(Z_{in}\text{-}R1)}}$$

$$\Theta = \mathrm{Tan}^{-1}\ \frac{(Z_{in}\, Z_o - Z_oR)}{X\, Z_{in}}$$



For Z_{in} = 13 Ohm $\qquad Z_L = 23.0 + j\ 25.5$

Z_o = 33.8 Ohm Characteristic Impedance
$\Theta = 45.6°$ Electrical length

Figure 4

In an effort to hold the physical length of the transmission line to a minimum, a second shunt capacitance is next computed. This second shunt capacitance is located on the high impedance end of the transmission line. The actual value of this capacitance may vary within limits, since it is within the capacity of the transmission line to match a range of impedances. The larger the shunt capacitance the shorter the required transmission line. The maximum value of this capacitance is limited by the region of physically realizable transmission lines (1).

To maintain the bandwidth and performance of this circuit, the capacitance should rotate from a value of impedance with Q_s less than the device Q_s, to the load impedance.[2] For the example shown in Figure 3 the shunt capacitance (C_2) rotates from an impedance of 23.0 + j25.5 ohms along a constant admittance circle to 50 ohms. To accomplish this rotation a capacitance value of 3.69 pF is computed in Figure 4b (3.69 pF may seem like an odd capacitance until one computes the low frequency capacitance value to be 3 pF).

The transmission line used to match from 13 ohms to 23.0 + j25.5 ohms is next determined. The characteristic impedance and electrical length of the transmission line can readily be calculated. (1) As is shown in Figure 4c, to match between the two impedances a transmission line of characteristic impedance Z_0 = 33.8 ohms and electrical length Θ = 45.6° is used.

This Smith chart method is used to establish a midband impedance match that will maintain good performance at the band edges. Curves A and B in Figure 5 show the band edge mismatch to be less than 1.6:1 VSWR. The example shown only requires a single section of matching. If, however, a lower Q matching filter had been required, additional transmission line/shunt capacitor sections may have been needed.

The initial design of the amplifier described in this article was generated at a midband frequency of 925 MHz using the Smith chart design techniques described. This design was later computer analyzed and optimized. The final design presented in this article is the Smith chart design with only minor computer aided optimizations.

Circuit Construction

Care must be taken to properly prepare the printed circuit board before any components are mounted or soldered in place. Whenever transmission lines are meandered there exists a real danger that coupling between the lines and other components will lead to a potentially unstable circuit that will be difficult to tune. For this reason a good ground plane must be maintained to insure proper performance. The ground plane integrity is enhanced by two separate but related mechanisms. First, all the edges of the board are wrapped and soldered with copper foil. This edge wrapping eliminates the electrical separation between the topside ground surfaces and the bottom ground plane. The result is a unified ground plane throughout the circuit.

Second, after wrapping eyelets are installed at strategic points on the board to provide short ground paths for the shunt capacitors. This too serves to electrically connect the top and bottom ground surfaces[3] (see component placement diagram for eyelet placement). A final step to board preparation is to use copper foil to wrap the ground edges of the transistor mounting holes. This must be done to minimize the parasitic common lead inductance of the device and optimize the performance of the transistor.

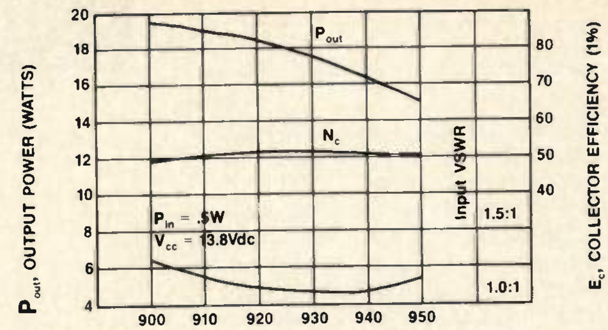
After the printed circuit board has been prepared circuit components are soldered in place. The component placement diagram shows the proper placement of all components. Slight lateral movement of the shunt capacitors, especially the shunt capacitors associated with the collector of the MRF843, is generally necessary to tune the circuit.

The final step to circuit construction is to provide a good heat sink for the transistor. The heat sink must be capable of maintaining a worst case junction temperature (T_{junc}) of less than 200°C (refer to the manufacturer's data sheets for specific thermal specifications on the individual transistors).

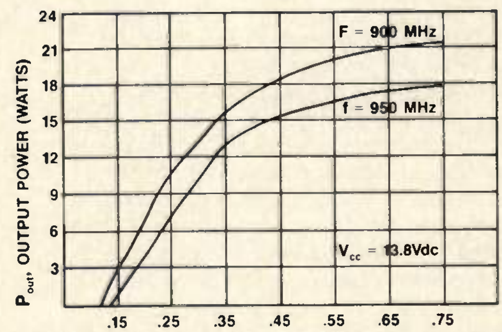
Circuit Performance

The circuit performance is shown in Figures 6-9. A comparison of this performance data to the design criteria given in Table 1 shows the amplifier to meet or exceed the desired specifications.

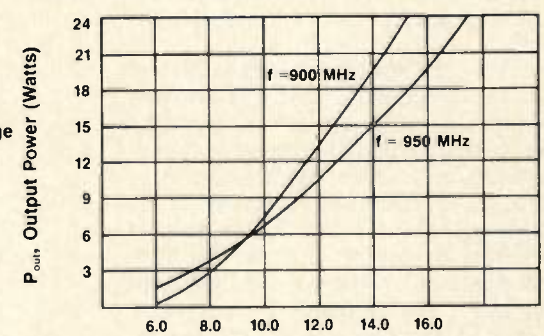
Figure 6 shows the efficiency across the band to be quite flat at about 50%. Also shown in Figure 6 is the input VSWR which is better than 1.3:1 across the band.



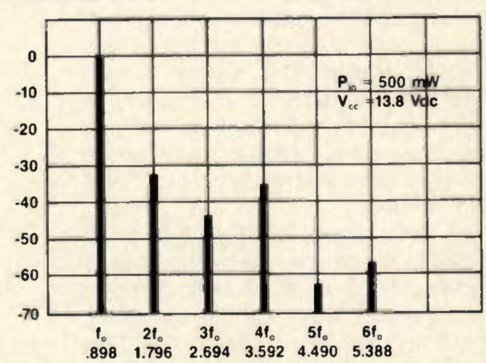
f, FREQUENCY (MHz)
TYPICAL PERFORMANCE
Figure 6



P_{in}, INPUT POWER (WATTS)
OUTPUT POWER VERSUS INPUT POWER
Figure 7



V_{cc}, Supply Voltage (Vdc)
Output Power Versus Supply Voltage
Figure 8



f, Frequency (GHz)
Output Spectrum
Figure 9

Footnotes

1 For a detailed explanation of effective capacitance see "Designing Transistor Test Fixtures For the 800 MHz Frequency Spectrum" by Dan Moline, *R.F. Design*, March/April issue, 1984.

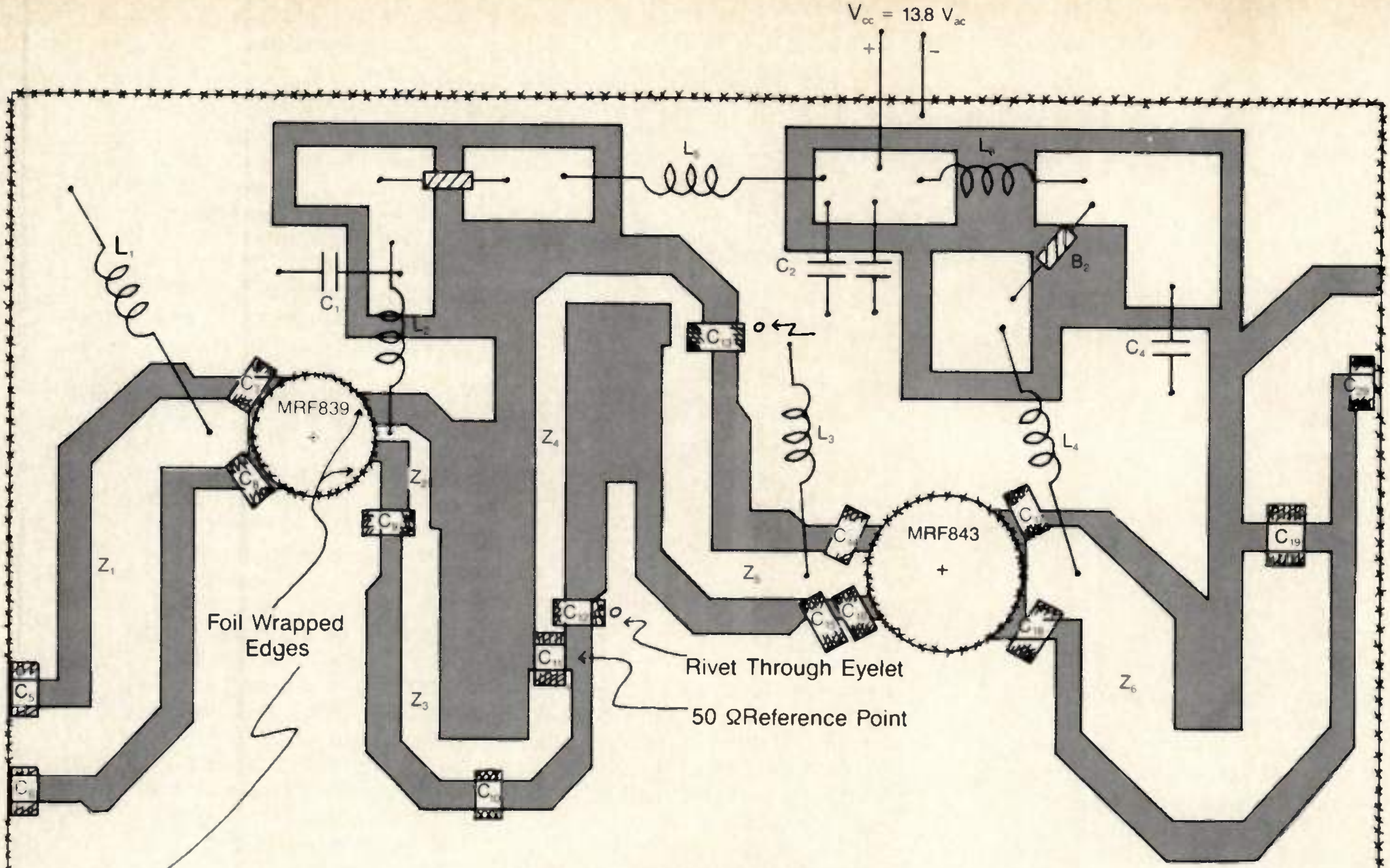
2 The design example presented herein is for maximum bandwidth ($Q_{transistor} = Q_{maximum}$). It should be noted however, that maximum bandwidth design is not always desirable and may be limited by other system requirements.

3 If available, edge plating and plated through holes are a preferred alternative to edge wrapping and eyelets.

References

1. Kurt P. Schwan, "Matching: When Is A Single Line Sufficient?", Microwaves December 1975.

David Miller is Applications Engineer for Land Mobile Products. He can be reached at Motorola, Inc., P.O. Box 2953, Phoenix, AZ 85062.



Component Placement Diagram

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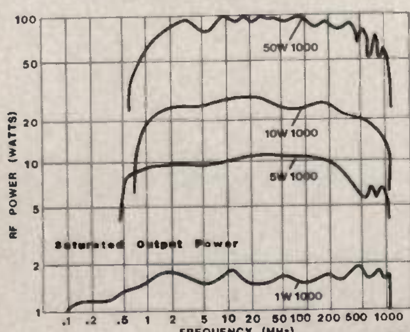

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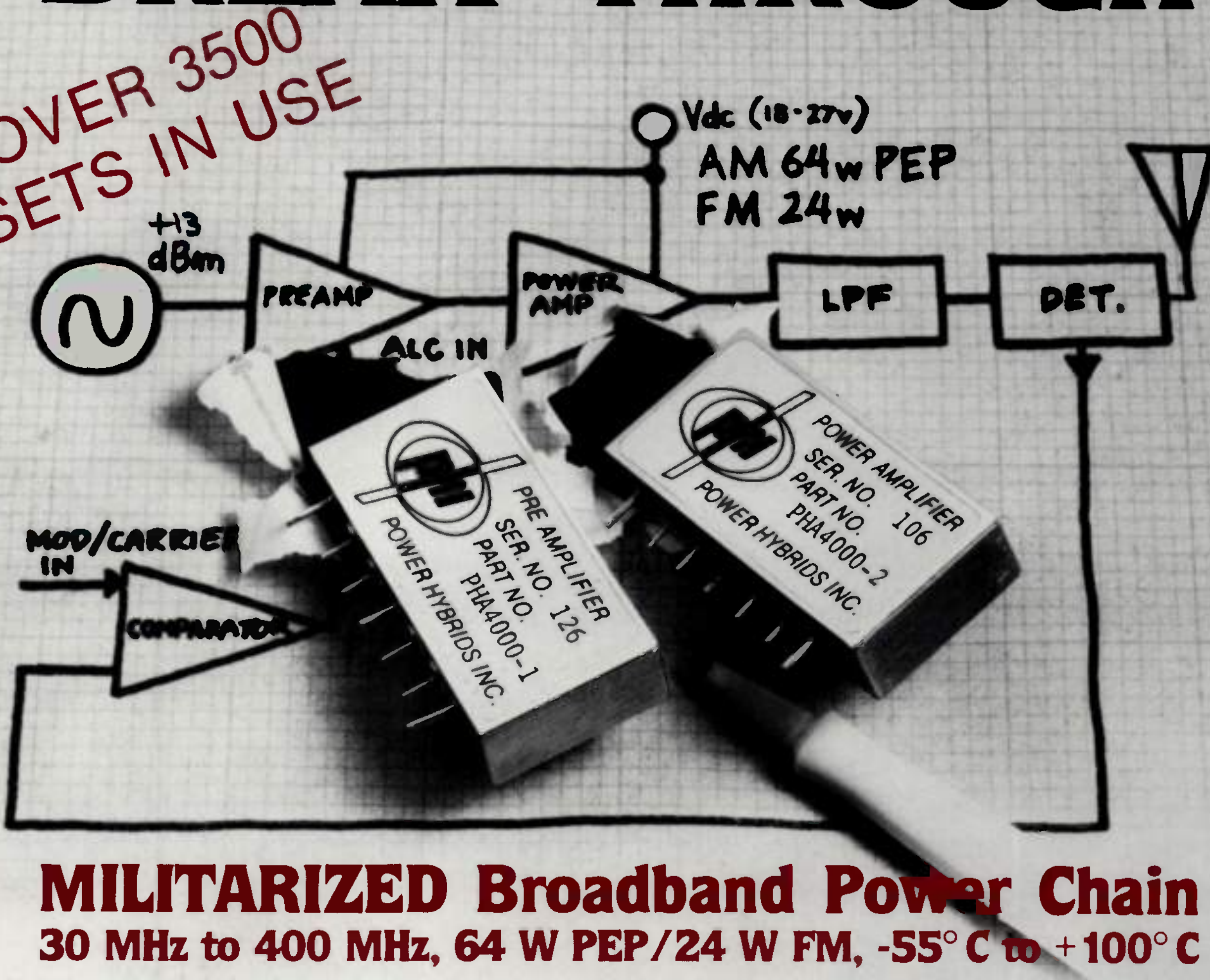

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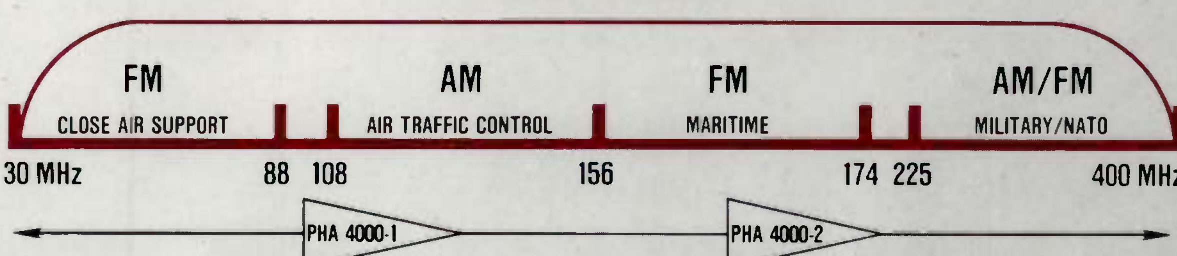

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In a standard 10 W airborne transceiver radio application, the PHA4000-1 and PHA4000-2 provide the needed design margin. The modules are series connected to amplify a +13 dBm signal to 24 watts CW/FM over the 30 to 88 MHz, 116 to 174 MHz and 225 to 400 MHz bands, and to 64 W PEP from 116 to 174 MHz, and 225 to 400 MHz.

The modules are constructed in hybrid format with the circuitry distributed among metalized ceramic carriers and interconnected with microstrip and coaxial transmission lines. Each module is constructed in a compact housing measuring 1" x 2⅛" x ½". DC and RF connections are made through hermetic feed-thru pins along the 2⅛" dimension. The PHA4000-1 utilizes a nickel plated aluminum package (30 grams) and the PHA4000-2 is housed in a nickel plated copper package (75 grams).

Each module is internally compensated for gain variation of the transistors over frequency through the use of amplitude equalization networks. In a typical radio transmitter system, gain of the pre-amplifier is adjusted through the automatic leveling control (ALC) input which can be programmed for flat gain across all bands. The ALC pin can also be used as a modulation input for AM transmission. Under this type of operation, an external envelope detector is used to sense the output envelope of the power amplifier, and supply a feedback signal to the ALC loop to linearize modulation. The units are capable of being modulated from DC to over 1 MHz which makes them useful for voice, data, or even video transmission.

The PHA4000-1 and PHA4000-2 are designed and tested to withstand a tactical military radio environment and will provide the specified performance from -55°C to +100°C.

Production testing is accomplished using a 3-bay computer controlled test console with full range high and low temperature test capability.

TABLE 1
AMPLIFIER SPECIFICATION

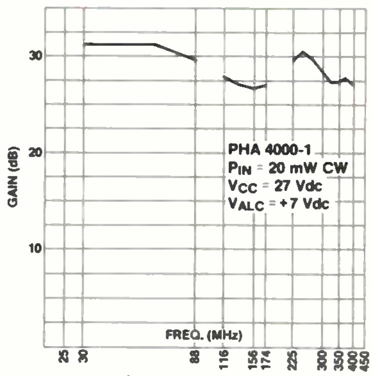
PARAMETER ELECTRICAL (TYPICAL)	PHA4000-1 (PREAMPLIFIER)	PHA4000-2 (POWER AMPLIFIER)
P_{IN}	20 mW (+13 dBm)	13 W (+41.1 dBm)
P_O	13 W (+41.1 dBm)	64 W (+48.1 dBm)
V_{CC}	+18 to +27 Vdc	+18 to +27 Vdc
V_{alc}	-4 to +10 Vdc	N/A
V_{bias}	N/A	5.1 V at 150 mA typ.
Gain Control Range	60 dB min.	N/A
VSWR (in)	3:1 max.	compatible with PHA4000-1
VSWR (load)	2.5:1 All phase	2.5:1 All phase
Gain Variation with Freq.	±3 dB	1.5 dB
Even Harmonics	-25 dBc typ.	-25 dBc min.
Odd Harmonics	-15 dBc typ.	-15 dBc typ.
Spurious Output	-80 dB min.	-80 dBc min.
P_{dc} ($V_{CC} \times I_C - P_O$)	N/A	39 W for P_{OUT} = 24 W

NOTE 1: Adequate heat sinking required.

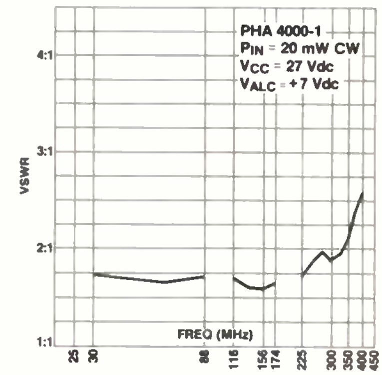
MECHANICAL		
Size	1" × 2⅛" × ½"	1" × 2⅛" × ½"
Weight	30 grams	75 grams
Housing	Ni plated Al	Ni plated Cu

TYPICAL AMPLIFIER PERFORMANCE CHARACTERISTICS

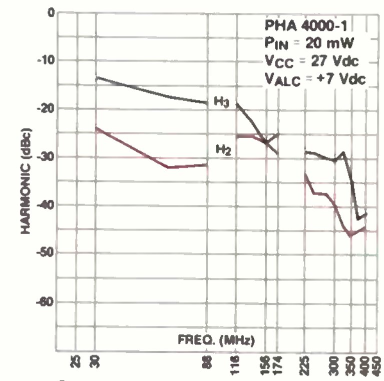
(25°C HOUSING UNLESS OTHERWISE SPECIFIED)



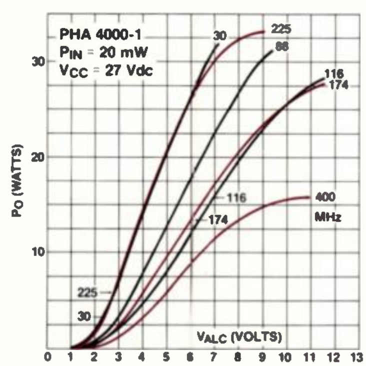
GAIN vs FREQUENCY



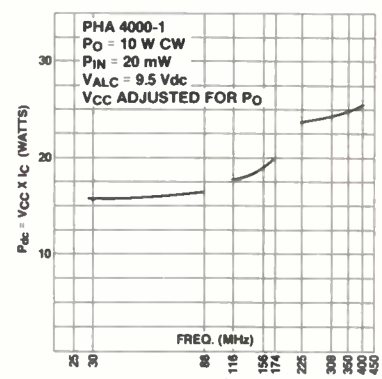
INPUT VSWR vs FREQUENCY



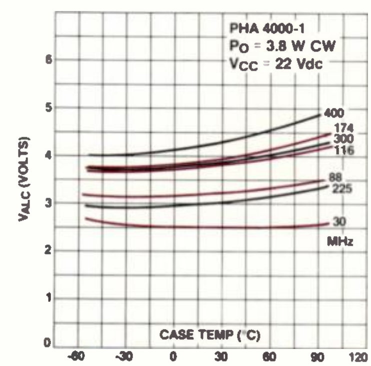
TYPICAL 2nd & 3rd HARMONIC vs FREQUENCY



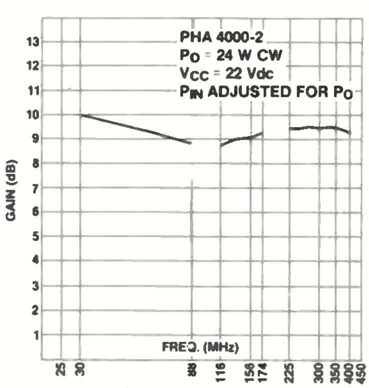
PO vs VALC & FREQUENCY
(See Note 1)



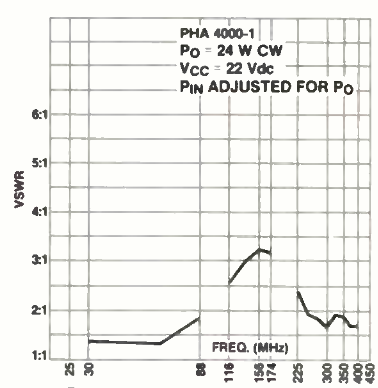
Pdc vs FREQUENCY



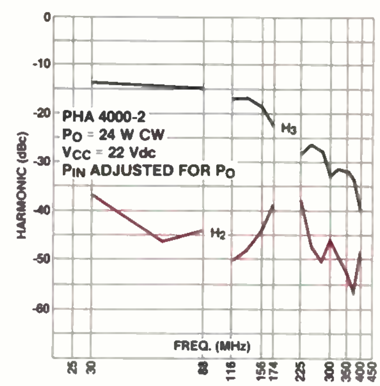
VALC vs TEMPERATURE & FREQUENCY



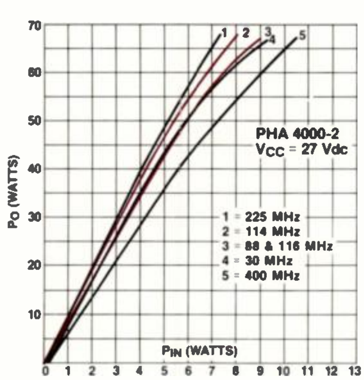
GAIN vs FREQUENCY



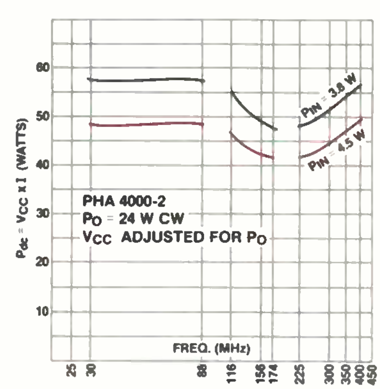
TYPICAL INPUT VSWR vs FREQUENCY



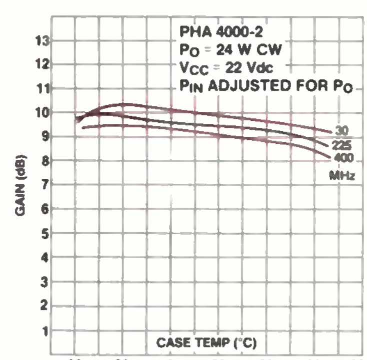
TYPICAL 2nd & 3rd HARMONIC vs FREQUENCY



POUT vs PIN & FREQUENCY
(See Note 1)



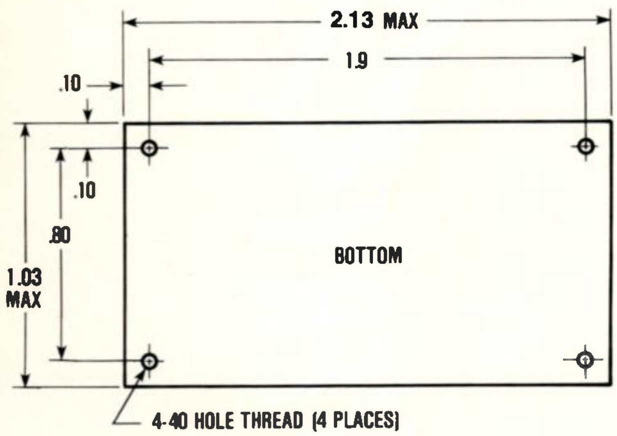
Pdc vs FREQUENCY & PIN
(See Note 1)



GAIN vs TEMPERATURE & FREQUENCY

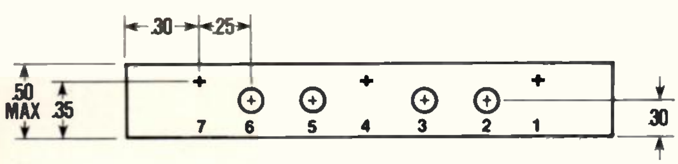
PHA 4000-1	PHA 4000-2
Aluminum Nickel Plate Mil C 26074B	Copper Nickel Plate MIL C 26074B
Overall Finish 63μ inch	Bottom Finish 50μ inch

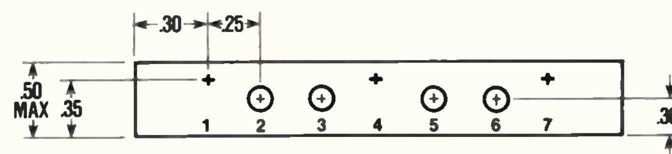
OUTLINE



PHI's COMPUTER CONTROLLED TEST CONSOLE

PRE ELECTRICAL	PRECONDITIONING	FINAL ELECTRICAL
15 Frequencies	Temp Cycle	15 Frequencies
Gain	200 Cycle	Gain
P_{OUT}	Mil 883-Method 1010	P_{OUT}
VSWR	Condition C	VSWR
2nd/3rd Harmonics		2nd/3rd Harmonic
Saturated Pout		Saturated P_{OUT}
2.5:1 All Phase VSWR		2.5:1 All Phase VSWR





Pre Amplifier (PHA 4000-1)

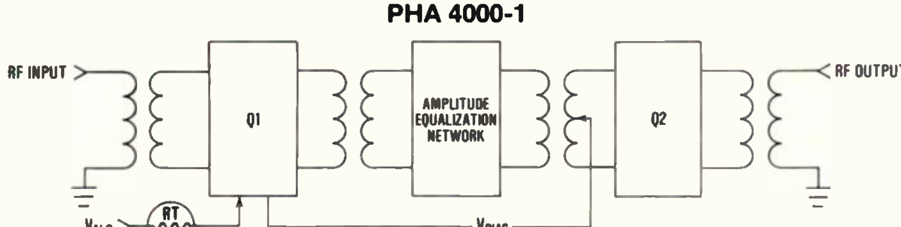
PIN(S)	Function	PIN(S)	Function
1,4,7	Ground	5	Vdc Input
2	RF Input	6	RF Output
3	V_{ALC} Input		

Power Amplifier (PHA 4000-2)

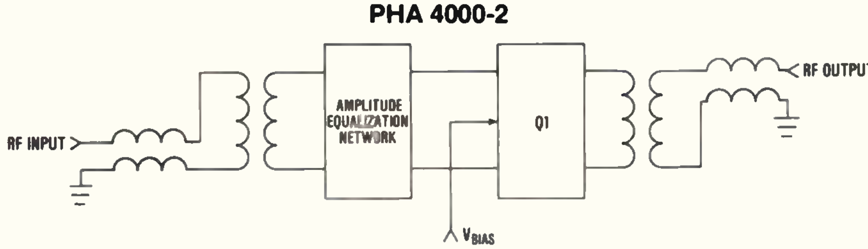
PIN(S)	Function	PIN(S)	Function
1,4,7	Ground	5	Vdc Input
2	RF Input	6	RF Output
3	V_{BIAS} (5.1 Volts)		

FUNCTIONAL DIAGRAM

PHA 4000-1



PHA 4000-2



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INFO/CARD 28

BASIC Program Computes Values For 14 Matching Networks

By Alan J. LaPenn

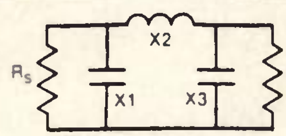
The ever increasing number of personal computers and their relatively low cost and portability makes them excellent tools for scientific calculations and model evaluations. The program that follows was intentionally kept simple and should run on any computer running the BASIC programming language. No special graphic routines have been used and all display formatting is implemented as standard BASIC print statements. There are no multiple statement lines and input prompting is provided by the use of print statements, since some BASIC interpreters do not support prompt strings imbedded in an input statement. All output is directed to the standard output device (video display). No facility has been provided to redirect output to a line printer or mass storage device such as a disk drive or cassette, since such techniques tend to be machine dependent and cause a loss of program portability.

The program has been run on the following computers without modification: Commodore Vic-20, Commodore 64, Texas Instruments TI99/4A, TRS80, Atari 400 and 800.

The program consists of 122 lines of code, including remark statements for documentation purposes. The 14 network values are calculated in eight separate subroutines. Seven of the subroutines calculate networks one, three, five seven, nine, 11, and 13. The eighth subroutine calculates the inverse values of the above mentioned networks, providing the remaining seven networks two, four, six, eight, 10, 12 and 14.

Program output is provided by a print subroutine located at line number 1200 and ending at line number 1470. User input is provided at the beginning of the program. After the network design is completed the user has the option of exiting the program or designing a new network.

Network #1
Lowpass
$R_S \leq R_L$

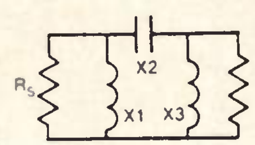


$$X1 = -R_S \sqrt{\frac{R_L/R_S}{Q^2 + 1 - (R_L/R_S)}}$$

$$X2 = \frac{Q\,R_L - (R_S\,R_L/X1)}{Q^2 + 1}$$

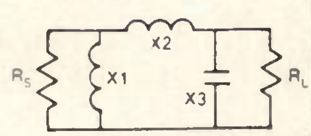
$$X3 = -\frac{R_L}{Q}$$

Network #2
Highpass
$R_S \leq R_L$



Highpass Values Are Negative Of Corresponding Lowpass Values

Network #3
Lowpass
$R_S < R_L$



$$X1 = \frac{R_S}{\sqrt{\frac{R_S\,(Q^2 + 1)}{R_L} - 1}}$$

$$X2 = \frac{R_L\,Q}{Q^2 + 1}\left(1 - \frac{R_S}{Q\,X1}\right)$$

$$X3 = -\frac{R_L}{Q}$$

There are two reasons for the use of subroutines to calculate network values and provide output. The use of subroutines reduces the number of lines of code significantly and allows the user to make personal modifications easily. Subroutines for mass storage, output to a line printer and graphics can be added to the print subroutine without having to change the rest of the program.

Use of the software is extremely simple, as the program prompts the user for all the input data required, performs the required calculations and displays the output data values. To run the program simply type "run" from the keyboard and press the enter or return key. The user will then be prompted to enter the following information:

Enter source resistance in ohms:

Enter load resistance in ohms:

Be sure to observe the restrictions concerning the size of the source resistance (RS) compared to the load resistance (RL). RS may be smaller than RL or equal to RL for some of the networks, but never larger than RL. If the user enters a value for RS that is greater than RL, the program will issue the following error message and the user will be prompted to enter RS and RL again:

RS must be less than or equal to RL.

At this point Qmin will be calculated by the program. Next, the user will be prompted for the desired frequency of operation.

Enter frequency in hertz for results in henries and farads or 0 for results in reactance values.

The user is then prompted for the network number to be designed.

Enter desired network (1-14):

Note that for some networks RS only can be less than RL and for other networks RS can be less than or equal to RL. If the user attempts to design a network that fails the above conditions the program will issue one of the following error messages.

RS must be less than or equal to RL for network XX

RS must be less than RL for network XX

where XX is the network number the user wished to design. The user then will be prompted to enter a new network number.

The program next displays the computed value of Qmin. If the network to be designed is not network 13 or 14, the user is given the option of specifying another value of Q. The following prompt will appear:

Enter desired value of Q (Q≥Qmin):

Note that the range of Q must be greater than or equal to the computed value of Qmin, but not less than Qmin. If the user enters a value of Q that is less than Qmin the program will issue the following error message and the user will be prompted for another value of Q.

Q must be greater than or equal to XX where XX is the current value of Qmin.

At this point the program will compute the required network elements and display them in the following format:

Source resistance = XX ohms
Load resistance = XX ohms
Qmin = XX

If Qmin is not equal to the value of Q the following will also be printed:

Q = XX

The network number that was designed will be displayed next.

Network number XX

If zero was entered for the frequency, the following will be printed:

For two element networks:
X1 = XX ohms
X2 = XX ohms

For three element networks:
X1 = XX ohms
X2 = XX ohms
X3 = XX ohms

(Note positive values are for inductive reactance and negative values are for capacitive reactance.)

Examples

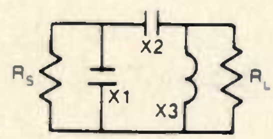
Design a matching network to transform a 50 ohm antenna output to 200 ohms to match an amplifier input at 75 MHz, with a required Q of 10.

(Note: user input is underlined and <cr> is the enter or return key on the computer.)

Enter source resistance in ohms:
? 50 <cr>
Enter load resistance in ohms:
? 200 <cr>
Enter frequency in hertz for results in henries and farads or 0 for results in reactance values:
? 75000000 <cr>
Enter desired network (1-14):
? 12 <cr>
Qmin =1.732050808
Enter desired value of Q (Q ≥ Qmin):
? 10 <cr>

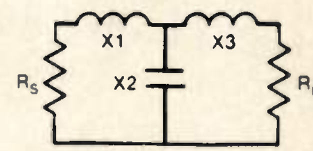
Source resistance = 50 ohms
Load resistance = 200 ohms

Network #4
Highpass
$R_S < R_L$



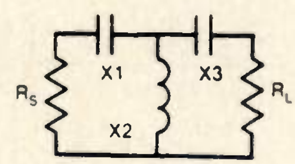
Highpass Values Are Negative Of Corresponding Lowpass Values

Network #5
Lowpass
$R_S \leq R_L$



$$X1 = R_S\,Q$$

Network #6
Highpass
$R_S \leq R_L$



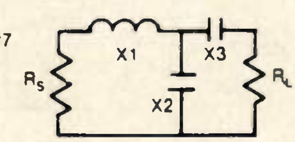
$$X2 = \frac{-R_S\,(1 + Q^2)}{Q + \sqrt{\frac{R_S\,(1 + Q)^2}{R_L} - 1}}$$

Highpass Values Are Negative Of Corresponding Lowpass Values

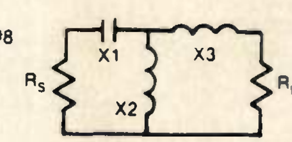
$$X3 = R_L\sqrt{\frac{R_S\,(1 + Q^2)}{R_L}}$$

Standard Tee Networks.

Network #7
Lowpass
$R_S < R_L$



Network #8
Highpass
$R_S < R_L$



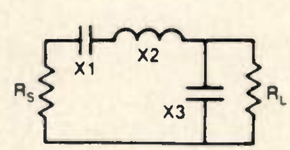
$$X1 = R_S \times Q$$

$$X2 = \frac{-R_S\,(1 + Q^2)}{Q - \sqrt{\frac{R_S\,(1 + Q^2)}{R_L} - 1}}$$

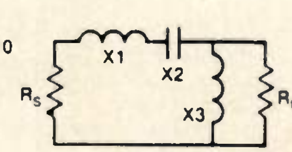
$$X3 = -R_L\sqrt{\frac{R_S\,(1 + Q^2)}{R_L} - 1}$$

Highpass Values Are Negative Of Corresponding Lowpass Values

Network #9
Lowpass
$R_S < R_L$



Network #10
Highpass
$R_S < R_L$



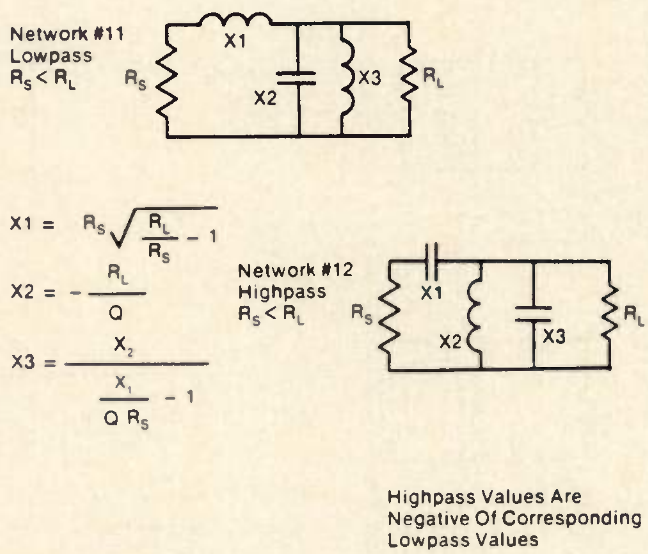
$$X1 = \sqrt{R_S R_L - R_S^2 - Q R_S}$$

$$X2 = Q\,R_S$$

$$X3 = \frac{-R_S\,R_L}{X1 + X2}$$

Highpass Values Are Negative Of Corresponding Lowpass Values

Series Enhanced -Q L Networks.

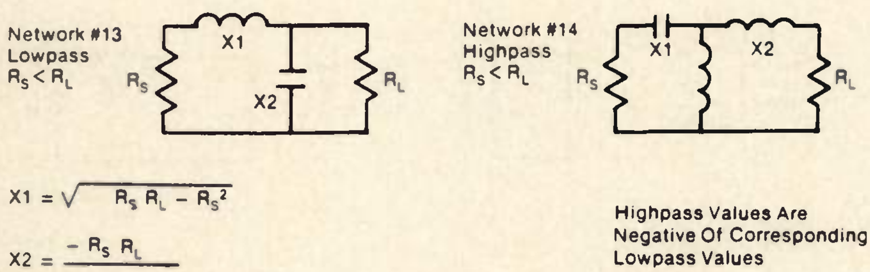


$$X1 = R_S\sqrt{\frac{R_L}{R_S} - 1}$$

$$X2 = -\frac{R_L}{Q}$$

$$X3 = \frac{X_2}{\frac{X_1}{Q\,R_S} - 1}$$

Shunt Enhanced - QL Networks



$$X1 = \sqrt{R_S R_L - R_S^2}$$

$$X2 = \frac{-R_S R_L}{X1}$$

Simple L Networks.

```
          Qmin  =  1.732050808
             Q  =  10
Network number     12
     Frequency  =  75000000
                   hertz
C1 = 2.4503506E-11 Farads
L2 = 4.2441318E-8 Henries
C3 = 8.7725667E-11 Farads
Enter 1 to run program again 0 to end:
? 0 <cr>
```

The following example is the same as the previous except that the frequency is set equal to zero and output values are in units of reactance.

```
Enter source resistance in ohms:
? 50 <cr>
Enter load resistance in ohms:
? 200 <cr>
Enter frequency in hertz for results in henries and farads or 0 for results in reactance values:
? 0 <cr>
Enter desired network (1-14):
? 12 <cr>
Qmin =1.732050808
Enter desired value of Q (Q ≥ Qmin):
? 10 <cr>
Source resistance     =50 ohms
Load resistance       =200 ohms
Qmin                  =1.732050808
Q                     =10
Network number         12
X1 = -86.60254038 ohms
X2 = 20 ohms
X3 = -24.18979548 ohms
Positive values for inductive reactance and negative values for capacitive reactance.
Enter 1 to run program again, 0 to end:
? 0 <cr>
```

Alan LaPenn can be contacted at 157 Saunders Hill Rd., New Boston, NH 03070.

```
10   rem Main program
20   print "Enter source resistance in ohms:"
30   input rs
40   print "Enter load resistance in ohms:"
50   input rl
52   if rs ≤ rl then 60
54    print "RS must be less than or equal to RL"
56   goto 20
60   qm = sqr (rl/rs-1)
70   print "Enter frequency in hertz for results in henries and
     farads or 0 for results in reactance values:"
80   input fo
90   print "Enter desired network (1-14):"
100  input net
105  print
110  print "Qmin ="; qm
112  print
115  q = qm
120   if net > 12 then 150
130  print "Enter desired value of Q (Q ≥ Qmin):"
140  input q
142  if q ≥ qm then 150
144  print "Q must be greater than or equal to "; qm
146  goto 130
150  on net gosub
     400,400,500,500,600,600,700,700,800,800,900,900,1000,1000
160  if fo = 0 then 300
170  on sgn (x1) + 1 goto 190,200
180  f1 = (1/(6.28*fo*x1) )*-1
190  goto 210
200  f1 = x1/(6.28*fo)
210  on sgn(x2)+ 1 goto 230,240
```

```
220 f2 = (1/(6.28*fo*x2) )*-1
230 goto 250
240 f2 = x2/(6.28*fo)
250 if net > 12 then 300
260 on sgn (x3) + 1 goto 280,290
270 f3 = (1/(6.28*fo*x2) )*-1
280 goto 300
290 f3 = x3/(6.28*fo)
300 gosub 1200
305 print
310 print "Enter 1 to run program again 0 to end:"
320 input d
330 if d = 1 then 20
340 end
400 rem net1 rs≤ rl
410 x1 = rs*(sqr ( (rl/rs)/(q∧2 + 1-(rl/rs) ) )* -1
420 x2 = (q*rl-(rs*rl/x1) ) / (q∧2 + 1)
430 x3 = (rl/q)*-1
440 if net = 1 then 460
450 gosub 1100
460 return
500 rem net3 rs<rl
510 x1 = rs/(sqr( (rs*(q∧2 + 1) ) / rl-1) )
520 x2 = ( (rl*q) / (q∧2 + 1) ) * (1-(rs / (q*x1) ) )
530 x3 = (rl / q)*-1
540 if net = 3 then 560
550 gosub 1100
560 return
600 rem net5 rs ≤ rl
610 x1 = rs*q
620 x2 = (rs* (1 + q∧2) * -1) / (q + sqr( (rs* (1 + q∧2) ) / rl-1) )
630 x3 = rl*sqr ( (rs* (1 + q∧2) ) / rl-1)
640 if net = 5 then 660
650 gosub 1100
660 return
700 rem net7 rs < rl
710 x1 = rs*q
720 x2 = (rs* (1 + q∧2) *-1) / (q-sqr ( (rs*(1 + q∧2) ) / rl-1) )
730 x3 = rl*sqr ( (rs* (1 + q∧2) ) / rl-1) *-1
740 if net = 7 then 760
750 gosub 1100
760 return
800 rem net9 rs < rl
810 x1 = sqr (rs*rl - rs∧2-q*rs)
820 x2 = q*rs
830 x3 = (rs*rl*-1) / (x1 + x2)
840 if net = 9 then 860
850 gosub 1100
860 return
900 rem net11 rs < rl
910 x1 = rs*sqr (rl / rs-1)
920 x2 = rl / q*-1
930 x3 = x2 / (x1 / (q*rs)-1)
940 if net = 11 then 960
950 gosub 1100
960 return
1000 rem net13
1010 x1 = sqr (rs*rl-rs∧2)
1020 x2 = (rs*rl*-1) / x1
1030 if net = 13 then 1050
1040 gosub 1100
1050 return
1100 rem inverse subroutine
1110 x1 = x1*-1
1120 x2 = x2*-1
1130 if net = 14 then 1150
1140 x3 = x3*-1
1150 return
1200 rem print routine
1204 print
1206 print
1210 print "Source resistance = "; rs; "ohms"
1220 print "Load resistance = "; rl; "ohms"
1230 Print "Qmin = "; qm
1240 if qm = q then 1270
1250 print "Q = "; q
1270 print "Network number"; net
1280 if fo <> 0 then 1340
1300 print "X1 = "; x1; "ohms"
1310 print "X2 = "; x2; "ohms"
1315 if net > 12 then 1330
1320 print "X3 = "; x3; "ohms"
1324 print
1326 print "Positive values for inductive reactance and negative
     values for capacitive reactance."
1330 return
1340 print "Frequency = "; fo; "hertz"
1345 on sgn (x1) + 1 goto 1360,1370
1350 print "C1 = "; f1; "farads"
1360 goto 1380
1370 print "L1 = "; f1; "henries"
1380 on sgn (x2) + 1 goto 1400,1410
1390 print "C2 = "; f2; "farads"
1400 goto 1420
1410 print "L2 = "; f2; "henries"
1420 if net > 12 then 1470
1430 on sgn (x3) + 1 goto 1450,1460
1440 print "C3 = "; f3; "farads"
1450 goto 1470
1460 print "L3 = "; f3; "henries"
1470 return
```

Errata:

The article, "The Phase/Frequency Detector," in the February 1985 issue contained several important typographical errors. The following equations are correct:

$$(1)\quad f^*(t) = \sum_{n=0}^{n=\infty} f(t)\,\delta\,(t-nT)$$

$$(4)\quad F(s) = \sum_{n=0}^{n=\infty} \int_{0}^{\infty} f(t)\,\delta\,(t-nT)\exp(-sT)\,dt$$

$$(5)\quad F^*(s) = \sum_{n=0}^{n=\infty} f(nT)\exp(-nsT)$$

$$(12)\quad E^*(s) = \frac{\sum_{n=-\infty}^{n=\infty} \Phi r(s - j\,n\,Ws) / T}{1 + HG^*(s)}$$

(16)-(20) R1 should be RL

Determining Receiver Performance With a Computer Spreadsheet

By Gregory R. Quinn
HRB Singer

Spreadsheets are software programs that transform a computer's memory into a large worksheet made up of columns and rows. Each separate location on this worksheet is called a cell. Into these cells the user can insert values, labels or formulas instructing the computer to perform calculations. According to the user's commands, the program will recalculate any results based on new or modified data entered.

The main advantage with such a program is the ability to alter data or formulas to explore the possibilities of a particular set-up. All spreadsheets available have commands similar to those in BASIC that allow the cells to be programmed in a variety of ways to calculate answers from data found on the spreadsheet. The user can program a cell in much the same way that he or she can write out the formulas by hand.

Logical decisions within the cells are controlled by IF statements. These commands are supplemented by math functions which will operate on specified ranges of numbers, such a SUM, MAX, MIN and AVERAGE. In this application, the most complicated structures used are IF and SUM.

Two programs are mentioned: VisiCalc and SuperCalc. The information presented for the spreadsheet cells should work without alteration in either program. In fact, the set-up shown should not need any changes to work on the majority of spreadsheets available for different computers.

Electronic worksheets or spreadsheets are ingenious software tools for personal computers. These packages allow the user to make redundant calculations and "what if?" speculations very quickly once a model has been formulated. Because of their flexibility electronic spreadsheets have applications in fields other

A1	P = "NAME	A12	P = "T GAIN
A2	P = "IIP2	A13	P = "BW (MHz)
A3	P = "IIP3	A14	P = "DR2
A4	P = "COMP PT	A15	P = "DR3
A5	P = "GAIN	A16	P = "IN N FLR
A6	P = "NF	A17	P = "OUT N FLR
A7	P = "CIIP2	B1	P = "INITIAL
A8	P = "CIIP3	B6	P = 0
A9	P = "CCMP PT	B7	P = 100
A10	P = "CNF	B8	P = 100
A11	P = "TAKEOVER	B9	P = 100

All of the cell contents listed above are in protected cells.

C1 TR B13, C2-6 $

These cells are for the data describing each part of the system and they are formatted for two decimal places.

```
C7   $TR =IF(C2=0,NA,+C2-20*LOG10 (1+SQRT (10^(.1*(C2+C5-B7)))))
C8   $TR=IF(COUNT(C3)=0,NA,+C3-10*LOG10 (1+(10^(.1*(C3+C5-B8)))))
C9   $TR=IF(COUNT(C4)=0, NA, +C4-10*LOG10 (1+(10^(.1*(C4+C5-B9)))))
C10  $TR=IF(COUNT(C6)=0, NA, +C6+10*LOG10 (1+(((10^(B10/10))-1)/((10^
     (C6/10))*(10 ^(C5/10))))))
C11  $TR =IF(AND(COUNT (C2:C6)>0, COUNT(D2:D6)=0), +C10-B10+C5, NA)
```

The variables in all of the above formulas are relative.

```
C12  $TR=IF(AND(COUNT(C2:C6) >0,COUNT(D2:D6)=0), SUM (B5:C5), NA)
C14  $TR =IF(AND(COUNT (C2:C6) >0, COUNT(D2:D6)=0), .5*(C7 +114-10*
     LOG10 (B13)-C10), NA)
C15  $TR =IF(AND(COUNT (C2:C6) >0, COUNT(D2:D6)=0),.67*(C8 + 114-10*
     LOG10 (B13)-C10), NA)
C16  $TR =IF(AND(COUNT(C2:C6) >0, COUNT(D2:D6)=0),-114 +10*LOG10
     (B13), NA)
```

In these formulas, all the variables are relative except for B5 and B13, which are constant.

```
C17  $TR =IF (AND (COUNT (C2:C6) >0, COUNT (D2:D6) =0), C16+C10+C12, NA)
```

All the variables in this formula are relative.

Table 1

than business and finance. For example, they can be used to calculate receiver performance, one of the most tedious chores in designing receivers.

A worksheet set-up for this purpose was designed with SuperCalc (version 1.12) on an Osborne 1. Differences between SuperCalc and other worksheet packages are so minor that the contents of this worksheet could be adapted easily to the others. This article assumes that the prospective user has a working knowledge of computer worksheets and of basic receiver design.

This worksheet accepts the following data about each module of the string:
1) A short label to identify each module
2) The second order input intercept point of the module
3) The third order input intercept point of the module
4) The 1 dB compression point of the module
5) The module gain
6) The module noise figure
7) The system operating bandwidth.

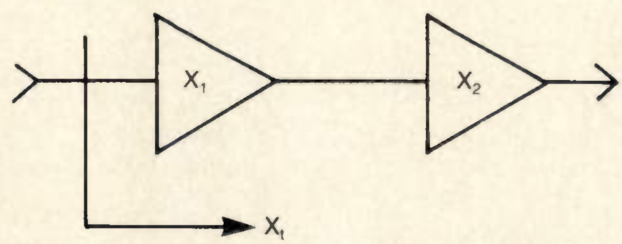
Given these inputs, the following system characteristics are calculated:
1) Cascaded second-order input intercept point
2) Cascaded third-order input intercept point
3) Cascaded 1 dB compression point
4) Cascaded noise figure
5) The noise takeover factor of the first element of the string
6) Total gain
7) Second order spurious-free dynamic range
8) Third order spurious-free dynamic range
9) Input noise floor
10) Output noise floor.

In the first six rows of the worksheet are cells that hold the necessary information to make receiver system calculations. A specific characteristic may be omitted, e.g. the second-order input intercept point, but if a characteristic is unused, all modules must have a nil ("blank" but not zero) value in that cell. Otherwise, an error in recalculation will occur. Where certain calculations are either meaningless or not possible an "N/A" appears. The worksheet also detects the first element of the string (last column of the worksheet) and stops calculating values at that point.

Worksheets generally calculate from left to right and from top to bottom. Therefore, the string of the receiver modules must be entered in reverse order on the worksheet, so the last module will appear first as one reads the worksheet from left to right.

A	B	C	D	E	F	G
1:NAME	INITIAL	Spltr	Pad	Mixer	Fltr	Amp
2:IIP2		100.00	100.00	8.00	100.00	28.00
3:IIP3		100.00	100.00	10.00	100.00	15.00
4:COMP PT		100.00	100.00	.00	100.00	15.00
5:GAIN		-3.00	-9.00	-6.00	-.50	15.00
6:NF	0	3.00	9.00	6.00	.50	
7:CIIP2	100	95.35	95.89	8.00	8.50	-6.66
8:CIIP3	100	98.24	99.25	10.00	10.50	-4.55
9:CCMP PT	100	98.24	99.25	.00	.50	-14.50
10:CNF		3.00	12.00	18.00	18.50	8.24
11:Takeover		N/A	N/A	N/A	N/A	4.74
12:T GAIN		N/A	N/A	N/A	N/A	-3.50
13:BW (MHz)	100.00					
14:DR2		N/A	N/A	N/A	N/A	39.55
15:DR3		N/A	N/A	N/A	N/A	54.41
16:IN N FLR		N/A	N/A	N/A	N/A	-94.00
17:OUT NFLR		N/A	N/A	N/A	N/A	-89.26

Table 2 — Sample Spreadsheet



$I_t = I_1 - 20\log[1+\sqrt{i_1 g_1/i_2}]$
Cascaded Second Order Input Intercept Point

$I_t = I_1 - 10\log[1+i_1 g_1/i_2]$
Cascaded Third Order Input Intercept Point

$CP_t = CP_1 - 10\log[1+g_1 cp_1/cp_2]$
Cascaded Compression Points

$F_t = F_1 + 10\log[1+(f_2-1)/(f_1 g_1)]$
Cascaded Noise Figure

$DR_2 = .5[IIP_2 + 174 - 10\log BW - NF]$
Second Order Spurious Free Dynamic Range (Bandwidth in Hz)

$DR_3 = .67[IIP_3 + 174 - 10\log BW - NF]$
Third Order Spurious Free Dynamic Range (Bandwidth in Hz)

$\text{Takeover} = NF_t - NF_{\text{system less 1st stage}} + G_1$
Noise Figure Takeover

("g" is the numeric ratio for gain. All other lower case variables are expressed in units of milliwatts and all upper case variables are expressed in units of dB or dBm.)

Table 3

CALL FOR PAPERS

RF TECHNOLOGY EXPO 86

January 30-February 1
Hilton Hotel and Towers
Anaheim, Calif.

Proposals are now being accepted for papers to be presented at the second annual RF TECHNOLOGY EXPO, the conference and exhibit for RF engineers sponsored by *RF Design* magazine. More than 60 papers are needed for the 3-day event. Presenters will receive free conference registration and a copy of the Proceedings.

Papers dealing with practical, design-oriented information are preferred. They can be instructional, aimed at new RF engineers and those working in unfamiliar fields, or more advanced analysis for senior engineers. Descriptions of new commercial products are acceptable if the presentation features a new design concept or a significant development of general interest. All papers should be about 30 to 40 minutes in length.

Suggested topics include, but are not limited to, RF circuit design, design techniques, components, computer aided design, EMC/EMI, digital interfacing, component mounting, antennas and testing.

Hurry to submit your proposal for a paper in outline form to James MacDonald, Editor of *RF Design*. The proposal should be stated in one page and should specify what audio-visual aids and working materials would be needed for presentation.

Your proposal must be received by July 26, 1985. Selection of speakers and papers will be announced by August 30.

James MacDonald *R.F. Design*

6530 S. Yosemite St. Englewood, CO 80111

Certain conditions must exist to initialize the calculations. An ideal noise figure, intercept point and compression point must appear at the receiver output. Column B holds these initializing conditions. A system performance bandwidth must be supplied by the user. This value is inserted into cell B13. Errors will occur if the system bandwidth is not supplied.

Because of the Osborne 1's screen size limitations, abbreviations are used here for each row name. These abbreviations are: IIP2: Second-order input intercept point in dBm; IIP3: Third-order input intercept point in dBm; COMPT PT: 1 dB compression point in dBm; GAIN: Module gain in dB; NF: Noise figure in dB; CIIP2: Cascaded second-order input intercept point in dBm; CIIP3: Cascaded third-order input intercept point in dBm; CCMP PT: Cascaded 1 dB compression point in dBm; CNF: Cascaded noise figure in dB; TAKEOVER: A dimensionless factor by which the first element of the string determines noise figure. (Values of 7 or more mean that the first element greatly determines system noise figure); T GAIN: The total gain of the system in dB; BW (MHz): The second system operating bandwidth in MHz; DR2: The second-order dynamic range in dB; DR3: The third-order dynamic range in dB; IN N FLR: Input noise floor of the system in dBm; OUT N FLR: Output noise floor of the system in dBm.

When devices such as attenuators, isolators or other passive elements appear in the string, their high intercept and compression points are approximated best by the value 100, unless it has been determined that the characteristic is not infinitely high and that there is some real limit less than 100 dB. Values higher than 100 in this application seem to cause software problems and inaccuracies.

The cascaded intercept points, noise figure and compression points are displayed on the worksheet for every module. This way modules contributing to poor system performance can be identified quickly.

Formulas and cell formats are given in Table 1. The formulas and formats in column C, once entered, are replicated to as many columns as the user needs. Whether variables in the formulas are relative or constant is shown in Table 1. A boiler plate file of 25 elements was made to eliminate replicating each formula in a new spreadsheet whenever a receiver is to be analyzed.

An example of a completed analysis is given for the user to check his setup (Table 2). A format that has only two places past the decimal was used. For those desiring greater accuracy, the format can be changed to suit particular applications.

The advantage of worksheets is that they permit data and values to be changed simply and quickly. Although calculators relieve some of the burden in analyzing receivers, worksheets greatly speed up the iterative process that is invariably required in receiver analysis.

In SuperCalc the default format is left justification for text and right justification for numerics.

Gregory Quinn is an RF engineer at HRB Singer, a defense electronic contractor, in State College, Pennsylvania. Address correspondence to Mr. Quinn at HRB Singer, Dept. 118, P.O. Box 60, State College, PA 16804.

Digital Signal Processing: The Digital Processor

By Thomas Callaghan
Watkins-Johnson Company

A digital processor refers to any form of hardware and/or software that has been built and/or programmed to perform signal processing algorithms on the data output from the sampler/quantizer. This definition encompasses a broad range of computing power. For the purposes of this article, we will concentrate on those processor architectures that lend themselves to signal processing and on the basic structures used in determining the processor(s) configuration.

Basically a digital processor should be modular in design; i.e., the processor, by itself, is capable of such rudimentary tasks as addition, subtraction, multiplication, memory transfers, and I/O transfers. Additional support, such as direct interface to A/D and D/A converters and the capability of working with blocks of data, would also be helpful. Although it is not expected to have all of these capabilities, the processor should still perform whatever capabilities it does have without outside support. In this way, when a simple task needs to be executed, only one module is used. As the task becomes more complicated, processor modules can be added to handle the extra load. Indeed, most applications in signal processing lend themselves readily to this modularity. Each application can be broken down into several smaller algorithms that can be further decomposed into simpler tasks.

Multiple processors can be implemented using two basic approaches, a parallel structure or a sequential structure. A parallel structure is defined by Tewksbury, et al,[1] as being the concurrent execution of several functional operations using a number of distinct functional modules under the coordination of a common control structure. A sequential structure, on the other hand, sequentially executes all the functional operations of the algorithm in a single functional module. One could go on to say that a sequential structure could have several modules, but one module cannot begin processing until the one preceding it is finished.

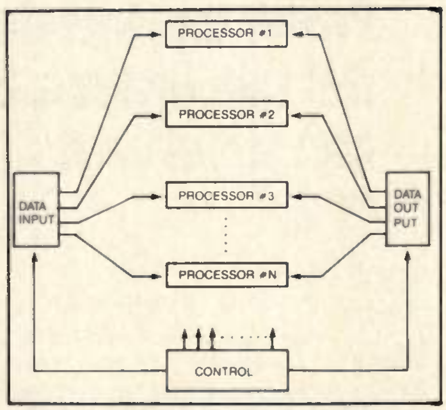


Figure 1. Parallel Processor Structure

Parallel Structures

A parallel structure is shown in Figure 1. Each processor receives its data from a shared input source. Each processor then sends its processed data to a shared output. Using this type of structure, the functional operation speed can be increased by dividing the data processing over a greater number of processing modules. However, there is a point of diminishing returns for additional processors due to the increased complexity of the control structure.

Another advantage of a parallel structure is that each processor module can be composed of an efficient functional unit with limited capabilities. This does, however, deviate from the strict definition of modularity and allows fewer common tasks, such as multiplication, to be handled by processors especially designed for the functional task. Other general purpose processors can then handle some of the more common tasks; i.e., overflow detection, or be reprogrammed to handle different tasks. In this way overall data processing speed can be increased for the structure by allowing each processor to handle the tasks for which it is best suited.

One of the disadvantages of parallel structures is that their control structures can be quite complex. Since each module is operating at a different throughput, timing of all the functions becomes another critical area. For both of these reasons, hardware design and, consequently, programming become difficult.

Sequential Structures

A sequential processor is shown in Figure 2. The first processor in the sequence receives the incoming data. The first processor performs its assigned tasks on the data and passes along this new data to the next stage. The process continues as each processor performs its specific tasks until the final data output is reached. It is not necessary that each processor work on all the incoming data. It could just pass some of the data through to the next stage. The next stage's

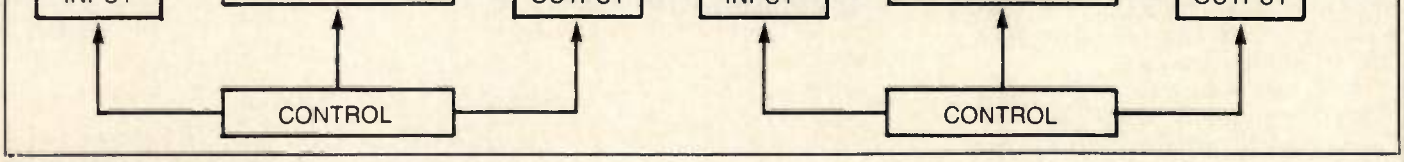


Figure 2. Sequential Processor Structure

processor, however, would wait until it received all of the data from the previous stage before it started processing.

The added delay caused by each stage waiting for the previous stage to finish processing is one of the sequential structure's disadvantages. This same delay also produces one of the advantages; it simplifies controller design. The controller does not have to keep track of data that is earmarked for a particular stage. At each stage, all of the data is passed along at once. A simpler controller allows more efficient, more straightforward hardware designs. Consequently, sequential structures are easier to program.

Parallel vs Sequential

Ultimately, the choice between parallel or sequential structuring depends greatly on how well a particular signal processing algorithm lends itself to one or the other. Indeed, some algorithms may incorporate both. Another design consideration would involve a trade-off of hardware/software cost and complexity to that of speed. If speed is not a prime consideration, the less expensive, easier hardware designs of the sequential processor would be preferred.

Information Extraction

The final end product of any form of signal processing, analog or digital, is the extraction of information from the input signal. The information can be a breakdown of the signal into its frequency components for signal analysis. The information could also be the altering of the signal's spectrum, as in filtering. It can be the intelligence content of the signal, as in detection. Whatever the reason for signal processing, the end product is as varied as the system designers who try to make use of it.

Why Use DSP

The number one force driving the push into DSP is cost. Using Fast Fourier Transform (FFT), signal analysis can now be performed at a substantially lower cost than that encountered using swept banks of analog filters. Once digitized, the power of analysis begins. Algorithms are being developed that can determine the type of modulation being used, phase detection, direction finding and digital demodulation.

The number one force preventing the acceptance of DSP is also cost. The cost of a couple of op-amps, some resistors and capacitors for a simple two pole active analog filter is only a few dollars, compared to a few hundred dollars for digital multipliers, memories and support processing for a digital filter. Of course, if the processor can be time-shared among many modules, the cost factor depreciates. For one two-pole filter, there is a big difference in cost; for a hundred two-pole filters, the analog version increases one hundred fold, whereas the digital increase is negligible. The digital version uses the same hardware plus a few other components to multiplex the data and processor.

Another consideration in DSP is the stability of digital parts. Once coefficients are computed for a filter, they will not drift over time nor change with temperature. This allows sharp cutoffs in filters to be realized using digital processing. Furthermore, provided the hardware is set up properly, a simple change in software will turn an FFT unit into a bandpass IIR filter. Another change will result in a lowpass filter. Thus, digital components are very versatile.

Perhaps the greatest advantage of DSP is performance. A digital signal monitor can achieve a much finer resolution at a faster scan rate than an analog version. The cutoff frequency of filters can be more precisely tuned and show a steeper roll-off than analog filters.

Finally, many communications are being done in a digital format, for example, T1 standards of the Bell system. With this digital format, analog signal processing becomes the expensive option.

References

1. S.K. Tewksbury, R.B., Kieburtz, J.S. Thompson, and S.P. Verma, "Tutorials on Signal Processing for Communications, Part II, Digital Signal Processing Architecture," *IEEE Communications Society* Magazine, January 1978.

Tom Callaghan is Head of Digital Processing at Watkins-Johnson Company, 700 Quince Orchard Road, Gaithersburg, MD 20878.

Line Impedance Stabilization Networks: Theory and Use

By Mark Nave

The use of Line Impedance Stabilization Networks (LISNs) to measure the effects of filters on conducted emissions (CE) is specified in most major specs, including FCC, VDE, CISPR, MIL-STD-461 and others. While real-life conducted emissions measurements and filter performance may vary considerably from test conditions, some common reference and testing standard is necessary. LISNs allow test facilities to obtain results with greater consistency and repeatability. This article discusses methods for analyzing common-mode and differential-mode noise and examines the effects of the LISN on CE measurements.

Conducted emissions are an important, but often misconceived electromagnetic interference (EMI) phenomenon. In addition to conducted interference, power leads can act as unintentional antennas, radiating due to CE or receiving noise from the electrical ambient. Proper filtering of the leads to and from the equipment is essential to control this phenomenon. A filter's effectiveness is dependent on an impedance mismatch to both the power source (power mains) and load impedances. Figure 1 shows the statistical distribution of mains impedance with its approximate 40 dB variation. Also depicted is the variation of impedance with frequency and the ~ 50 Ω centroid behavior of the mean.

Noise Types

There are three basic noise types present on power buses: Differential Mode (DM) and Common Mode (CM) Types I and II. Differential-mode noise is the simplest kind of noise. It occurs between the leads of the intentional current path (phase-neutral or phase-phase).

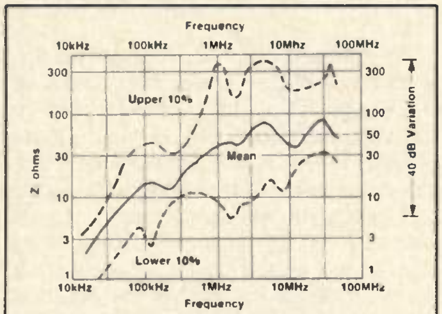


Figure 1. Absolute Mains Impedance (CM or DM) of Power Networks

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Typical sources of differential-mode noise are switching transients and motors.

Common-mode Type I noise occurs when the noise source is between safety ground and the phases, including neutral. Common-mode Type II noise occurs when the noise source is between earth ground and all phases, including neutral, and safety ground wire.

Measurement Variation

Figure 1 illustrates the approximate 40 dB variation of the mains impedance, which can result in up to a 40 dB variation in the measured value of the CE. This effect can be understood by analyzing the interaction of the bus and the source under the assumption that the noise frequency is in the constant (50 Ω) region. Let the bus impedance (Z_b) vary by a ratio, χ, $0.1<\chi<10$, so that $Z_b=\chi 50\Omega$. The measured voltage, V_m, is the result of voltage division across the internal impedance of the source, Z', and the bus impedance, Z_b. The expected measured voltage ($\chi=1$) is:

$$V_m = \frac{50}{50 + Z'}$$

The voltage measured under varying bus impedance ($\chi \neq 1$) is:

$$V'_m = \frac{\chi 50}{\chi 50 + Z'}$$

The normalized variation of the measured voltage then becomes:

$$\frac{V'_m}{V_m} = \frac{\chi 50 + \chi Z'}{\chi 50 + Z'}$$

For a low impedance noise source, as Z' becomes small with respect to 50 Ω, the normalized variation approaches unity. This means that the varying bus impedance has little effect on the measured voltage. However, for a high impedance source, as Z' becomes large with respect

CONCEPTUAL DIAGRAMS OF LISN's

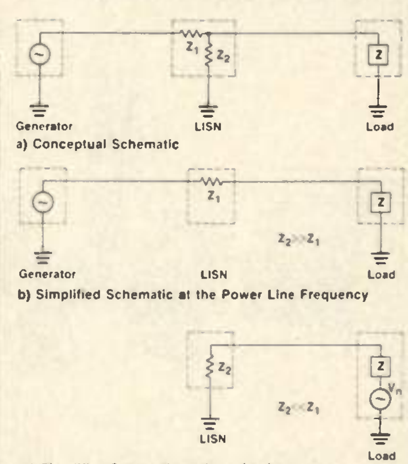

Figure 2a and 2b. Simplified Schematics

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

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

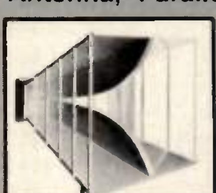
The Electro-Mechanics Company has been designing and manufacturing EMI/RFI Test Accessories for over 25 years.

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

What exactly is your major product line?

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

Typical Military Antennas for Radiated Immunity (RS) and Emissions (RE) Testing cover the frequency ranges from **30 Hz to 18 GHz,** and are noted in MIL STD 462, Notice 3, Table 1. EMCO currently manufactures **Magnetic Field Loops,** the 41" **Rod Antenna, Parallel Strip Line,** both **Biconical Antennas,** the **Conical Log Spirals** and the **Double Ridged Guide Antennas** shown on this table.

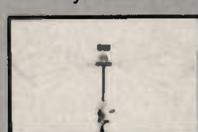


Antennas which are currently acceptable for use in FCC Volume II, Part 15 Emissions Testing include, **Adjustable Element Dipole Sets,** Broadband **Biconical Antennas** and Broadband **Log Periodic Antennas**. EMCO manufactures all of these separately or can include them as part of an FCC "Class A"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

What differentiates your antennas from your competitors?

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

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

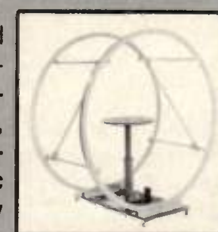


One last difference and maybe the most important, is EMCO's continual Product improvement thru Research and Development. For example, our **Dipole** and **Biconical Balun** design is much improved from the old DM-105 and military designs . . . and we are continually researching and redesigning to make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

What other Test Equipment and Accessories do you offer?

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

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



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

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

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

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

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

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

The Electro-Mechanics Company

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

INFO/CARD 32

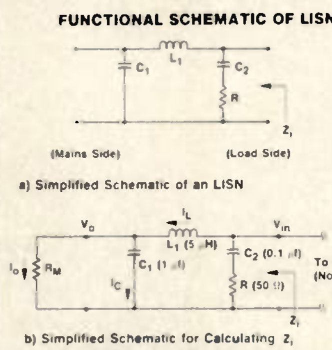


Figure 3a and 3b. Functional Schematic of LISN

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to 50 Ω, the normalized variation approaches χ. The worst case variation, then, is:

$$\frac{\chi_h}{\chi_l} = \frac{10}{0.1} = 100, \text{ or } 40 \text{ dB.}$$

Such a wide variation in measurements renders the data virtually useless! For this very reason, the LISN for AC mains was developed.

Schematic Concept

A LISN's purpose is to provide a stabilized impedance to conducted emissions without interfering with the normal power flow required by the Equipment Under Test (EUT). A conceptual schematic of the generator, LISN and load is shown in Figure 2.

At the power line frequency fp, the LISN shown in Figure 2 provides a low impedance path from the power source to the load impedance Z, and a high impedance path (virtual open circuit) from the load to the ground. At the noise frequency, fn(fn>>fp), the LISN provides a high impedance path from the power source to the load, and it provides an impedance approaching 50 ohms at high frequencies from the load to ground. The high impedance, low frequency impedance is provided by a capacitor to ground. The 50Ω impedance to ground ("R" in Figure 3) is actually the input impedance of the spectrum analyzer or EMI meter used to measure the noise. All LISN output ports must be terminated in a 50 Ω impedance, either by meter input impedance or by a 50Ω dummy load. Figure 2c shows this, whereby the LISN provides a stable impedance to the load and eliminates the effects of the varying mains impedance at noise frequencies.

Single Phase Test Set Up

In order to provide impedance stabilization for both DM and CM, the LISN is connected between phase to ground and neutral to ground. Figure 4 shows a practical single phase test set-up. Figure 4a is drawn to emphasize the effects of a LISN on CM Type I noise. At high frequencies the inductor is a virtual open circuit while the capacitor is a virtual short circuit. The high frequency equivalent circuit is shown in Figure 4b. The impedance of the two LISNs combine in parallel to present a 25 Ω impedance to the noise source.

With DM noise, the situation is altogether different. Figure 4c shows the single phase set-up redrawn to emphasize the effects of a LISN on DM noise. Under the high frequency assumptions, the equivalent circuit shown in Figure 4d results. For DM noise, the LISNs combine in series to present a 100 Ω impedance to the noise source. Use of the 50 Ω LISN has caused an unexpected impedance when used in a practical circuit, and the situation becomes worse with a three phase circuit.

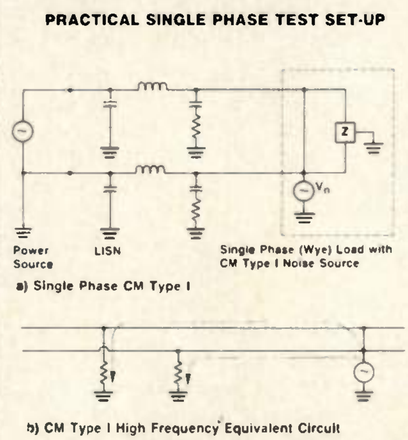

Figure 4a and 4b. Practical Single Phase Test Set-Up

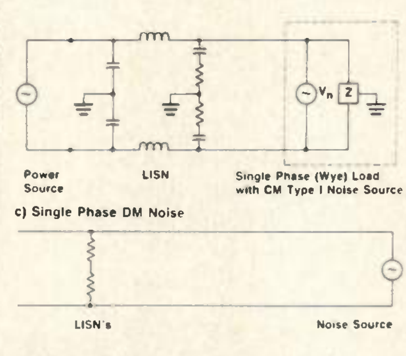

Figure 4c and 4d. Practical Single Phase Test Set-Up

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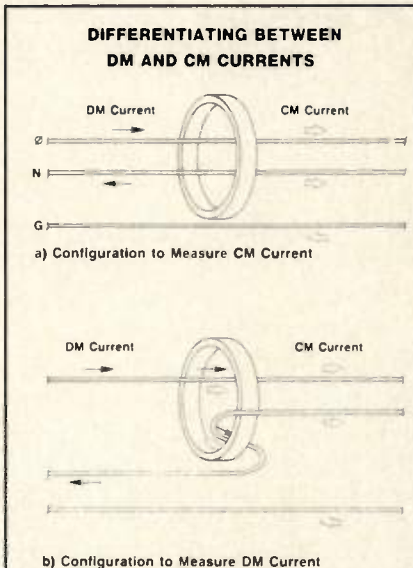

Figure 5. Differentiation Between DM and CM Currents

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Measurement Techniques

The most common method of measuring the value of the conducted emissions with a LISN is with an EMI meter or a spectrum analyzer. Either of these will give the sum of the CM and DM emissions. Although this is usually the method called for in specifications, it provides no information as to whether the emissions are CM or DM!

The current probe makes it possible to differentiate between CM and DM. The theory is that the sum of the instantaneous currents at a point on a transmission line equals zero. Proper selection of the lines to sum (to put inside the current probe) will allow use of this principle. The application is to cancel out the DM currents to determine CM currents, and vice versa. Figure 5a shows how to use the probe so that the DM currents sum to zero and twice the CM current is measured. Figure 5b shows how the CM currents cancel and the DM currents are measured.

The LISN may also be used for susceptibility testing. If the impedance of the power mains is too low, injecting a signal of a given level may prove difficult because of the loading effect on the signal generator. This condition may be alleviated by using the LISN in the same configuration as that used for testing, except that the signal is *injected* into the LISN "output" port (now used as an input).

Mark Nave can be reached at 8270 Vernon St., Manassas, VA 22110.

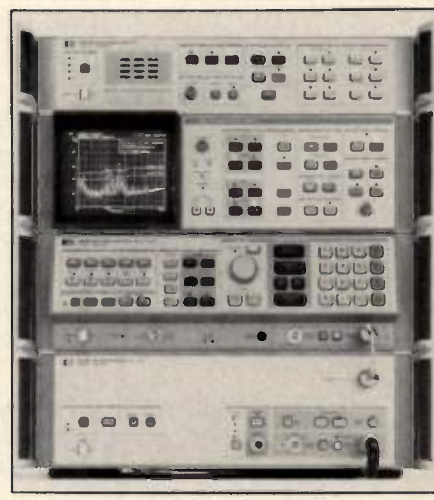
An RF Preselector for EMI Measurement

The HP 85685A RF Preselector is designed to be used with an HP Spectrum Analyzer and Quasi-Peak Adapter for EMI testing. The combination produces an EMI receiver with the characteristics recommended in CISPR publication 16. The RF Preselector provides the sensitivity and overload protection needed for FCC and VDE radiated emission testing at open sites. For commercial and MIL-STD conducted EMI tests the low frequency input tolerates large impulses and Line Impedance Stabilization Network (LISN) transients.

A built-in calibrator ensures ±2 dB absolute-amplitude accuracy, as required by the FCC and VDE. For measurement confidence a linearity check tests for system overload and distortion. To prevent overload from high-level ambient signals at +107 dBμV/m, a spectrum analyzer needs input attenuation. However, this increases displayed noise, which can mask the low-level emissions. The RF Preselector eliminates the need for adding attenuation. The noise of the spectrum analyzer alone exceeds the VDE limit, but the spectrum analyzer/test receiver noise is more than 10 dB below the lowest limit.

The RF Preselector enhances the spectrum analyzer with tracking filters and preamplifiers that cover the 20 Hz to 2 GHz range. The spectrum analyzer/test receiver is sensitive to low-level signals while providing overload protection from out-of-band signals. The result, in the presence of broadband interference, is a measurement range 30 dB greater than that of the spectrum analyzer alone.

The test receiver is easy to operate. The operator simply uses the spectrum analyzer controls without concern for preselector settings. The preselector automatically adjusts input-filter tracking, and the spectrum analyzer reports preselector operating conditions on the display. For remote operation with a computer the receiver system is fully HP-IB programmable.

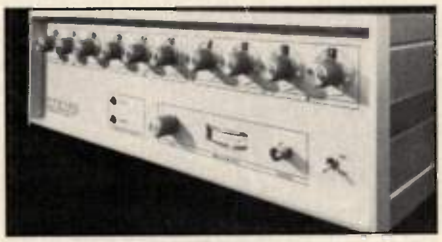


Used for signal monitoring, the RF Preselector improves signal reception for the broadband signal environment of a mobile test station. In the 150-170 MHz Business Band, the preselector reduces interference from radio and TV broadcast stations and amateur radios. For the 800-900 MHz Cellular Band, the spectrum analyzer/test receiver makes field strength measurements on cellular base-station transmitters while the preselector filter rejects interference from cellular mobile transmitters.

The test receiver can achieve the same measurement range as the spectrum analyzer alone with a wide-resolution bandwidth, which allows a faster sweep time. For example, to measure spurious signals over a 1 GHz frequency range at -100 dBc relative to the transmitter carrier, a spectrum analyzer itself needs 3000 seconds, but when configured as a test receiver it requires only three seconds.

Frequency Synthesizer

The new PTS 160 J/K synthesizer features table-look-up (TLU) synthesis and steady-phase-switching (SPC) and covers 0.1-160 MHz. These characteristics are needed for certain critical applications but they were available in the past at premium cost only. New PTS technology has led to a performance-to-price break-thru in this



area. The 1 Hz resolution version (J) has manual-remote, oven frequency standard, 55 dB spurious output. The 0.1 Hz resolution version (K) has manual-remote, oven frequency standard, 75 dB spurious output. **Program Test Sources, Littleton, Mass., INFO/CARD #176.**

21.4 MHz Crystal Discriminator Series

Piezo Filters announces the availablity of a new line of 21.4 MHz crystal discriminators. Piezo's discriminators are particularly well suited for use in such communications systems as FM demodulators. Less than one cubic inch in size, with no power supply requirements, the Piezo discriminators are ideal in portable and airborne applications. **Piezo Filters, Carlisle, Penn., INFO/CARD #174.**

FET-Based Switcher Power Supply

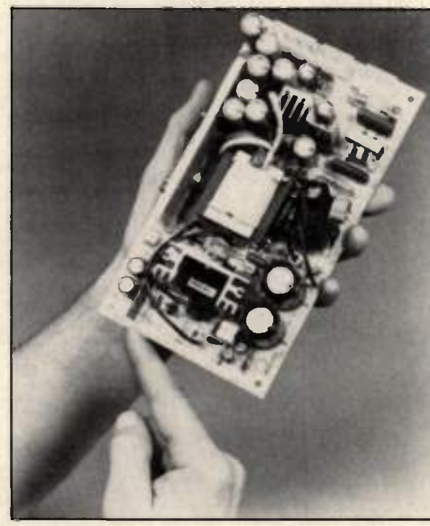
Kepco, Inc. introduces the newest member of its popular "MRM" power supply family, budget priced, "frameless," multi-output power supplies. The newcomer, Model MRM 250KV, is a 4-output, 60 watt switcher using an economical flyback circuit with a power FET. The MRM 250KV has been approved to IEC 380 and VDE 0806 by TUV Rheinland and boasts an on-board EMI filter to meet the conducted noise requirements of VDE and FCC (Class B). A feature of the design is a custom hybrid microcircuit composed of surface-mount components on a ceramic substrate. **Kepco, Inc. Flushing, N.Y., INFO/CARD #175.**

Dual 125 MHz Digital Oscilloscope

The LeCroy 9400 Dual 125 MHz Digital Oscilloscope combines the advantages of an oscilloscope and a transient recorder in an easy-to-use and portable (30 lb/14 kg) instrument. It includes all the control, display and analysis functions required by demanding applications. In addition, the LeCroy 9400 features complete programmability and extensive interfacing options for remote control and computer archiving. This highly sophisticated tool will find wide use in such diversified applications as electronic engineering, physics research, test and measurement automation, telecommunications, electromagnetic pulse and interference measurements, laser-radar and ultrasonic related research. **LeCroy Research Systems Corp., Spring Valley, N.Y., please circle INFO/CARD #172.**

Commercial Metal Film Resistor

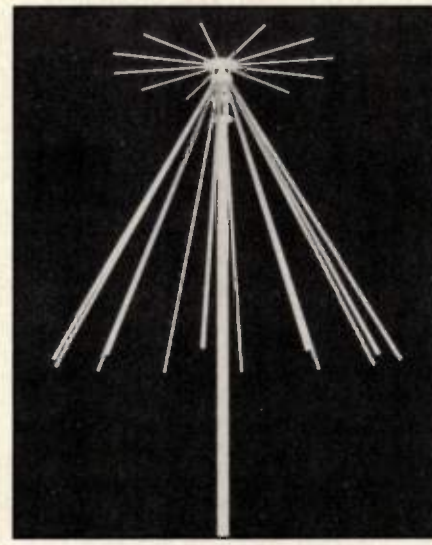
The CCF-50, a compact new metal film resistor from Dale Electronics, Inc., provides designers with ¼ watt (at 70°C) in the same size as conventional ⅛ watt resistors. Now available from stock, the new commercial grade resistor has .020" leads that make it suitable for automatic insertion. It has a tolerance of ±1% over a resistance range of 10 ohms to 1 megohm. Resistance temperature coefficient is ±100 PPM/°C over the operating temperature range of -65°C to +165°C. Maximum working voltage is 200 volts RMS. The CCF-50 is color-banded and is



available on tape and reel packaging (EIA standard RS-296-D, class 1) with 5,000 pieces per reel. **Dale Electronics, Inc. Columbus, Nebr., INFO/CARD #171.**

VHF/UHF Antenna

Interad Ltd. announces the introduction of Model 5002 VHF/UHF Discone Antenna. The 5002 ruggedized antenna covers the frequency range of 100 to 400 MHz,



with vertical polarization, 1.8 dBi nominal gain, 50 ohm impedance and 1.8:1 maximum VSWR. **Interad Ltd., Gaithersburg, Md., INFO/CARD #168.**

Dual Linear Bar Graph Displays

Dale Electronics is now producing a versatile family of dual linear bar graph displays using flat panel plasma technology. The new displays are designed for use in a wide range of process control, meter, depth, level and analog indicator applications. Currently, four models are available in the Dale bar graph display family. All offer excellent visibility by combining a wide viewing angle (120°), good light output (60-70 foot lamberts) and a pleasing, neon orange color. Internally,

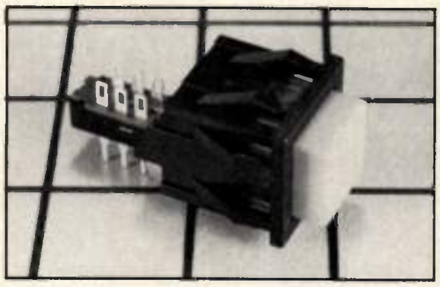
the displays use the proven "glow transfer" technique which minimizes the number of drivers needed to operate the two channels. Three of the four new displays (models PBG-12201, 12203 and 16101) require only six active drivers to operate both channels. The remaining model (PBG-12205) requires eight. Depending on the model chosen, Dale bar graph displays can be specified with 101, 201 or 203 elements per bar. **Dale Electronics, Inc., Columbus, Nebr., please circle INFO/CARD #167.**

RF Power Source

A new solid state RF power source for plasma use provides 600 watts of CW output power at 13.56 MHz. The PS 600 is capable of local and remote operation and has a bidirectional digital power indicator to monitor both forward and reflected power. Amplifier status indicators and remote control lines can be accessed via rear panel connections. The PS 600 power protect system allows maximum power to be safely delivered into any load VSWR. Cooling power supply options are available. **American Microwave Technology, Inc., Fullerton, Calif., please circle INFO/CARD #166.**

Pushbutton Switch Series

ITT Schadow introduces the FML switch series. The FML features a complete new family of buttons and bezels that give these pushbutton switches a sleek, high-tech front panel appearance. The FML Series buttons can be used with any of ITT Schadow's LT, F and F power switches. The FML Series offers a wide variety of behind the panel options, such as 2 PDT through 6 PDT, switching from 10 mA at 5 Vdc through 15 amp, ½ HP, with front panel mounting. **ITT Schadow Inc., Eden Prairie, Minn., please circle INFO/CARD #165.**



Miniature Dielectric Resonator Oscillator

E.S.C. 206-41 is a miniature high stability 13 GHz dielectric resonator oscillator with 10 mW of output power. Size of the unit (excluding connectors) is .8 x 1.2 x 1.4 inches. Temperature stability is better than 1 PPM/°C. This unit features high resolution mechanical tuning, internal voltage regulator and RFI shielding. Power required is +15 V dc at 50 mA and weighs less than 2 oz. **Electronics Surveillance Components, Inc., Palo Alto, Calif., INFO/CARD #164.**

10 Watt Attenuators

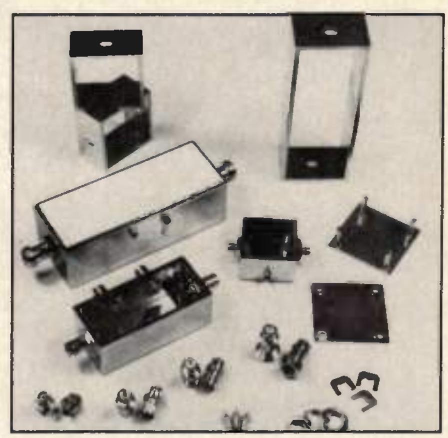
New 10 watt attenuators from EMC Technology, Inc. provide attenuation values from 10 to 60 dB in 1 dB steps through frequencies up to 6 GHz. The new attenuator will prove useful to the microwave engineer who requires medium average power dissipation and precise attenuation characteristics. Available with male and female SMA connectors for input and output, the new attenuator is only 2½" long x ½" diameter to be accommodated in small packages. The unique body configuration provides superior heat transfer qualities which enable the attenuator to perform well without exhibiting any electrical breakdown. **EMC Technology, Inc., Cherry Hills, N.J., INFO/CARD #163.**

Package Features 2465 DVS Scope, TEK EZ-Test Software

A new measurement package, the MP2903, is designed for users needing fast implementation of an automated portable oscilloscope measurement system. It includes an enhanced version of the industry standard Tektronix 2465 DVS scope, the powerful MC68000-based 4041 System Controller and a 4105 Color Display Terminal. Standard with the new measurement package is TEK EZ-TEST Software, a test program generator. The MP2903 Measurement Package is also available in a number of alternate configurations. Upgrades are available with a number of attractively priced options, including higher performance color graphics terminals. **Tektronix Corp., Vancouver, Wash., INFO/CARD #162.**

RF Shielded Enclosure

The MODPAK packaging system is a unique RF shielded enclosure that provides easy access to both sides of the PC board, quick board installation and excellent RF shielding. Twenty-six standard



MODPAK boxes come complete and ready to use with everything you need from screws to connectors, even blank labels for unit identification. **Adams-Russell, Burlington, Mass., please circle INFO/CARD #161.**

Switching Power Supplies

NCR has announced the immediate availability of a four-output, 175-watt unit. With a 50 kHz switching frequency and built-in brownout protection, the system is ideally suited for use in computer, computer peripheral and other office equipment applications. At outputs one through three load regulation is ±.4% across the no-load to full-load range. At output four the load is regulated ±4% over the same range. The unit reliability exceeds 78,000 hours MTBF on a demonstrated basis. The 175-watt, four-output unit meets every applicable EMI and safety requirement set by UL, FCC, CSA, VDE (TUV) and IEC. **NCR, Lake Mary, Fla., please circle INFO/CARD #160.**

Binary Coded DIP Switches

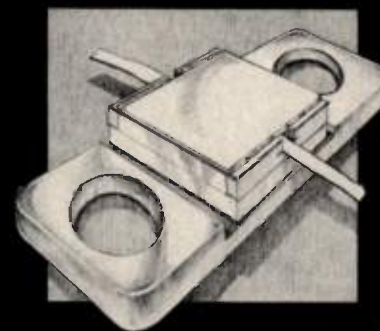
Japan Aviation Electronics Industry, Ltd. has introduced the 41J and 42J Series of Binary Coded Rotary DIP switches. Ideal for programming electronic equipment, the economical and space-saving switches are designed to replace traditional DIP switches where logic line switching is required. The 41J/42J rotary DIP switches eliminate the need to actuate multiple rockers to achieve the desired output. With the 41J/42J Series, simply set the desired binary number and the appropriate terminals will automatically be closed internally — greatly reducing the margin of error for setting. The 41J/42J Series DIP switches are available with binary 10-position and hexadecimal 16-position codes. Complement code is also available. **Zemco, Santa Ana, Calif. INFO/CARD #125.**

Miniature High Power Filters

Miniature high power filters are now available from Wavetek Indiana's RF & Microwave Components Department. The latest advanced design techniques incorporated in this new series provide high power handling capability in small lightweight packages. Miniature high power filters are available in lowpass and bandpass configurations. The power handling capabilities of these filters are up to 100 watts CW. This high power performance is offered for application in the 50 MHz to 1000 MHz frequency range. **Wavetek Indiana, Inc., Beech Grove, Ind., please circle INFO/CARD #128.**

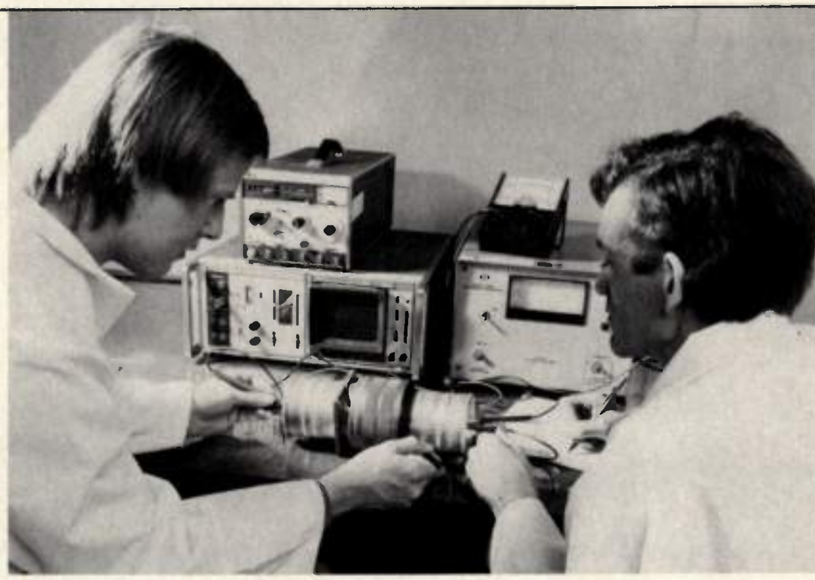
Plug-In Housings

A series of durable, lightweight plug-in housings used to protect relays, filter net-



G & H Technology

ELECTROMAGNETICS LABORATORY



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

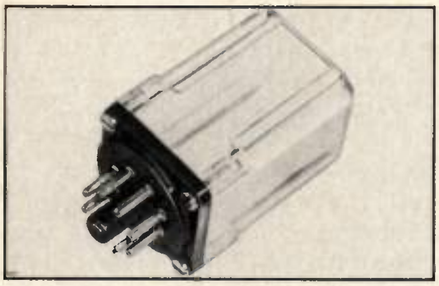
This state-of-the-art facility provides scientific expertise in EMC, EMI, EMP and Tempest testing. From this location, G&H offers a wide spectrum of testing services including:

- Technical Proposal Preparation
- Design Control Plans
- Engineering and Qualification Testing to TEMPEST requirements
- Test Plans (461/462 and TEMPEST)
- Testing Per Mil-Std 285 and Mil-Std 461-462
- Failure Analysis
- Test Reports
- Preparation of Specifications

G&H Technology's advanced Electromagnetics Laboratory gives you quality and reliable service whatever your E^3 testing requirements may be.

G&H Technology, Inc.

750 West Ventura Boulevard, Camarillo, CA 93010, (805) 484-0543
Telex 181095 TWX 910-336-1237



works, logic circuits, modules and other assemblies is the latest group of electronic accessories manufactured by Keystone Electronics Corp. Available in Lexan, Nylon, or Polystyrene and in a range of sizes and colors, Keystone plug-in housings protect vital components from dust and dirt while providing excellent resistance to chemical and moisture absorption. Headers for the plug-in housings are molded of general purpose black phenolic and are supplied in two sizes with a variety of pin configurations. All socket pins are made of nickel plated brass. **Keystone Electronics Corp., New York, N.Y., INFO/CARD #156.**

Quick Release Connector

LANCE-A-LOCK is a self locking, quick release connector. It has a molded construction that increases reliability. LANCE-A-LOCK mates securely with an audible click to readily available latching blocks or posts without the use of tools. LANCE-

A-LOCK is available in a wide range of colors and molding materials and can be identified with a customer's logo and/or part number. It is designed to EIA Standard RS 449 and RS 232. **Lance Wire & Cable, Inc., Hamden, Conn., please circle INFO/CARD #155.**

300 Watt L-Band Transistor

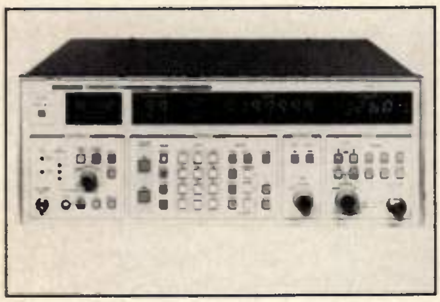
A single-ended 300 watt RF power transistor designed primarily for use in short and medium pulse radar applications in the L-band frequency range from 1200 to 1400 MHz is now available. Designated the SD1507, the RF power transistor employs a multiple-base cell geometry with emitter site ballasting, doped passivation and refractory barrier gold metallization. For wideband performance over the entire frequency range, the SD1507 has internally-mounted input and output matching networks within the package utilizing tightly controlled semi-automatic wire bonding techniques. The package uses metal ceramic hermetic stripline technology. **Thomson Semiconductors, RF Marketing Group, Montgomeryville, Penn., INFO/CARD #154.**

RF Transmitting Type Capacitors

High voltage ceramic capacitors are available in military and commercial grades and are provided in NPO, X7R and X5U dielectrics. Voltages are available in 5 kV to 50 kV with capacitance ranges from 10 pF and 1000 pF and temperature range from −55° to +125°C. **KD Components, Inc., Santa Ana, Calif., please circle INFO/CARD #153.**

Programmable Synthesized AM/FM Signal Generator

This new programmable signal generator covers the frequency range from 1 to 520 MHz in 100 Hz steps. Output level is calibrated in dBμ or dBm and selectable from -20 to 126 dBμ (-133 to +13 dBm) with 0.1 dB resolution. Convenient front panel keyboard control allows easy entry of frequency and attenuation. Single digits of the output frequency can also be selected and changed without disturbing any of the other operating parameters. Memory stores up to 100 different test conditions including frequency, output level and modulation type for later recall. Stored data is protected from accidental loss by battery back-up. AM (0-90%) and FM (0-100 kHz) 0-50 kHz (32.5-65 MHz) modulation is available by external signals or internal signs at 300 Hz, 400 Hz, 1 kHz or 3 kHz. Reverse power protection with automatic recover is provided to prevent damage to the output circuits from accidentally keyed transmitters. **Leader Instruments Corp. Hauppage, N.Y., please circle INFO/CARD #141.**

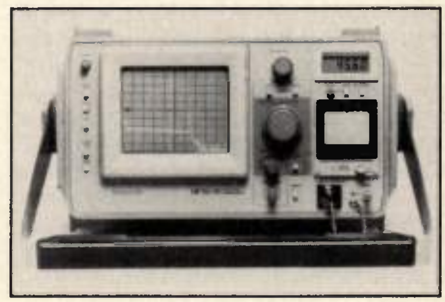


200°C Power Op Amp

APEX introduces the PA12H low cost, high temperature power op amp especially made for short term use in extreme environmental situations such as down hole instrumentation. The amplifiers can power mechanical or electronic transducers and can drive the long transmission lines associated with these applications. The PA12H basic version meets the standard PA12 specifications and the static and dynamic 125°C tests listed in subgroups two and five of the military PA12M data sheet. The quiescent current and the voltage swing are tested at a cast temperature of 200°C. Using dual 45 volt supplies, the maximum quiescent current is 100mA. Using 15V supplies, the minimum output swing is ±11V with output currents of 1A. Additional screening or testing at 200°C is available. **Apex Microtechnology Corp., Tucson, Ariz., please circle INFO/CARD #140.**

Fiber Optic Tester

The OF151 Fiber Optic Time Domain Reflectometer (FOTDR), operating at 1300 nanometers, locates faults and breaks and also measures splice loss in single-mode fiber links. The OF151 typically measures breaks through a maximum of 33 dB cable loss, and splices to ±0.1 dB through 10.5 dB one-way cable loss, depending on fiber characteristics. Maximum readout range is 60 km; and max-



imum distance for non-reflective break is 18 dB of cable loss. This FOTDR meets the rigorous specifications of MIL-T28800, Type III, Class 3, Style C, except for Radiated Emission RE-01 and Non-Operating Temperature specifications. The instrument performs at virtually any altitude (to 15,000 feet) or temperature (-15° to +55°C), from a 12 V vehicle system or an external rechargeable battery pack. The OF151 serves the communications industry, primarily in the installation and maintenance of long wavelength single-mode fiber optic links. **Tektronix, Redmond, Ore., INFO/CARD #132.**

Reverse DIN Connector

Stanford Applied Engineering has introduced the TL5800 reverse DIN backplane connector series featuring TRI-LOK press-fit compliant pins. Available in fully shrouded, four wall configuration the product is ideal for mother/daughter board connections. Preassembled reversed DIN connectors with compliant pins allow press-fit installation providing a gas-tight pressure joint between pins, plated thru holes and printed circuit board. In addition to the preassembled product, users

rf products Continued

can choose to have SAE insert the connectors into a customer-supplied backplane. **Stanford Applied Engineering, Santa Clara, Calif. please circle INFO/CARD #131.**

Fiber Optic Analog Links

The LeCroy 5400 Series of high performance analog transmitters and receivers provides for transmission lengths of up to 2 km and offers bandwidths as high as 250 MHz. Two versions are offered: Model 5413 features transmission lengths of up to 2 km with a signal bandwidth of 60 Hz to 50 MHz; Model 5403A has a bandwidth of 60 Hz to 250 MHz for distances up to 300 m and a bandwidth of 60 Hz to 170 MHz for distances up to 300 M. These links are especially suited to applications involving high voltage isolation, radar, telemetry, and situations in which EMI, RFI, and MPI isolation are required. The 5400 Series links will accommodate a wide range of fiber optic cable lengths without user adjustments. **LeCroy Research Systems Corp., Spring Valley, N.Y., INFO/CARD #129.**

rf literature

New Literature

Engineer's Relay Handbook

This 326 page book contains a complete source of information on the operating principles, properties and performance characteristics of the various types of relay in addition to application requirements, specifications and testing. **Magnecraft Electric Company, Chicago, Ill., INFO/CARD #119.**

Applications Handbook

A manufacturer of switching, linear and ferroresonant power supplies, as well as IEEE-488 compatible digital programmers, announces the publication of a new, thoroughly updated version of its full-line catalog. In addition to complete details and specifications on all the products in Kepco's extensive line, the catalog devotes 45 pages to application notes, explanations of power supply theory and a comprehensive glossary of power supply terminology. **Kepco, Inc., Flushing, New York, INFO/CARD #118.**

Surface Mounted Component Brochure

Kyocera International, Inc. has published an eight-page technical brochure outlining their new surface mounted component line including chip capacitors, chip resistors, potentiometers and trimmer capacitors. The brochure contains size information, temperature coefficients, voltages, capacitance and resistance characteristics and packaging options for each product. **Kyocera International, Inc., San Diego, Calif., INFO/CARD #117.**

rf literature *Continued*

Wall Chart Antennas

The Antenna Specialists Co. has a chart that permits quick and accurate identification of the exact model required to meet virtually any portable replacement antenna need. The chart permits immediate cross-referencing of radio brand, frequency range and antenna style desired to pinpoint the exact model which should be ordered. Accommodating virtually every brand of portable radio, the chart references more than 110 different antennas in a range of six different configurations covering all portable applications from 30 to 866 MHz. **The Antenna Specialists Co., Cleveland, Ohio, INFO/CARD #114.**

Power Amplifiers

A four page brochure explains low cost approaches for the production of RF power amplifiers for OEM applications. Amplifiers and self-containing RF power sources are available in ranges from 10 kHz to 3 GHz with power ratings up to 1 KW. **American Microwave Technology, Inc., Fullerton, Calif., INFO/CARD #113.**

Miniature Coax Terminations

A one page product bulletin on 3mm/SMA coax terminations has been published by EMC Technology, Inc. The bulletin provides full technical data on the company's Model 4120 plug and jack terminations including photo, engineering drawings, applications/advantages and specifications. The terminations described in the new bulletin represent the first in a series to be offered by the company which provide maximum power handling capabilities in minimum space along with outstanding electrical characteristics. **EMC Technology, Inc., Cherry Hill, N.J., INFO/CARD #112.**

Multicoupler and Filter Catalog

The product bulletins in this catalog describe high performance antenna multicouplers and tunable RF filters for military and civilian government communications systems. **RF Products, Inc., Camden, N.J., INFO/CARD #111.**

Micro-Ohmmeter Brochure

Cambridge Technology, Inc. has published a two page brochure on its new Model 510 4-½ Digit Micro-Ohmmeter. This instrument is designed to measure the resistances of switch and relay contacts, transformer and motor windings, connectors or any other low resistance devices. The Model 510 features three measurement modes, five ranges from 19.999 milliohms to 199.99 ohms, full scale, 1 micro-ohm resolution, and a basic accuracy of 0.02%. **Cambridge Technology, Inc., Cambridge, Mass., INFO/CARD #110.**

Coaxial Cable Assemblies

A 24 page catalog features a full line of coaxial cable, coaxial adaptors, coaxial connectors, coaxial terminations and coaxial assemblies. Pricing on over 1,000 standard catalog items as well as technical specifications are included. **Pasternack Enterprises, Irvine, Calif., INFO/CARD #95.**

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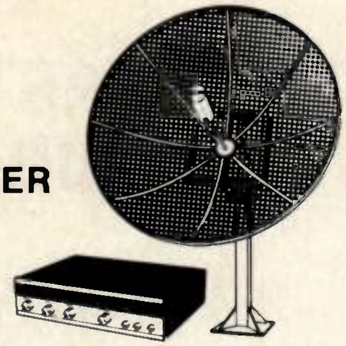

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