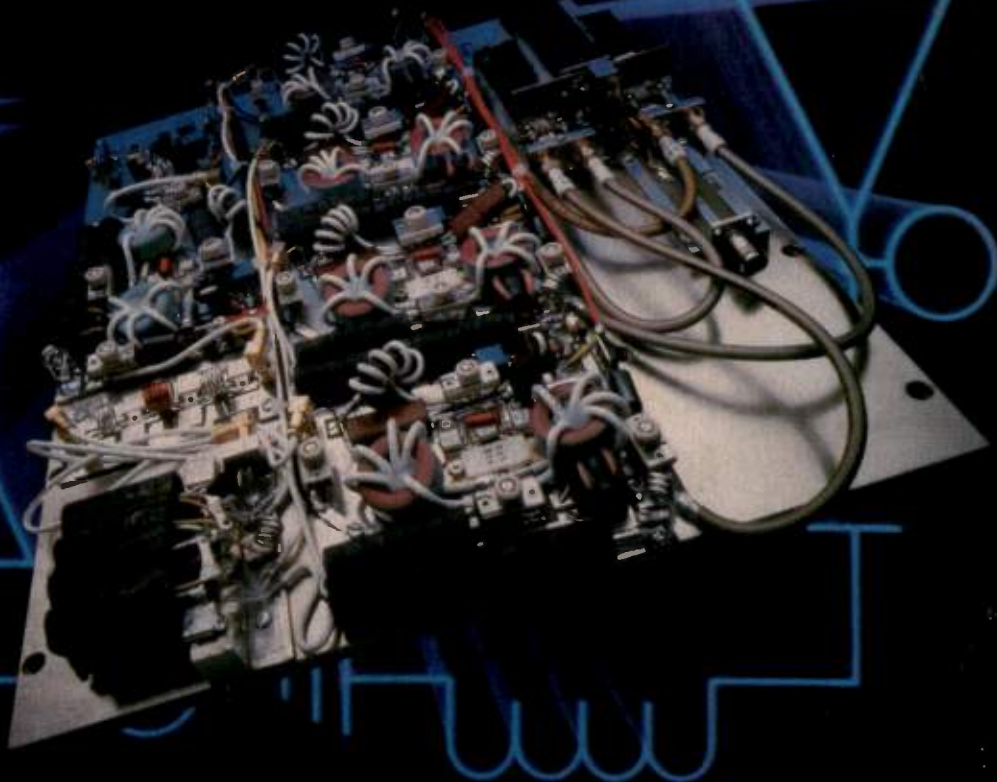


rfdesign

ideas for engineers

February 1985

Modules Lead the Way



RF Technology Expo '85 Issue

TOUCHSTONE/RF™

Now! CAE with everything the RF engineer needs— at a price your company will go for!

TOUCHSTONE™
Finally! the microwave engineering tool you want—
right where you want it!

Touchstone is today's most advanced software for RF/microwave computer-aided engineering. Yet Touchstone runs on IBM® and IBM-compatible PCs. So total cost is \$40,000 or less—including computer! That means the new industry standard of microwave CAE can be under your own, instant, exclusive control.

And Touchstone truly is the new standard. Touchstone delivers results, start to finish, faster than any other program for interactive engineering—even Super-Compact™ on a mainframe. It's also more interactive and more sophisticated, making Touchstone easier to use even for the most complex topologies.

Consider just a few features:

- Modal description for analysis of unlimited topologies
- Versatile measurements: x-ray circuit as you build it
- Interactive tuning
- Full screen editor
- Immediate graphic display of circuit response
- Complete element catalogue
- Most up-to-date optimizer

EEsof

31194 La Baya Drive, Suite 205, Westlake Village, CA 91362
Surely you HAVE to know more. Send for a brochure.
Better yet, call (818) 991-7530 right now.

Touchstone is a trademark of EEsof, Inc. IBM is a trademark of International Business Machines Corp. Super-Compact is a trademark of Compag Software, Inc.

Touchstone is designed by microwave engineers for microwave engineers.

It's like sitting at the bench. You design, predict performance, explore topologies, optimize, tune—all on the computer. You change circuit elements, hit a key, and sweep over any frequency range. You try things. Whenever you want, for as long as you want. No waiting. No sharing. Touchstone is all yours. It brings your PC to life as a professional engineering tool.

Touchstone is a new product of EEsof—
an Electrical Engineering software company that provides total, continuing support for all its products.

Everything you've read about Touchstone™—the new standard of microwave computer-aided engineering—applies to Touchstone/RF, the version specially tailored for RF engineers. With four exceptions:

- ① Both programs also run on the Hewlett-Packard series 200, models 9816 and 9836.
- ② Touchstone/RF costs less than half of Touchstone's price.
- ③ Touchstone is really over-engineered for work in the RF range. Touchstone's physical models of microwave elements are a major expense. They're vital to account for loss, dispersion, and discontinuities in microwave transmission media. But you don't need them. Without them, errors even in most of your extremely complex RF circuit designs are insignificant.

So why pay for what you won't use? Touchstone/RF has all you need, like lumped elements, ideal transmission lines, transformers, and device models; now even g-, h-, y-, and z-parameters. (Later, if you design microwave products, you can exchange Touchstone/RF for Touchstone, and get full credit.)

Like Touchstone, new Touchstone/RF makes your productivity soar. And the price makes approval a cinch!

For full information, call or write. (We've already outgrown our original offices. Note our new address below.)

EEsof

31194 La Baya Drive, Suite 205, Westlake Village, CA 91362 (818) 991-7530

SEE US AT THE RF/TECHNOLOGY EXPO 85, JAN. 23-25, DISNEYLAND HOTEL, ANAHEIM, CA, BOOTHS 610 & 612

INFO/CARD 1

Introducing a high-quality RF source at a radically low price.



The Fluke 6060A general-purpose 1GHz signal generator.

This is Fluke's greatest price/performance breakthrough yet, created from 20 years of proven RF design experience. The 6060A is our newest, lowest cost, general-purpose generator.

General purpose because its broad frequency and amplitude ranges and modulation versatility offer the performance you need for virtually all RF design, development and testing applications.

General purpose because the 6060A meets these application needs with

—60 dBc non-harmonic spurious throughout its broad range. Fluke's years of designing and building RF instruments gives the 6060A the reliability you demand.

But the real breakthrough on our new 6060A is its price: **\$4500***

Because it is so much less than you might expect to pay for a comparable unit, the 6060A is the lowest-cost generator in its class.

Clearly, the 6060A signals a new era in generator price/performance for the RF industry.

For more information about the innova-

tive 6060A, call **1-800-426-0361** or contact your local Fluke Sales Engineer or Representative.

Fluke 6060A

Frequency range	100 KHz — 1050 MHz
Amplitude range	+13dBm to —137dBm
Accuracy	±1.5dB
Harmonics	< —30dBc
Spurious	< —60dBc
Modulation	AM/FM
Radiated RFI	< 1µV at carrier frequency
IEEE-488 Interface, opt. 488 switch speed	< 100 ms, typ.

IN THE U.S. AND NON-
EUROPEAN COUNTRIES


John Fluke Mfg. Co., Inc.
P.O. C9090, M/S 250C
Everett, WA 98206
(206) 356-5400; Tlx: 152662

IN EUROPE:

Fluke (Holland) B.V.
P.O. Box 5053, 5004 EB
Tilburg, The Netherlands
(013) 673973; Tlx: 52237



GOING THE DISTANCE



*O*n May 11, 1926—a 16-man team of international explorers, led by South Pole discoverer Roald Amundsen, sailed the dirigible Norge from Spitzbergen, Norway to the "top of the world." The flags of the United States, Norway, and Italy were released as the 348-foot airship crossed the North Pole. Then the weary crew pressed on, fighting ice and high winds. After 46 bone-numbing hours, the Norge reached Alaska, setting down in an Eskimo village 3,200 miles from the starting point.

NOW ACRIAN IS GOING THE DISTANCE TO INTEGRATED POWER MODULES

Acrian has already earned an industry-wide reputation as the leader in high reliability microwave and RF power transistors.

Today Acrian is going even farther, building verti-

cally to provide our customers with single-stage and integrated hybrid modules, both custom and standard, for military, commercial, and industrial RF power applications.

Acrian's Module Division is fully staffed with RF engineering, manufacturing and quality control experts. And our new design and production facilities utilize the latest in state-of-the-art technologies.

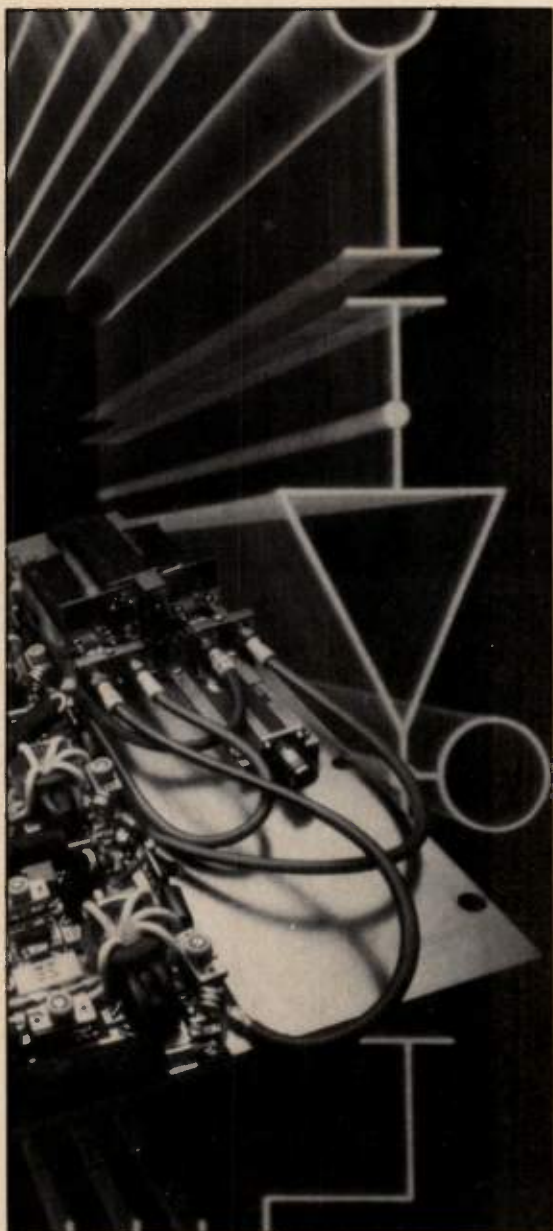
With our resources, we have the in-house capability to compress your design cycle and reduce your engineering time, while assuring absolute quality control. The

result: a higher quality product that saves you time and money.

Ask us today for details on the new lineup of Acrian integrated power modules and hybrid assemblies. We'll be glad to send you data on these or any of more than 500 Acrian products designed to go the distance in communications, radar and avionics. Call (408) 294-4200. Or TWX (910) 338-2172.

Acrian, Inc., 490 Race Street
San Jose, California 95126

 **ACRIAN**
POWER WITH A PURPOSE



Cover

February Cover —

The PB-2022 one-kilowatt amplifier provides 50 dB of gain in one modular "supercomponent." The PB-2022, and many other products, will be exhibited at RF TECHNOLOGY EXPO 85. Cover photograph courtesy of Acrian.

Features

26 Special Report: Modules Lead the Way at RF TECHNOLOGY EXPO

Modular "supercomponents" can simplify life for the design engineer. Also a preview of the exhibits at RF TECHNOLOGY EXPO 85. Kiyoshi Akima.

36 The SAW Resonator: How It Works

The first part of this two-part series provides an introduction to the subject of surface acoustic wave resonators. A TI-59 program is given to model the responses of these devices. Jeff Schoenwald.

46 The Phase/Frequency Detector

This article discusses the design of phase-locked loops employing phase/frequency detectors. James Crawford.

Departments

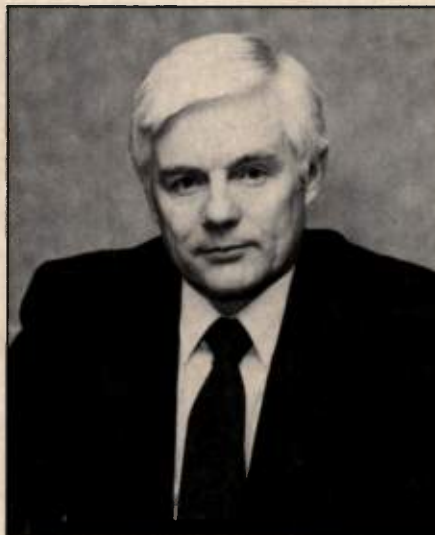
- 6 Editorial
- 8 Publisher's Notes
- 11 Letters
- 16 News
- 61 RFI/EMI Corner
- 62 The Digital Connection
- 64 RF Designer's Notebook
- 67 Info Card
- 71 Product of the Month
- 72 New Products
- 88 New Literature
- 94 Advertisers Index

Special Report p. 26

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in June. February 1985, Volume 8, No. 2. Copyright 1985 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6530 S. Yosemite Street, Englewood, CO 80111 (303) 694-1522. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802, (1-800-346-0085). Subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: \$15 per year in the United States; \$25 per year in Canada and Mexico; \$25 per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are \$5.00 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.

POSTMASTER & SUBSCRIBERS: Please send address changes to: R.F. Design, P.O. Box 6317, Duluth, MN 55806.

The Boom in RF Communications



Jim MacDonald
Editor

A news item in last month's issue told about the sales a new California company anticipates in communication systems operating below 2 GHz. Many companies are expecting a growing market for RF communications equipment, especially overseas.

Much of the world depends on the RF spectrum for local communications. The Europeans have been using cellular radio for years, getting their components from American firms. *RF Design* has learned that one African nation has contracted with an American firm for a nationwide Rf telephone system.

We at *RF Design* expect to see an RF communications boom in the next few years to rival the computer phenomenon of the last 20 years. People in ordinary occupations are finding they need to communicate faster. Stock brokers in New York, for example, can no longer rely on the telephone or the "tape" for the kind of minute-by-minute stock and bond quotations they need in a volatile market. They are turning to radio as highly selective narrowband antennas make radio communication possible in the canyon-like streets.

Even the military, the largest user of satellite communications, is a large-

volume buyer of RF equipment. Tactical battlefield communications and control systems still use VHF to a large extent, partly because short-range, line-of-sight communications are more secure.

Information exchange in the civilian sector is becoming increasingly time-sensitive. The speed at which we can access information and perform calculations with digital equipment is mind-boggling, but how valuable is the information unless it can be communicated to the right people when they need it? America, with the best telephone system in the world, will probably continue to develop and improve satellite communications, but other nations may not have this capability for years.

Futurists talk about the decentralized workplace. They predict people will work at home on computers tied to a central office mainframe. If this does come about, think how important short-range radio and telephone communication may become. Electronic mail is no substitute for person-to-person conversation, either for conveying complex ideas or for that contact with other people we all need.

We are flooded with information about the world, but we have little communication with each other. Most of us probably know more about the health of the latest Russian leader than we do about the health of our next door neighbor. Sociologists may know why we isolate ourselves — maybe it is necessary. The recent growth in amateur radio, however, and the tenacity with which CB radio has held on in spite of its problems indicate a deep desire to communicate with our fellow human beings, even when we have nothing important to say.

As this issue goes to press the *RF Design* staff is preparing for the RF Technology Expo, January 23-25, bringing together engineers, physicists and manufacturers in the RF field. We hope this exposition and symposium will provide the foundation for a continuing exchange of information. *RF Design* will provide a forum for this ongoing exchange.

A handwritten signature of Jim MacDonald in dark ink.

TRAVEL LIGHT

Whether you're designing backyard handsets or communicating worlds away, our hi rel crystals and filters help your product travel light. Our ruggedized units (Swept Quartz; high G's; shock; and h.f. vibration to 3000 Hz) are not only tough travellers; they're also valuable spacesavers. We currently make the industry's smallest matched filter sets. We'll make you *any* 2-pole crystal or filter from 10-20 MHz in an HC45 package. Higher frequencies? Believe 1/10" diameter by 1/4" high.

When you need precise, durable monolithics, time delays, or matched sets (quality and inspection to MIL-I-45208) give us a call. Or send us your specs. For now and light-years to come, we've got your ticket to travel light.



Sokol
Crystal Products, Inc.

"Where the Impossible Becomes the Ordinary."

121 Water St.
Mineral Point, WI 53565
Phone 608-987-3363



ATTENUATORS TERMINATIONS MATCHING PADS DETECTORS

FIXED ATTENUATORS

DC-2 GHz BNC, TNC, SMA or Type N
DC-18 GHz SMA or Type N

TERMINATIONS

DC-2 GHz BNC or SMA
DC-8 GHz Type N
DC-18 GHz SMA

PUSHBUTTON ATTENUATORS

DC-750 MHz BNC, TNC, SMA or Type F

DETECTORS

100 KHz - 1000 MHz

Units available 50 or 75 Ohm



JFW Industries, Inc.
5134 Commerce Square Dr.
Indianapolis, IN 46237
317-887-1340

Giving Birth to a Community



Keith Aldrich
Publisher

As I write, the first RF TECHNOLOGY EXPO is still three weeks off... too early for a final count of attendees or exhibits or for a final assessment of its success. One thing is already clear, however, from the comments and attitudes of the people who have signed up in advance to be there. When closing time comes at noon on Friday, January 25, RF TECHNOLOGY EXPO 85 will have given birth to an RF engineering community.

A community is defined as a group of people who have been drawn together by some common interest. It is the "together" that has been missing. Heaven knows, from the enthusiasm that has greeted every step of the development of RF TECHNOLOGY EXPO, that the common interest was already there. But RF engineers have never been able to congregate before and they have missed it. They have *needed* it. They have had to work in near isolation, even as their technology boomed.

We expect well over a thousand RF engineers at the Disneyland Hotel for the first RF TECHNOLOGY EXPO. That's no multitude, but it is a very good start of an influential and coherent community. We expect those engineers to go back to work renewed in their skills and rekindled in their zeal because of the association

with their peers and counterparts from around the world. We expect their work to profit and a fresh infusion of design ideas and solutions. We expect new relationships to develop between people and companies that ought to know each other and will profit because they do.

A lot to ask? It's only the sort of thing that occurs in every strong community. And this one is just bursting to be born.

A word about my simile: "giving birth" to a community. Birth is generally accompanied by a lot of hard, even painful, labor. This one has been no exception, and I'd like to give credit to the main coordinators.

Kathy Kriner, manager of Cardiff Publishing's Trade Show Division, has brought a high degree of professionalism to the task of convention manager. I didn't realize (it's hard to imagine) how many details there are to be tended to in that chore and she hasn't missed any.

Andrzej Przedpelski, VP of Development for ARF Products, Inc., has given the event its essential character through his selection of the more than sixty papers that make up the technical conference. He has been tireless in what amounted to a second full-time job during a peak-load period in his main one. *RF Design* will always be grateful.

Publisher
Keith Aldrich

Editor
Jim MacDonald

Consulting Editor
Andy Przedpelski

Editorial Review Board
Alex Burwasser
Rob Coe
Doug DeMaw
Dave Krauthelmer
Ed Oxner
Andy Przedpelski
Jeff Schoenwald
Raymond Sicotte

Account Executives
Eric Nleman
Kathryn L. Walsh

Sales Service Administrator
Lisa Fontana

Advertising Services
Elise Froistad

Circulation Director
Ron Kinnes

Circulation Manager
Trish Shapiro

Circulation Assistant
Sharron Rlerson

Production Manager
Madeline Price

Assistant Production Manager
Mary Barr Felker

Artists
Carol Bates
David Hauschild
Maurice Lydick
Matt Park
Bill Schmitt

Composition
Jay Jarrett
Kristi Kalb

President
Robert A. Searle

Vice President
Judy L. Rudrud

Controller
Mike Drake

Operations Manager
Cheryl Greenman

Published by

CARDIFF
PUBLISHING COMPANY, INC.

6530 S. Yosemite St.
Englewood, CO 80111
(303) 694-1522

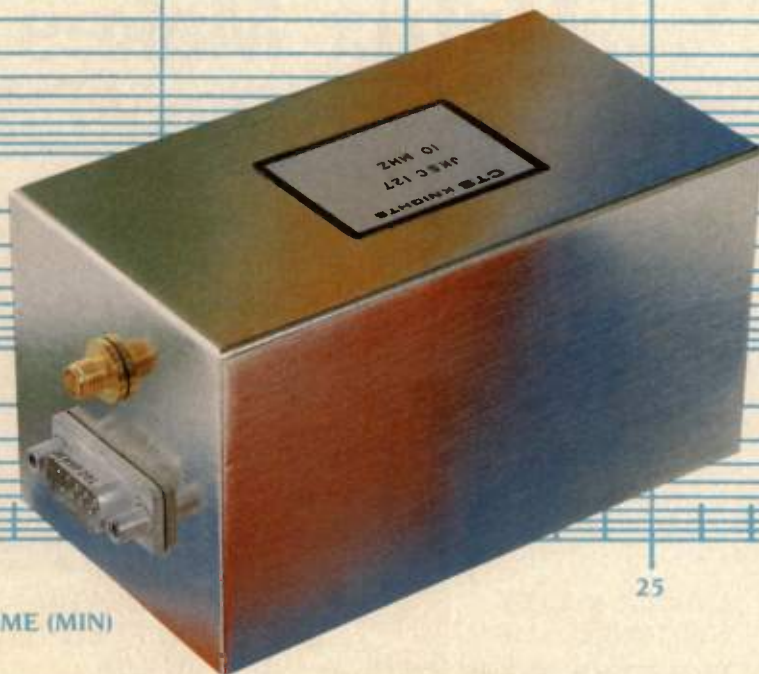
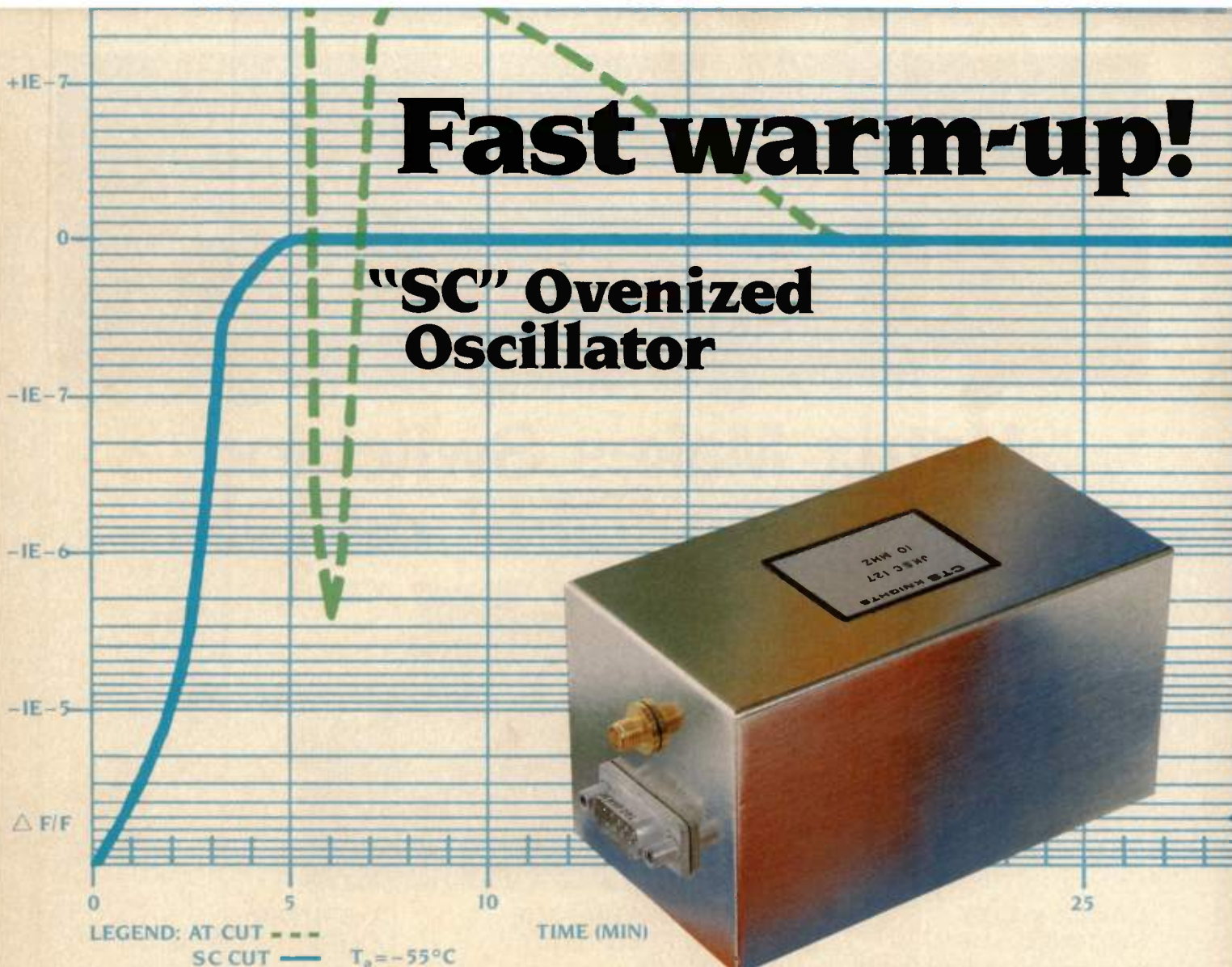
V BPA

Member of Business Publications Audit of Circulations, Inc.

Please address subscription inquiries to:
RF Design, Cardiff Publishing Company,
P.O. Box 6317, Duluth, MN 55806
Postmaster: send form 3579 to the above address.

Fast warm-up!

"SC" Ovenized Oscillator



These proven CTS Ovenized Oscillators provide fast warm-up, low power, excellent stability and low phase noise. When you need premium quality, state-of-the-art precision oscillators for industrial and military applications, you can depend upon CTS. With the largest staff of engineers in the industry, we've been building premium crystal products for 40 years. Because we manufacture our own precision crystals, you are assured of consistent oscillator performance

and quality. With extensive design and manufacturing capabilities, CTS Knights Division crystal products have become the choice when reliability cannot be compromised.

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

INFO/CARD 6

General Specifications

JKSC-127 Ovenized Oscillator (Stress Compensated)

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

CTS MEANS RELIABILITY

CTS CORPORATION • ELKHART, INDIANA



Voltage Controlled Crystal Oscillators
Standard and hybrid designs.
Phone: (815) 786-8411
INFO/CARD 7



Temperature Compensated Crystal Oscillators
High stability and reliability.
Phone: (815) 786-8411
INFO/CARD 8



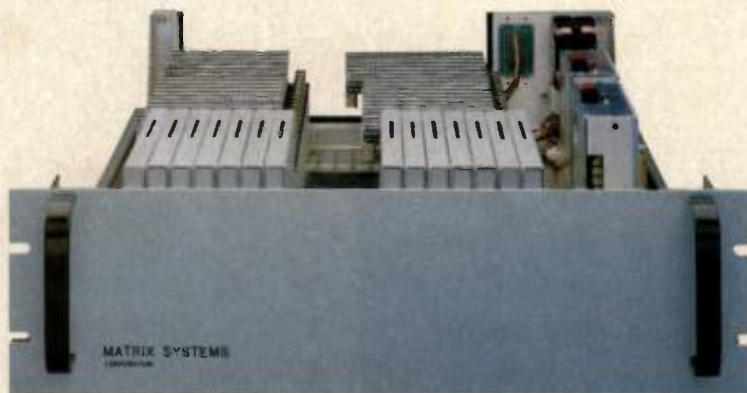
Connectors
Custom PC board and military styles.
Phone: (612) 533-3533
INFO/CARD 9



Memory Systems
Ruggedized, non-volatile data storage.
Phone: (612) 941-9100
INFO/CARD 10



Matrix Makes Switching as Easy as "OFF" or "ON"



MATRIX MAKES SWITCHING A SNAP

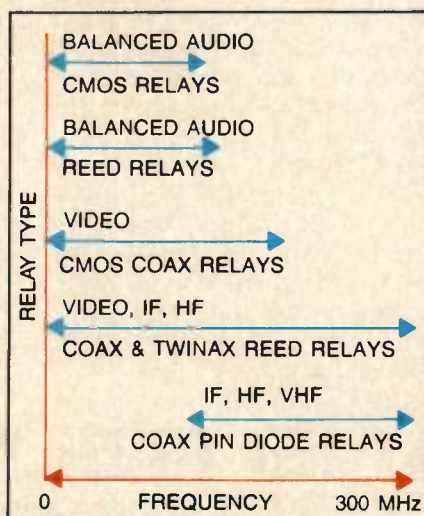
Whether you're switching VHF, HF, IF, video, audio or DC, Matrix Systems makes it a snap. That's because we can tailor a system to your exact needs using Reed, CMOS, or Pin Diode relays. The chart tells the story.

It pays to deal with a company like Matrix who really understands the switching business. We've been designing and delivering state-of-the-art systems for over 15 years to defense contractors, government agencies, the TV industry, ATE manufacturers - and more. Built to the toughest electrical and packaging specs imaginable.

BUILT TO YOUR SPECS

Don't spend months designing a custom switching system when we can do it faster and for far less money. We assume total system responsibility, including computer compatibility, control panel, status indicators, scanning functions and power supplies. We can switch any type of cable system: coax, twinax, triax, common ground, floating ground or twisted pair. And because our systems are modular, repairs can be made in minutes.

MATRIX COVERS THE WHOLE FREQUENCY SPECTRUM



COMPUTER COMPATIBILITY

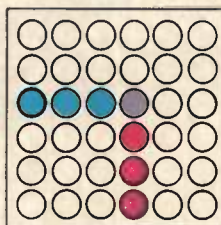
Just apply a control input from your computer and the system will instantly route your signal to as many points as needed. 16 bit parallel interface is standard, and we also offer IEEE-488 and RS232, all with status feedback.

NEW PRODUCTS

We have a lightweight portable system which is perfect for test, and service. Plus an ULTRA-FAST (microsecond range) pin diode coaxial system.

LEAVE THE SWITCHING TO US

Don't make switching a chore. Make it a snap. Matrix has the answers to your switching problems, no matter how tough they may be.



MATRIX

SYSTEMS CORPORATION

5177 NORTH DOUGLAS FIR ROAD
CALABASAS, CALIFORNIA 91302
(818) 992-6776 • TWX 910-494-4975

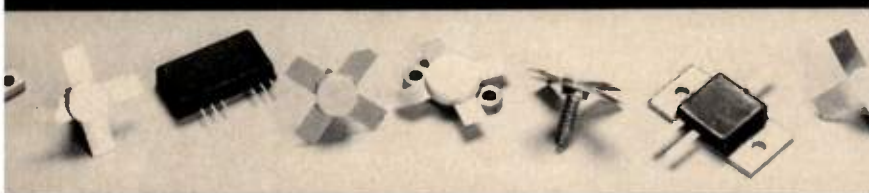
INFO/CARD 11



These Numbers Mean Business



Now —reliable RF Transistors from 900 MHz down to 1 MHz for Mobile Communications.



Amperex®

A NORTH AMERICAN PHILIPS COMPANY

Amperex, 230 Duffy Avenue, Hicksville, New York, 11802,
or phone 516/931-6200, TWX 510/221-1839.

MOBILE APPLICATIONS					
900 MHz	Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V) Package
		0.5	900	9.0	12.5 SOT-103 E1
				7.5	12.5 SOT-172
				6.5	12.5 SOT-172
				7.3	12.5 SOT-122
				8.0	12.5 SOT-171
				6.0	12.5 SOT-171
				6.0	12.5 SOT-171
				6.0	12.5 SOT-171
				6.0	12.5 SOT-171
				6.0	12.5 SOT-171

MOBILE APPLICATIONS					
400 to 512 MHz	Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V) Package
		60	470	4.8	12.5 SOT-119
		45	470	5.1	12.5 SOT-119
		30	470	6.0	12.5 SOT-119
		20	470	6.5	12.5 SOT-119
		30	470	5.0	12.5 SOT-119
		10	470	6.0	12.5 SOT-119
		5	470	10.5	12.5 SOT-122
		4	470	8.0	12.5 SOT-122
		2	470	9.0	12.5 SOT-122
		2	470	6.0	12.5 TO-39

MOBILE APPLICATIONS					
175 MHz	Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V) Package
		75	175	7.0	12.5 SOT-119
		45	175	6.5	12.5 SOT-119
		30	175	8.2	12.5 SOT-119
		45	175	5.0	12.5 SOT-120
		28	175	9.5	12.5 SOT-120
		25	175	6.0	12.5 SOT-120
		4	175	10.5	12.5 TO-39E
		2	175	10.5	12.5 TO-39E

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

AMPLIFIER MODULES FOR LAND MOBILE					
66 to 870 MHz	Type	Freq. (MHz)	P In (MW)	P Out (W)	VCC Package
		68-88	100	20	12.5 SOT-132
		80-108	100	20	12.5 SOT-132
		132-156	150	20	12.5 SOT-132
		148-174	150	20	12.5 SOT-132
		148-174	150	13	12.5 SOT-132B
		400-440	100	7.5	12.5 SOT-132C
		400-440	150	13	12.5 SOT-132C
		440-470	100	7.5	12.5 SOT-132C
		440-470	150	13	12.5 SOT-132C
		470-512	100	7.5	12.5 SOT-132C
		470-512	150	13	12.5 SOT-132C
		68-88	150	30	12.5 SOT-301-A-03
		144-175	150	30	12.5 SOT-301-A-03
		400-440	30	1.5	9.6 SOT-26NC
		400-440	45	2.2	9.6 SOT-26NC
		430-470	45	2.2	9.6 SOT-26NC
		460-512	45	2.2	9.6 SOT-26NC
		380-512	50	2.9	12.5 SOT-75A
		380-480	2.5 WATTS	7	12.5 SOT-75A

the mobile communications industry. These proposals call for channel spacings of as low as 7.5 KHz using various forms of single sideband modulation. (Channel spacing of 12.5 KHz are already common in Europe in the VHF bands.) With most signal generators only just having acceptable performance at 20 KHz carrier offset (the current channel spacing), it is debatable that these generators will be able to perform off-channel tests or be useful for development work on the proposed new systems. Synthesized signal generators such as the Racal-Dana Model 9087 or Hewlett Packard 8662 feature similar phase noise at 3 or 5 KHz carrier offset as at 20 or even 100 KHz from carrier.

Very close to carrier, offsets of less than 1 KHz, the phase noise becomes important when working with low deviation phase modulation and/or when multiplying to microwave frequencies. Again, it is only the multi-loop sophisticated signal generators that can meet these demanding requirements.

Most modern FM communications systems feature either digital data transmission modes or selective calling with digital coding. To evaluate these systems under all operating conditions requires the ability to frequency modulate the carrier with very low rates, or in some cases even DC. The lower cost synthesized signal generators often only use a single phase locked loop which requires closed loop DC operation to maintain frequency stability. These systems usually can only FM at rates above 20 or 50 Hz. The more sophisticated multi-loop systems available from some manufacturers allow true DC coupled frequency modulation.

Switching speed/setting time is perhaps the third important

area that may demand the consideration of a higher cost signal generator. For general purpose applications, a faster switching speed means that more tests may be made in a shorter period of time which can be important when, for example, fully characterizing a filter or checking a receiver for spurious responses. There are other applications particularly in the electronic warfare area that necessitate using a fast switching signal generator. Radio jammers often use a commercial synthesizer as the local oscillator. The response time of the jammer to track frequency agile systems often depends solely on the switching speed of the synthesizer. Switching speed is also important when checking the new generation of anti-jamming (ECCM) communication systems such as SINCGARS. To test an ECCM receiver dynamically, and with both traceability and repeatability requires that the signal generator can respond faster to a message to change frequency than the receiver. Currently, frequency switching speeds of less than 1 millisecond are required, which again precludes the use of the new economy signal sources.

I look forward to reading a further article on signal generators when the technology breakthroughs that influence performance rather than price/performance will be reviewed and discussed.

Sincerely,
Malcolm Levy
RF Products Manager
Racal-Dana Instruments, Inc.
Irvine, CA 92714

For a power resistor that stays non-X up to vhf, there's only one choice.

The Carborundum® Type SP. Only Carborundum has a ceramic power resistor that behaves like a pure resistance rather than an inductor and/or capacitor. It operates from low audio frequencies up into the vhf range. Each unit is a solid body of resistive material. No windings, no film. Ideal for frequency-sensitive rf applications like feedback loops.

And it gives you extremely high power density, with great surge-handling capability because it's solid.

Our Type 234SP, for example, is about the size of a 2-watt carbon comp, but dissipates a full 10 watts in 40°C ambient air. Moreover, it can consistently absorb surges of over 10X rated power for several seconds and come back for more with very little ΔR . Forced-air-cooled, water-cooled or

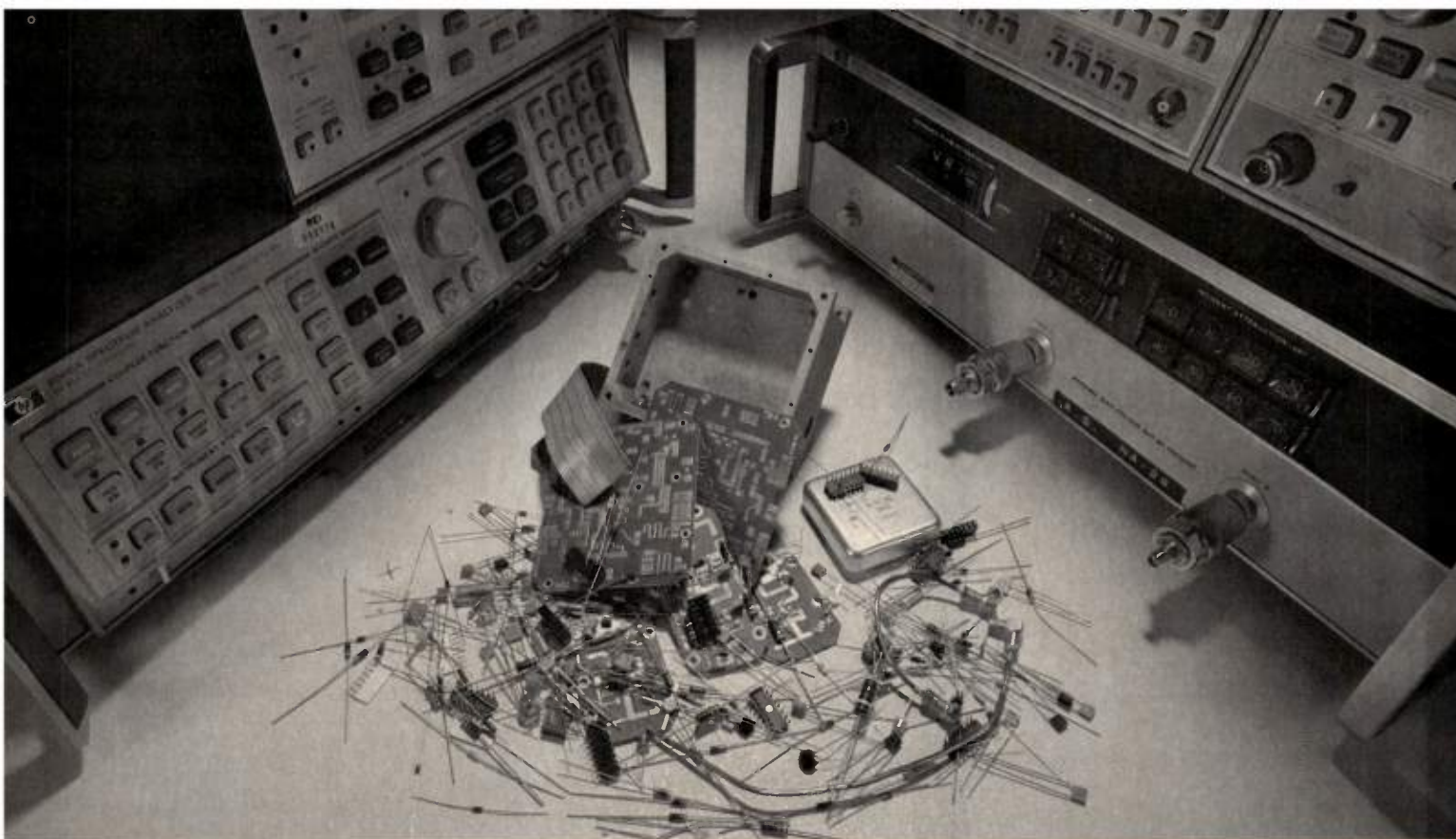
immersed in oil, it will handle even greater power overloads.

Other Carborundum Type SP resistors—including high-power, water-cooled configurations—are rated from 2.5 to 1000 watts. For further details, call or write E. B. (Woody) Hausler at (716) 278-2143.

The Carborundum Company
Electric Products Division
P.O. Box 339
Niagara Falls, New York 14302

CARBORUNDUM
A Sohio Company





Haven't you got better things to do than build your own frequency synthesizer?

Designing your own synthesizer from scratch can be a gut-wrenching experience. You can easily spend weeks, if not months, trying to get the performance you need.

Of course there aren't any "standard" units that meet your requirement. But that doesn't mean you have to go ahead and put the pieces together yourself. Better you should spend a few hours talking to us. And let us take it from there.

We Don't Start from Scratch.

We've already developed the building blocks for a wide range of frequency synthesizers. Working with these modules, we can supply an assembly in far less time than it takes for you to design your own.



This is an Andersen frequency synthesizer. It can save you time, money and endless headaches.

Totally Solid State.

Andersen frequency synthesizers are completely electronic,

so you get a small, lightweight unit with excellent environmental integrity. That's a big plus if you're concerned about vibration, temperature, humidity, sand, dust, etc.

Extremely Versatile.

We can provide a 25% tuning bandwidth with fundamental outputs from 100MHz to 1.3GHz, or multiplied/up-converted outputs to 10GHz. And our units have spurious and phase noise performance comparable to the best in the industry.

So spare yourself a ton of grief. Turn the job over to us. We've been through it all before – for both airborne and ground-based applications.

Just give us a call (203) 242-0761.

ANDERSEN LABORATORIES

Andersen Laboratories, Inc., 1280 Blue Hills Avenue, Bloomfield, CT 06002 Telephone (203) 242-0761 TWX 710-425-2390
Andersen SAW products are available in the United Kingdom and Europe through our sister company, Signal Technology Ltd., Swindon, Wiltshire, UK.

RF Design Launches First RF Technology Expo

Engineers from the United States and 10 foreign countries were among the more than 1,000 registrants expected at the first RF TECHNOLOGY EXPO '85, Jan. 23-25, at the Disneyland Hotel, Anaheim, California. Sponsored by *RF Design* magazine, this was the first expo held specifically for RF design engineers.

As this issue went to press, nearly the entire RF design engineering staff from several companies were planning to attend RF TECHNOLOGY EXPO '85 (Motorola Semiconductor, Phoenix, Ariz., was planning to bring 30 engineers). An *RF Design* reader survey early last year showed many engineers lacked basic RF design knowledge or had forgotten what they once knew. Electrical engineers were being pressed into service in this rapidly growing field with little or no training. Reponse to the expo has verified the reader survey.

Manufacturers of RF devices and tools rented more than 75 booths to display their new and established products, and discuss them with design engineers. Survey respondents had expressed a need to learn about available design components and tools.

Most engineers registered for the expo design communications equipment, many for government, military, aerospace and EMC/EMI applications. Many others design instrumentation and test equipment for military and commercial use.

More than 60 Papers Presented

In addition to the display booths, these interests were reflected in more than 60 papers scheduled in 16 sessions during the three-day event.

To accommodate as many specific interests as possible, three sessions were scheduled to run simultaneously each morning and afternoon. Each session featured several papers related to a general topic, i.e., components, circuits or techniques. Attendees could learn about several aspects of each topic without changing rooms. *RF Design* will publish a Proceedings of papers presented in all sessions that may be purchased by attendees forced to choose between equally

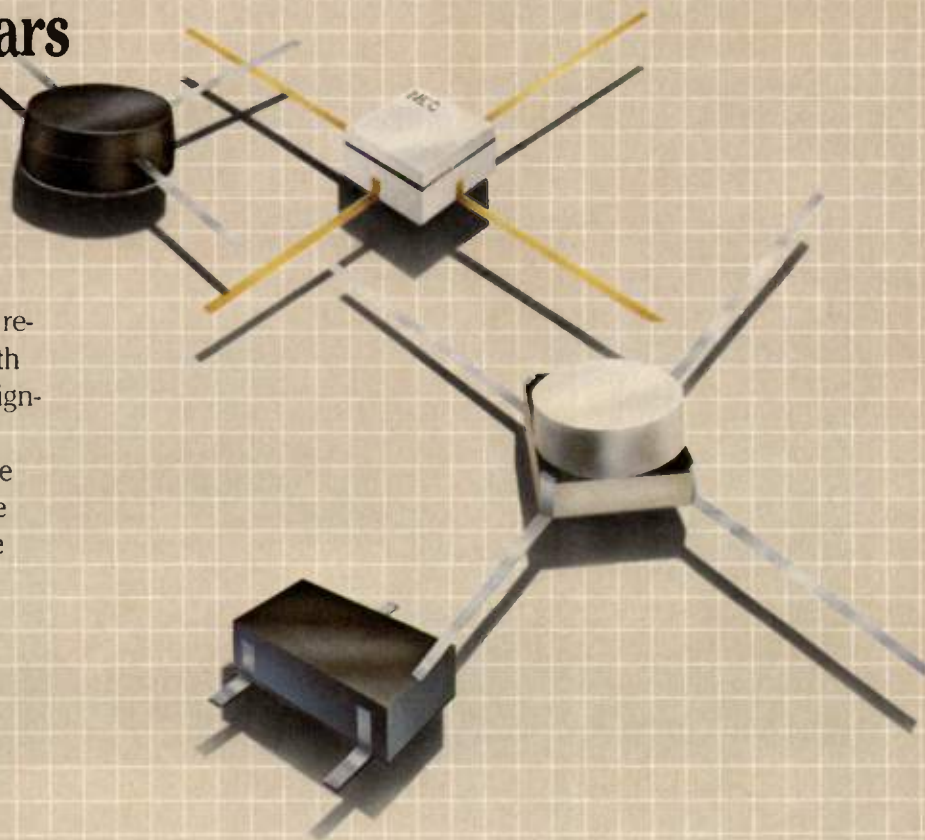
NEC

SOLUTION SOURCEBOOK #2: Small Signal Bipolars

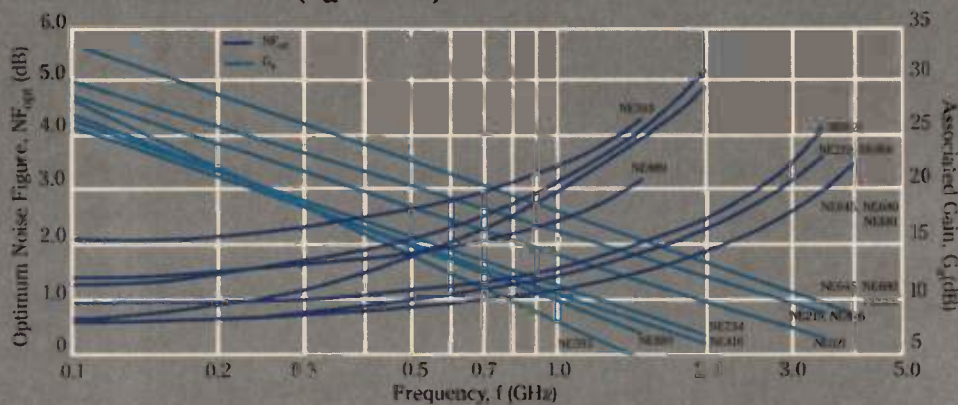
Too often, design engineers are forced to use several device suppliers, juggling cost, performance, reliability, and availability.

Here is the single source solution from NEC: a wide range of small signal bipolars that offer better reliability at a lower cost; good gain with low noise; and the confidence of designing with NEC.

Call your nearest district sales office listed below for data sheets and more information. NEC, the reliable source for complete solutions.



Performance Curves ($T_a = 25^\circ\text{C}$)



CALIFORNIA EASTERN LABORATORIES, INC.—U.S. and Canada
Exclusive sales agent for **NEC Corporation**, Microwave Semiconductor Products.

U.S. Headquarters ■ 3260 Jay Street ■ Santa Clara, CA 95054 ■ Tel: (408) 988-3500 ■ Tlx: 346-393 or 171-197
East Central Office ■ 12 Galloway Ave. ■ Cockeysville, MD 21030 ■ Tel: (301) 667-1310
South Central Office ■ 1101 E. Arapaho, Suite 145 ■ Richardson, TX 75081 ■ Tel: (214) 437-5487
In Europe Contact: NEC Electronics (Europe) GmbH ■ Oberrather Strasse 4 ■ 4000 Düsseldorf 30
■ West Germany ■ Tel: 0211/650301 ■ Tlx: 841/8581353 or 8587419

INFO/CARD 17

WRH

attractive sessions and readers who could not attend RF TECHNOLOGY EXPO '85.

An all-day course, Fundamentals of RF Design, was scheduled for each of the first two days. Course instructors included Les Besser, president, Microwave Education Programs, Los Altos, Calif.; Professor K.C. Gupta, University of Colorado, Boulder; J. M. Johnson, president, Microwave Modules and Devices, Mountain View, Calif.; John Morton, engineer-

ing manager, Microsonics, Inc., Weymouth, Mass.; and Carl A. Erikson, Jr., director of processing operations, Anderson Laboratories, Bloomfield, Conn. *RF Design* is planning to include a transcript of this course in the Proceedings.

Encouraged by the response to RF TECHNOLOGY EXPO '85, *RF Design* is already planning next year's show. It, too, will be held at the Disneyland Hotel in January.

RF Technology Expo '85 Exhibitors

A.H. Systems, Chatsworth, Calif., EMI test equipment and antennas

Acron, Inc., San Jose, Calif., Power transistors, products and assemblies

American Microwave Technology, Fullerton, Calif., OEM RF power amplifiers and sources

American Technical Ceramics, Huntington, New York, Porcelain and ceramic RF capacitors

Amperex Electronic Corp., Slatersville, Rhode Island, Wideband RF semiconductors and linear hybrids

Amplifier Research, Souderton, Penn., Amplifiers and accessories for RF and RFI susceptibility testing

Andersen Laboratories, Bloomfield, Conn., SAW oscillators and filters, frequency synthesizers and filter banks

ANZAC (Division of Adams-Russell), Dividers and log amplifiers

Applied Engineering Products, New Haven, Conn., Subminiature coaxial connectors and coaxial cable assemblies

Austron, Inc., Austin, Texas, Ovenized crystal oscillators and time frequency management equipment

Avantek, Inc., Santa Clara, Calif., Monolithic amplifiers, oscillators and mixer modules

Bird Electronic Corporation, Cleveland, Ohio, RF power measurement instruments, wattmeters and field-strength meter

Chomerics, Inc., Gardena, Calif., EMI shielding materials and components

Cirtech Corp., Stanley, Kansas, Frequency control products, crystal filters, etc. from DC to 200 MHz

Cohan-Epner Co., Brooklyn, New York, Plated coatings for laser cavities and metal optics

Coil Craft, Cary, Illinois, RF fixed and tunable inductors and transformers

Communications Consulting Corp., Upper Saddle River, New Jersey, RF and microwave design and analysis software

Compact Software, Palo Alto, Calif., Software for design, analysis and optimization of MICs

Crystal Technology, Inc., Palo Alto, Calif., SAW bandpass filters, resonators, delay lines, convolvers and VCOs

Dow-Key, Santa Barbara, Calif., Electromechanical coaxial RF/microwave switches

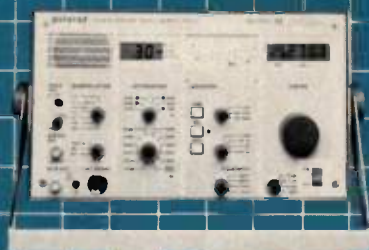
EEsof, Inc., Westlake Village, Calif., RF/microwave software for design and analysis: Touchstone and MICAD

Electronic Surveillance Components, Inc., YIG Tuned transistor oscillators and solid state HP-8551 BWO replacement

POLARAD EMI INSTRUMENTATION

FIELD STRENGTH OR EMI

Two Portables Make it Easier



MODEL ESH2
9 kHz to 30 MHz



MODEL ESV
20 MHz to 1GHz

Polarad's Test Receivers measure in accordance with CISPR, MIL, VDE, VG, SAE and FCC plus Field Strength directly in dB μ V/meter. Portable test receivers, ESH2 and ESV, feature automatic preselection and a digital frequency display with 100 Hz or 1 kHz resolution, respectively. Synthesized local oscillators provide crystal controlled frequency accuracy and stability. Built-in automatic amplitude calibration insures highly accurate selective voltmeter measurements. With Polarad antennas, read-out is directly in dB μ V/meter.

A full line of accessories including antennas, probes and LISN's are available.

Polarad does make it easier.

NOW Buy or Rent.
For rental information
contact U.S.I.R.

**United States
Instrument Rentals, Inc.**



800-227-6884
In CA 415-572-6600
A U.S. Leasing Company

polarad polarad po

Polarad Electronics, Inc. 5 Delaware Dr., Lake Success, N.Y. 11042
Tel: 516-328-1100 TWX: 510-223-0414

Number 1 in a Series.

EMC Technology, Inc., Cherry Hill, New Jersey, SMA connectors, terminations, loads, attenuators and MICs

ERBTEC Engineering, Inc., Boulder, Colo., Computer-enhanced HF CODAR radar system, amplifiers and time systems

Frequency Sources, Inc., Chelmsford, Mass., Semiconductor products, varactors, diodes and capacitors

Greenray Industries, Crystal oscillators, VCOs, temperature compensated oscillators

Hewlett-Packard, Spokane, Wash., Signal generators and phase noise measurement equipment

Holaday Industries, Inc., Eden Prairie, Minn., Isotropic broadband field strength meters with self-zeroing fields.

Intech, Inc., Santa Clara, Calif., Communications and satellite navigation equipment

JFW Industries, Inc., Indianapolis, Indiana, Fixed and programmable attenuators, divider and detectors

Johnson Manufacturing Corp., Boonton, New Jersey, Variable capacitors and microwave tuning elements

K & L Microwave, Inc., LC and cavity filters, phase meters and distortion analyzers

K & L Quartztek, Phoenix, Ariz., Quartz crystal filters and oscillators

Kay Elemetrics Corp., Pine Brook, New Jersey, RF attenuators

Keene Corp./Ray Proof Div., Norwalk, Conn., RF shielded rooms, anechoic chambers, absorbers and filters

L & M Engineering South, Inglewood, Calif., RF and microwave components and subsystems

Logimetrics, Inc., TWT amplifiers and RF signal generators

Marconi Instruments, Allendale, New Jersey, RF power meters, microwave scalar analyzer and signal generators

Matrix Systems Corp., Calabasas, Calif., Coaxial and audio switching systems and modules

Microwave Research Corp., RT/duroid microwave materials

Microwave Modules and Devices, Mountain View, Calif., High-power, solid state microwave modules, including amplifiers

Microwave Semiconductor Corp., Somerset, New Jersey, A full line of RF/microwave semiconductor products and components

Motorola, Inc., Franklin Park, Illinois, Quartz crystals, filters, oscillators and resonators

Motorola Semiconductor, Tempe, Ariz., RF transistors — module and discrete, linear products, logic functions

P & H Laboratories, Inc., Ferrite

isolators and circulators, isoadapters and wave guide assemblies

Pacific Research and Development, Phase locked oscillators and frequency multipliers

Polarad Electronics, Inc., Lake Success, New York, RF test and measurement equipment

Proto Stamping Corp., Redwood City, Calif., RF/EMI shielding and metal fabrication

Racal-Dana Instruments, Inc., Irvine, Calif., RF test and measurement equipment

Rogers Corp., Rogers, Conn., RT/duroid microwave materials

SAWTEK, Orlando, Florida, SAW devices

Soladyne, Inc., San Diego, Calif., Stripline and microstrip circuits

Swift and Associates, Van Nuys, Calif., Swift wrench and other products

NOW an automatic microwave power meter with ~~SPEED~~, accuracy and sensitivity



Take a good look at the New 6960 Power Meter from Marconi.

With the 6910 sensor specially calibrated for CAL factor and linearity, it provides unrivalled accuracy, speed and sensitivity of operation. Comprehensive built-in features enable even the most complex measurements to be rapidly made manually or on the bus.

It has full auto range, auto calibration and a unique auto zero circuit providing ease of operation and virtually eliminating zero carry-over errors, all this with full GPIB.

Complete instrument settings can be stored in the 6960's non-volatile memory and recalled at the press of a button. The μ P gives many benefits such as dB relative, dBm or watts and control of resolution and response time.

The 6960's sophistication doesn't cost a fortune...it's actually less expensive than those old style Power Meters that create as many problems as they solve.

6960 METER

- 0.5% Accuracy
- User Selectable Speed to 25 ms
- Unique Averaging Circuit
- Sensor Linearity Correction
- dB Relative Offset Facility
- Auto Duty Cycle Correction

6910 SENSOR

- 10 MHz to 20 GHz
- -30 to +20 dBm
- VSWR 1.18 from 2 to 12.4 GHz
- 1.28 from 12.4 to 18 GHz (other sensors to -70 dBm)

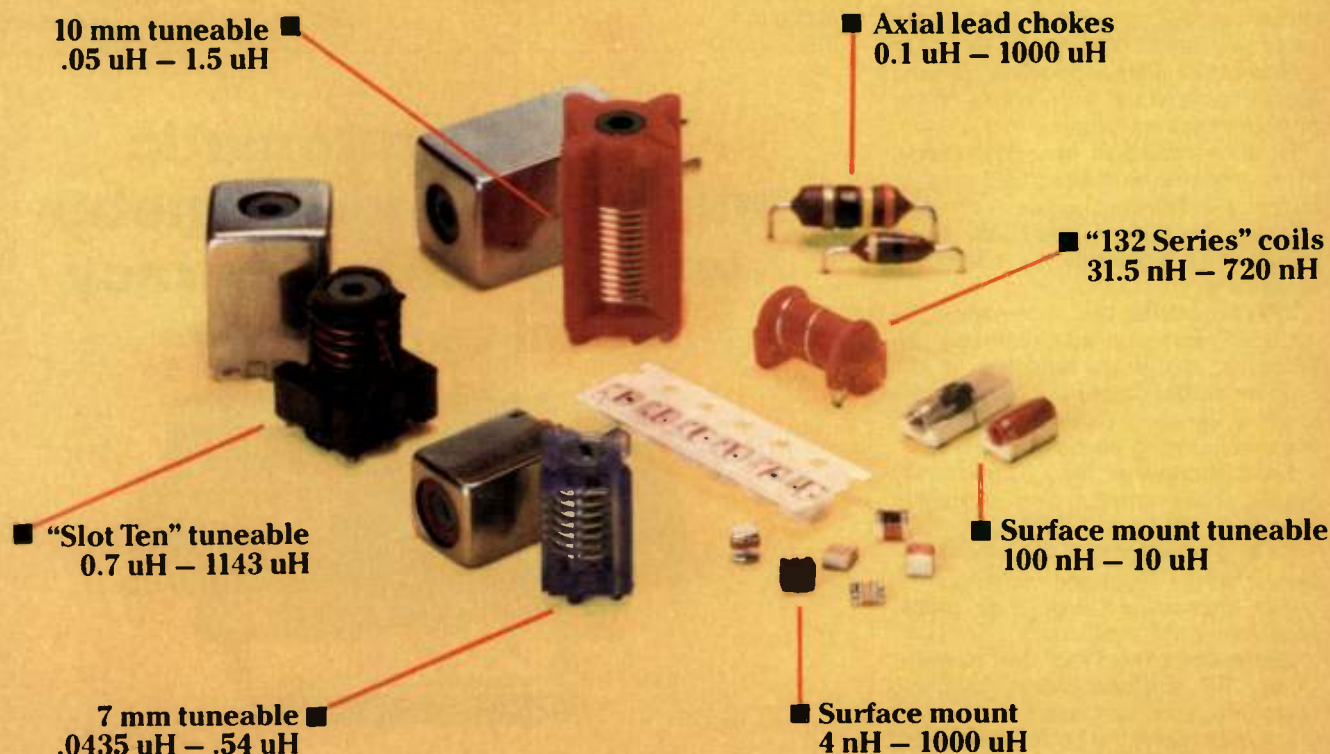
Get 20% more performance for 10% less than the old leader!

- Call for a demo today!
- Write for full brochure.



U.S.: 3 Pearl Court, Allendale, N.J. 07401
(201) 934-9050 (East) • (714) 895-7182 (West)
U.K.: Longacres, St. Albans, Herts AL4 0JN
Country Code 44 (0727) 59292. TELEX 23350
FRANCE: (1) 687-36 25
W GERMANY: (089) 845085

Leaded or surface mount— only Coilcraft gives you all these inductor options



They're all here—from 10 mm tuneables to surface mount inductors. And they're all in stock, ready for immediate shipment.

Our handy Experimenters Kits make it easy for you to pick the right parts. And our low, low prices make them easy to afford, whether you need five parts or five hundred thousand.

If you don't have our latest RF coil catalog, circle the reader service number. Or call Coilcraft at 312/639-6400.

Experimenters Kits

To order call 312/639-6400

Tuneable inductors

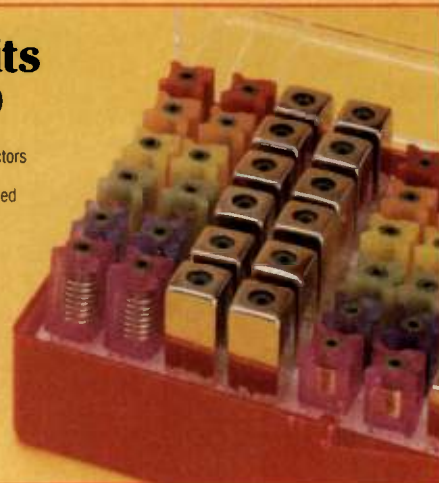
"Slot Ten" 10 mm inductors 0.7 uH-1143 uH 18 shielded, 18 unshielded (3 of each)	"Unicoil" 7/10 mm inductors .0435 uH-1.5 uH 49 shielded, 49 unshielded (3 of each)
Kit M100 \$60	Kit M102 \$60

Surface mount inductors

Fixed inductors 4 nH-1,000 uH 64 values (6 of each)	Tuneable inductors 100 nH-10 uH 11 values (6 of each)
Kit C100 \$125	Kit C101 \$50

Fixed inductors

Axial lead chokes 0.1 uH-1000 uH 25 values (5 of each)	"132 Series" coils 31.5 nH-720 nH 20 values (6 of each)
Kit F101 \$50	Kit F100 \$50



Coilcraft

Dept. D, 1102 Silver Lake Rd., Cary IL 60013 • 312/639-6400

See us at RF Tech Expo, Booth #420

INFOCARD 21



"I think we're almost there!" "How far did you say it was?"

ATTENTION: Managers and Engineers responsible for QA/QC, Design Test, Production Test, Field Service Test, Optical Inspection. . .

The World of Test, Measurement and Inspection Technology Opens to You May 14-16, 1985 at the San Jose Convention Center San Jose, CA

Whether you need to select or buy test, measurement or inspection equipment; or, to keep current with the latest developments in test, measurement

Areas of test, measurement and inspection technology covered by the technical program and exhibit:

Robotics and Machine Vision • Test Data Analysis • CAM/CAD/CAT
• Electro-Optics Test • Image Analysis for Test & Inspection • Factory of the Future Test, Measurement & Inspection • Subassembly/ System ATE • Test Software • VLSI Test • Component Test • Test Instruments • Communications Test • Microwave Test • Economics of Testing • Process Monitoring • Test/Analysis Services • Optical Inspection • Failure Analysis • Microelectronics Measurement • Fiber Optics Test • EMI/RFI Test & Evaluation • Precision Instruments • Production/QA/ATE • Test Hardware • Networking

and inspection technology, the 1985 Test & Measurement World Expo can expose you to the most productive approaches. Be certain to attend.

Test & Measurement World Expo, 215 Brighton Avenue, Boston, MA 02134, 617/254-1445

YES, I'M INTERESTED

- ☐ Please send me detailed information on the 1985 Test & Measurement World Expo technical program as soon as it is available.
- ☐ I want to show my products as an exhibitor at Test & Measurement World Expo.
- ☐ Please have a Representative phone me.

NAME _____ TITLE _____
COMPANY _____
MS/DEPT. _____
ADDRESS _____
CITY/STATE/ZIP _____
TELEPHONE _____

Return coupon to: Test & Measurement World Expo,
215 Brighton Avenue, Boston, MA 02134.

1985 Test & Measurement World EXPO

May 14-16, 1985 • San Jose Convention Center, San Jose, CA

INFO/CARD 22

The Program in Brief

Wednesday, Jan. 23, 8:30 a.m.-noon

Fundamentals of RF Design — Part 1

Computer-Aided Design

"Use of personal computers as a tool in prediction and control of EMI"
 "CAD methodology for microwave oscillators"
 "Small computers in RF design"
 "CIAO and design: circuit optimization and synthesis programs for personal computers"

Components — Transistors

"Hybrid varactor-tuned oscillator modules: their practical applications in RF communications"
 "Surface mounted components"
 "Integrated circuits for IF amplifiers and demodulators"
 "Motorola advanced amplifier concepts"

Transmitters

"A 4kW broadband (40 kHz to 40 MHz) pulsed power amplifier"
 "RF operation of 450 volts vertical power MOS transistors in an ultra-lightweight HF transmitter"
 "Low noise UHF transmitter design"

Wednesday, Jan. 23, 1:30 p.m.-5:00 p.m.

Fundamentals of RF Design — Part 2

Circuits

"Design compromise in single loop frequency synthesizers"
 "A temperature stabilized RF power detector"
 "An ultra-fast UHF voltage controlled attenuator with 35 dB linear dynamic range"
 "Design of GaAs power FETs module"

Techniques

"Mounting considerations for RF low power plastic packages"
 "Using Avantek MODAMP MMICs in broad and narrow-band filter design"
 "Computer-aided design of phaseback loop circuits"

Antennas

"Helical antenna design"
 "Snyder antenna"

Thursday, Jan. 24, 8:30 a.m.-noon

Fundamentals of RF Design — Part 1

Components

"The hybrid amplifier module for cellular telephone design"
 "High frequency blind mating connectors for efficient microwave packaging"
 "High voltage UHF power static induction transistors"

Circuits

"Aspects of discriminator design"
 "A precision glitch-free RF step attenuator"
 "A 900 MHz super amplifier"
 "Precise bandwidth combine filter realization"

Techniques

"Amateur satellite communication uplink"
 "Testing digital data systems"
 "Precision phase noise measurements of oscillators and other devices from 1 MHz to 20 GHz"
 "Adaptive HF radio systems"

Thursday, Jan. 24, 1:30 p.m.-5:00 p.m.

Fundamentals of RF Design — Part 2

Computer-Aided Design

"Matching network design using HP-41, HP-71 and HP-75 computers"
 "Computer and calculator aided design tools for the RF engineer"
 "RF computer aided engineering — main-frame performance on microcomputers"

Transmitters

"Large signal power amplifiers"
 "A 2 GHz amplifier provides telemetry capability"
 "An integrated Ka-band power amplifier"
 "Class-D power amplifier load impedance for maximum efficiency"

Techniques

"Application of digital signal processing"
 "ACSB — an overview of amplitude modulated sideband technology"
 "Electrical characterization of quartz crystal resonators through high performance vector network analysis"
 "Application of coherent digital memories of communications jamming"

Synergy Microwave, Patterson, New Jersey, Mixers, power dividers modulators, quadrature hybrids and transformers
Tektronix, Inc., Woodland Hills, Calif., Spectrum analyzer, tracking generator and accessories

Tele-Tech Corp., Bozeman, Montana, Signal processing components and RF/microwave subassemblies

Telonic Berkeley, Inc., Laguna Beach, Calif., RF and microwave filters, RF attenuators and DSWR systems

Texscan Corp., Phoenix, Ariz., Spectrum analyzers, sweep generators, synthesized signal generators

Trilectic, Inc., Las Vegas, Nevada, TRW RF Devices Division, Lawndale, Calif., Low noise small signal transistors, other transistors and RF amplifiers

Vari-L Co., Denver, Colo., Wideband signal processing components, mixers, transformers and hybrids

Varlan-Eimac, San Carlos, Calif., **Varitech Electronics, Inc.**, Lynbrook, New York, Fixed RF capacitors, dielectric and variable capacitors

Vectron Laboratories, Inc., Norwalk, Conn., Crystal oscillators, including TCXOs, VCXOs, VCOs, OCXOs and hybrids

Voltronics Corp., East Hanover, New Jersey, Precision trimmer capacitors

Wavetek, San Diego, Calif., Microwave and RF miniature components, RF signal sources

"Micro-Coax" Gives Its Name to New Company

A new company, Micro-Coax Components, Inc., has been formed by UTI Corp., Collegeville, Penn., out of its former Micro Delay Division in Collegeville, effective January.

Growing along with the booming RF market, the Micro Delay Division of UTI has had to expand its facilities four times in the past decade. The continuing growth has "dictated incorporation as a separate subsidiary," said Dr. Robert H. Schafer, president of the new Micro-Coax Components.

The Micro Delay Division was established in 1962 by Uniform Tubes (also a division of UTI) to produce miniature semi-rigid coaxial cable. The division developed several advanced techniques for producing a high quality, reliable semi-rigid coaxial cable and gave it the name Micro-Coax.

The Micro-Coax brand name's reputation was a major factor in selecting the name Micro-Coax Components, Inc., for the new operating company. Micro-Coax is the holder of patents for several other

Now! EMC testing services from Instrument Specialties— the company that knows shielding inside and out!

If you're involved with keeping RFI/EMI in or out, you already know about Instrument Specialties. You've probably used our beryllium copper shielding strips...received our engineering help...even used our new line of ESD devices.

And *now*—the superb EMC testing facilities we use to assure performance of our products is *available to you for the first time*. You now can access the sophisticated equipment you don't have—but *must* have—to secure the test results you need!

State-of-the-art computer-controlled emission and susceptibility measurements from 10 kHz to 1 GHz...RF gasket evaluation...FCC/VDE/CISPR and MIL-STD-461A/B Tests...networks for power line conducted RF emission tests...semi-anechoic shielded enclosure...confirming open field test site...computer-produced hard copy readout of test results—all are yours at Instrument Specialties.

Following testing, you'll leave our facility with the precise documentation you need. In the event you need help to meet required interference specifications, we can supply that as well. All this, from one qualified source!

For more information, rates, and schedule availability, phone us and ask for EMC Customer Service. Or, write us at Dept. RFD-10.



INSTRUMENT SPECIALTIES COMPANY, INC.

Delaware Water Gap, PA. 18327

Phone: 717-424-8510 • TWX: 510-671-4526

Specialists in beryllium copper since 1938

products, such as impedance transformer cable and assemblies, and low-pass, bandpass and high pass filters implanted within the cable assemblies. The "In-A-Cable" filters are being widely used for the suppression of undesired signals in transmitting sources and suppression of unwanted frequency bands in receiving systems. The company also offers a line of coaxial connectors, and coaxial and waveguide delay lines.

Micro-Coax Components, Inc., is planning to introduce several new products during 1985, according to Dr. Schafer.

EG&G/Cinox Pact Gives New Depth in Oscillators

Cinox Corp., a Cincinnati, Ohio firm familiar to *RF Design* readers as a maker of quartz crystals and crystal-based oscillators used for frequency control and stabilization, has been acquired by EG&G Inc. of Wellesley, Mass., for an undisclosed amount of cash.

Cinox has been since 1930 a privately-held company and now employs more than 200 people. Commercial and military applications of its components are primarily in the areas of communications, navigation, guidance, tracking and telemetry.

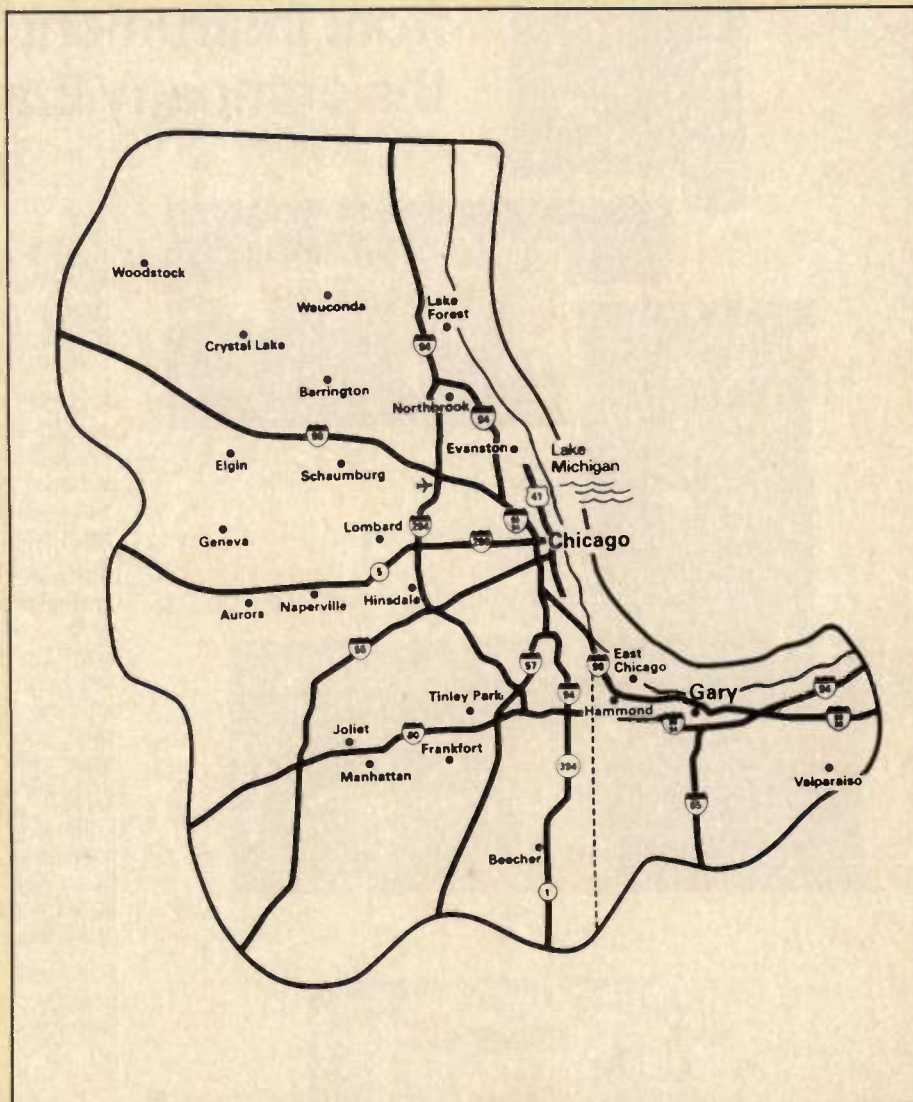
Cinox President W. Kirk Dance said the Cinox expertise in the design and manufacture of high-performance oscillators would complement that of EG&G's Salem, Mass.-based Electronic Components Division in the development of atomic frequency standards for future military and commercial voice and data communication systems; space and global navigation systems; and military command, control and intelligence systems.

"The acquisition makes sense," Dance said. "Their technology matches our technology." He said the acquisition provides Cinox with the capital backing to increase an already impressive rate of growth. "We have grown so rapidly in the past four years that it attracted EG&G's attention," Dance said. "They have more capital than we do so we can grow faster."

In a private interview with *RF Design* (the phone is now answered "EG&G Cinox"), VP of Marketing Ron Stephens alleged that new product developments traceable to the new connection would be announced "shortly." For more information contact Ron at (513) 542-5555.

Cells Multiply In Chicago Carphone Market

Ameritech Mobile Communications, Inc., operator of the nation's first commercial cellular carphone service — launched



Cellular Service coverage for the Chicago/Gary area.

in Chicago in October 1983 — recently announced plans to double the size of the Chicago system by mid-1985. The initial service area covered 2,500 square miles in the greater Chicago metropolitan area, ranging from Lake Forest on the north to Geneva on the west to Beecher on the south. In the announced expansion plan the coverage area will increase to 5,000 square miles, and range from Waukegan on the north to Gary, Ind., on the south (see map illustration).

Ameritech Mobile, which introduced its service with just 17 "cells," has since increased the number of cell sites to 29 and with the new expansion will boost that number to 56, including seven new cells specifically designed to improve service in downtown Chicago. The expansion will double customer capacity as well as system size. The company currently has about 12,000 customers. Capital invest-

ment to date has totalled \$45 million. The expansion is expected to require another \$21 million, according to Ameritech.

Most of the capital invested goes toward the purchase of RF equipment. Each cell site in the 56-cell system requires a transmitting/receiving tower and remote switching gear. Car telephone radios, receivers and antennas represent additional investment on the part of individual subscribers.

Ameritech Mobile, a subsidiary of Bell's Ameritech, also announced the availability of new custom calling features to enhance the carphone service. Call waiting, call forwarding, three-way calling and busy/no answer transfer are being introduced now to current customers. A revised tariff schedule filed with the Illinois Commerce Commission last October 24 reflects generally falling prices for standard services (e.g., \$20 one-time charge to establish service).



MOTOROLA



We must communicate with you at once. On land, at sea, in the air, the right semiconductor for your frequency.

Motorola RF devices are everywhere. They have to be. More communications technology means more progress in the information age and more profits for those immersed in its development.

There's a multitude of standard and state-of-the-art Motorola RF devices ready for your new designs, capable of new performance benchmarks, available for your order. Now.

New roads in land-mobile.



From MAACPAC™ to 300 MHz modules, you have total flexibility of choice and performance with Motorola. The new MRF 848/898, 55/60 W, 12.5 V and 24 V MAACPAC discretes provide unprecedented broadband performance and complement an already broad line for commercial/military applications. The 900 MHz MHW800-series modules increase reliability, minimize design time and provide improved performance in a lineup two years ahead and moving away from everyone else's.

In low-power, the U.S.-made, GaAs MRF 966 provides 1 dB gain at a gigahertz, the MRF 557 PowerMacro 1.5 W output in popular plastic packaging and the MRF 571 7-8 GHz f_T performance from the MRF 571.

Super carrier for marine (SSB) radio.



The largest, single transistor for RF frequencies is here now in the MRF 153/154 series—fully 600 W of power—and in TMOS™ FET technology, too. That means top efficiency to leap frog space and budget-limited designs for marine/SSB equipment.

You can choose from an assortment of over 50 devices for these frequency bands including power outputs from 1 W to 600 W, 12.5 V to 50 V.

Above it all in avionics/military.



Choose from the unquestioned broadest line of 28 V bipolar and

FET types.

And design in the new MRF 392, 125 W, push-pull broadband unit with built-in impedance matching for simplicity and cost-saving. It offers even-numbered harmonic suppression for the 30 to 500 MHz range.

In between, around and among these top new performers are more than 500 RF semiconductors that provide the complete application solution.

Available, mass-produced and economical, they're designed for your advanced engineering concepts.

One-on-one design-in help.

Get an engineer-to-engineer update on all the latest RF semiconductor products and technologies.

1-800-521-6274

Call toll-free any weekday, 9 a.m.-5 p.m. your time. Or, we'll have a local field application engineer drop by.

For Motorola RF technical literature send the coupon to Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036.

We're
on your
design-in
team.



MOTOROLA

*Input and output matching inside RF package.

INFO/CARD 25

To: Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036
Please send me more information on Motorola RF products.

224RFD020085



Name _____

Title _____

Company _____

Address _____

City _____

State _____

Zip _____

Call Me () _____

Modules Lead the Way at RF TECHNOLOGY EXPO

By Kiyoshi Akima
RF Design

Many of the exhibitors at RF TECHNOLOGY EXPO are displaying modular devices that can be used as "supercomponents." Very few engineers will take the time to design a component, for example a resistor, needed in a system. One simply specifies the desired performance, and purchases a resistor. In the same way, a designer can specify a device such as a power combiner or an amplifier, and purchase a module which can then be used as if it were a component.

Both active and passive devices are available as modules, and they are available as monolithics or hybrids. They may be constructed using either thin or thick film technology, or both. While the remainder of this article focuses on one of the most widely available types of modular devices, the power amplifier, most of the discussion is also applicable to other types such as attenuators and frequency mixers.

Each type of construction has its advantages and disadvantages. Monolithics are formed on a semiconductor substrate by deposition and photolithography, as a printed circuit. As a result, they are generally smaller physically and less expensive than the hybrid modules. They can require less than a square inch of board space, and cost under \$2 in production quantities.

Hybrids are constructed with discrete components on substrates. At the expense of size and cost, they provide better performance and higher power levels than can be achieved with monolithics. RF power amplifiers producing over 100 W are available, but they can cost as much as \$200 or more.

Being standard 50 ohm in/50 ohm out devices, modules can be used without the need for additional mixers and shunts. If a single module won't do the trick, more can be cascaded, within the limits of each unit's power rating. Most modules do not allow external adjustments and tuning.

Modules provide many advantages. Among them are repeatability, size, time, and cost. The variations in component values have been taken into account, and

the modules come "pre-tweaked" to meet tight tolerances. This can reduce the amount of adjusting and tuning required for each circuit.

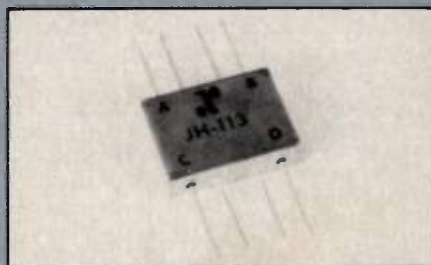
By using modules instead of discrete components, the resulting circuit can usually be made much smaller and simpler. Fewer components mean fewer interconnections. Fewer connections mean more leeway in the layout. Often the heat dissipation of a module is less than that of an equivalent discrete circuit. This can eliminate additional heat sinks or cooling systems.

The use of modules also considerably reduces the time required to produce a product. Once the requirements for an amplifier have been determined, the amplifier does not have to be designed and developed. The module manufacturer has already done this for you. The module, by being one component instead of a collection of elements reduces the time required to assemble the circuit. By not needing to tune each circuit the assembly time is reduced further.

Cost is another item that can be reduced by using modules. The time savings in the design and manufacturing phases translate directly into cost savings. Smaller circuits require less materials, and can be housed in smaller enclosures. Sometimes, the modules themselves also costs less than the discrete components required to build the equivalent circuit.

Supercomponents

The Anzac Division of Adams-Russell has developed a new quadrature hybrid to cover the 7 to 14 MHz band in a miniature flatpack. The JH-113 features typi-



Adams-Russell

cally 27 dB isolation and a low loss of 0.5 dB over the entire octave. Other features include 1.2:1 VSWR and 0.75 dB amplitude balance. The JH-113 is a hermetically sealed unit for military environments. Adams-Russell Co., Anzac Div., Burlington, MA 01803. Booth #321, 323, 325; Info/Card #112.

The Avantek MTO-8040 varactor-tuned oscillator covers 400 to 600 MHz with +10 dBm power output into a 50 ohm load. It



Avantek

is packaged in TO-8V transistor cans and is fully tested and guaranteed over the full -54 to 85 C military temperature range. Avantek, Inc., Santa Clara, CA 95051. Booth #516, 518; Info/Card #111.

The BT500 active bias thermal tracking device from TRW provides excellent thermal tracking and requires only limited external circuitry for operation. It is available in a variety of packages, including the standard hermetic TO-60. TRW Electronics Components Group, RF Devices Div., Lawndale, CA 90260. Booth #217, 219; Info/Card #110.

The Watkins-Johnson WJ-EA54 Economy Amplifier provides 27 dB typical gain from 10 to 250 MHz. The unit's noise figure is 3.8 dB and its output power the



Watkins-Johnson

(Continued on page 29.)

A 1000 watt (1 kilowatt) solid state amplifier, the Acrian PB-2022, is designed for military and industrial communications, and research equipment. It is characteristic of a family of standard wideband high power amplifiers available from Acrian, Inc.

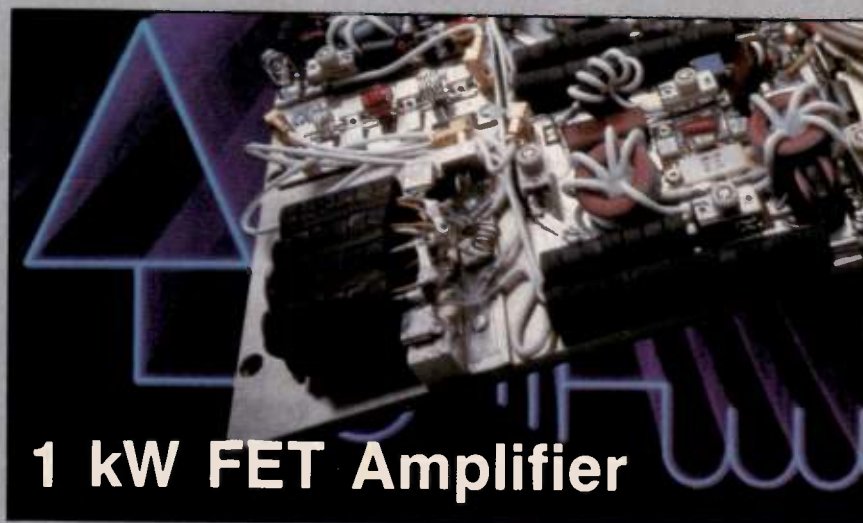
As the industry has grown in size and made advances in technology, competition has increased dramatically. Combined with a shortage of RF and microwave design engineers, it has become essential for systems manufacturers to shorten design time for customers. This has resulted in more and more component suppliers offering modules and sub-assemblies to systems houses. It saves customers substantial time and money in a rapidly moving market.

Custom sub-assemblies, like the PB-2022, are designed to meet these needs. Because they are familiar with advances in device technology, engineers at companies such as Acrian can select current state-of-the-art devices for wideband power amplifiers and therefore provide a technology edge for customers. Well-designed amplifiers can then be easily adapted to a standard product line, allowing systems companies faster access to markets.

The PB-2022

Designed to meet military specifications — like all Acrian sub-assemblies — the PB-2022 has wide instantaneous bandwidth (30-150 MHz), high power gain (+50 dB), ALC gain flatness, plus wide dynamic range (60 dB). It is unconditionally rugged and stable at 3:1 VSWR and has a wide temperature range (ambient to +50 C, with heat sink to +70 C). Offering superior performance, the PB-2022 uses Acrian's proprietary ISO-FET device technology.

As with all other Acrian sub-assemblies, the PB-2022 can be



1 kW FET Amplifier

repaired in the field. It can be easily removed and replaced to minimize down time should a failure occur. The input splitter and the output combiner have excellent port-to-port isolation. This is important in the event of a failure in the output stage. If this happens, the amplifier will continue to operate at a reduced power level.

Because the PB-2022 is so efficient, a simple heat exchanger can be used. The amplifier can be easily cooled with only conventional heatsinks and forced air. When mounted into a 19 inch by 7 inch high rack, the unit can be cooled by using a 300 CFM of air with a back pressure of 1 inch of water with the proper selection of heatsinks and mechanical layout.

Design Features

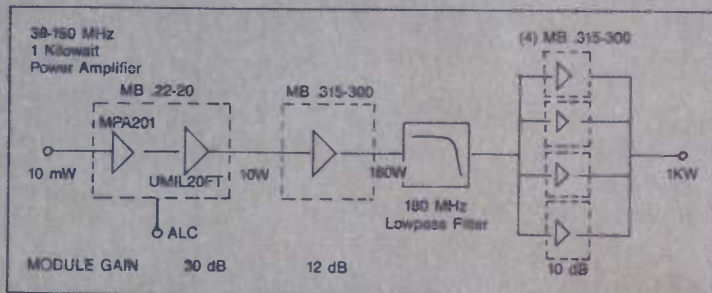
The PB-2022 is made from two basic 50 ohm power block modules. The first is a 20 watt pre-amplifier, similar to the Acrian MB22-20. Two stages of amplification are employed: the first is a 50 ohm hybrid followed by a power FET. An ISO-FET was used at this point in the line-up due to its superior gain versus controlled voltage

characteristic as well as its 4 dB noise figure and 15 dB of gain. More than 60 dB dynamic range is achieved in this single power block.

A common 300 watt module is used for the driver and in the combined output stage. Extensive use of ferrite-loaded coaxial transformers assure multi-octave bandwidths. The input has a 4:1 ratio, while the output has a 9:1 ratio. The quiescent current of each module may be individually set with an on-board potentiometer, thereby allowing module swapping. Typical module efficiency is greater than 60 percent.

The transistor is composed of 2 matched pills mounted on a common flange and is operated in the push-pull mode. This is called the "Gemini configuration." Both even and odd mode terminating resistors assure stable operation.

A conventional 50 ohm, 4-way in-phase splitter and combiner is used in the PB-2022. Unique combinations of 2-way, 6-way, and 2 x 4-way configurations have been demonstrated — all using the basic 300 watt power block module. Acrian, Inc., San Jose, CA 95126. Booth #301, 303; Please circle INFO/CARD #189.



Specifications

Operating Frequency	30 to 150 MHz Instantaneous
Power Output	1 KW into 50 ohm Load
Power Output into 2:1 VSWR	500 Watts Minimum
Power Input	+10 dBm
Power Gain	50 dB Minimum
ALC Control	Output Level Control Provision
Input Impedance	50 ohms 2.0:1 VSWR Maximum
Operating Voltage	28 Volts
Efficiency Overall	40% Min.
Harmonics	2nd <-25 dBc/3rd <-15 dBc
Stability	Unconditionally Stable in 3:1 VSWR

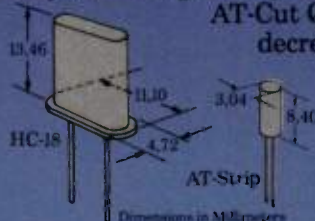
AT-STRIP QUARTZ CRYSTALS SET NEW SIZE AND PERFORMANCE STANDARDS.



**90% SMALLER THAN HC-18
WITH GREATER SHOCK
RESISTANCE AND A WIDE
FREQUENCY RANGE**

Motorola introduces the latest technology in crystal miniaturization. This success is part of our ongoing commitment to reliability and smaller size.

It is the 3.0 mm x 8.4 mm AT-Strip Quartz Crystal. You get the performance of conventional AT-Cut Quartz in a significantly decreased package volume.



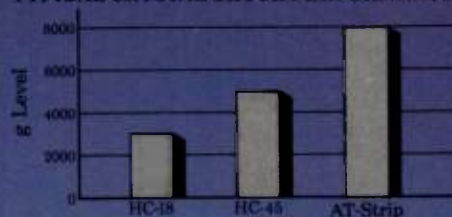
Both new and existing applications benefit from this development — pocket pagers, disk drives, modems, commercial communications devices, and driving microprocessor-based systems.

WITHSTANDS 8,000 g SHOCK FORCE

The new Motorola AT-Strip Crystals offer a shock survival level two and three times higher than traditional crystals.

These and other environmental characteristics are documented in tests performed in accordance with MIL STD 202.

TYPICAL CRYSTAL SHOCK PERFORMANCE



Our advanced manufacturing and quality assurance capabilities provide unsurpassed reliability in the field.

EXPANDING AVAILABILITY OF FREQUENCIES


Motorola AT-Strip Crystals are currently available in popular fundamental frequency ranges. And our engineers are adding frequencies daily — with the shortest lead times in the industry — to meet your needs.

That means you can start incorporating a new AT-Strip Crystal in your applications now. Give your new products an edge. And improve your current product's performance. Contact us for complete literature on the full line of Motorola Devices.

Motorola, Inc. Components Division,
2553 N. Edgington Street, Franklin Park, IL
60131. Phone (312) 451-1000, Ext. 4414
TWX 910-255-4619, Telex 4990104.



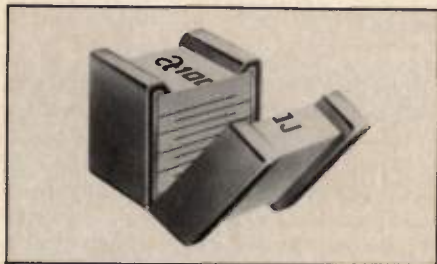
MOTOROLA INC.
Components Division

© 1985 Motorola, Inc. Motorola and  are registered trademarks of Motorola, Inc.

1-dB compression point is +5 dBm. Typical output VSWR is 1.2:1 and DC current required at 5 v is 30 mA. **Watkins-Johnson Co., Components Applications Eng., Palo Alto, CA 94304. Booth #500, Info/Card #109.**

Components

A new termination metallization called UNI-TERM has been developed by American Technical Ceramics. The process uses silver or silver palladium thick film as the primary layer. A proprietary nickel layer is then applied to the thick film material. A final application of a fugitive layer of pure gold completes the process. Some of the advantages of UNI-TERM are: compatibility with all standard circuit



American Technical Ceramics

attachment techniques including wire bonding, soldering, and epoxy bonding; excellent solderability; and reduced termination material migration. UNI-TERM is available at no extra cost on any ATC chip, and will be standard on new products. **American Technical Ceramics, Huntington Station, NY 11746. Booth #611; INFO/CARD #176.**

Surface acoustic wave hybrid oscillators from Andersen Laboratories are available in a standard design package for a wide range of applications. Compact,



Andersen Laboratories

low phase noise devices requiring no alignment, they are available with operating frequencies from 100 MHz to greater than 1 GHz. Both fixed frequency and VCO devices are available. **Andersen Laboratories, Inc., Bloomfield, CT 06002. Booth #211; INFO/CARD #175.**

A family of 21.4 MHz IF filters packaged in less than 1/2 cubic inch (1.75" L x 0.6" W

x 0.44" H) will be exhibited by Cirtech. The family is available in 3 dB bandwidths from 2 kHz to 10 MHz and features spurious responses of better than 60 dB, attenuation better than 70 dB, and ripple below 1 dB. The size uniformity is ideal for applications offering optional bandwidths. The 0.44" height allows half-inch board spacings. These filters conform to MIL-STD-202, Method 204, Condition B. **Cirtech Corp., Stanley, KS 66223. Booth #511; INFO/CARD #174.**

Coilcraft is exhibiting their line of surface mount inductors and transformers.



Coilcraft

Coilcraft, Cary, IL 60013. Booth #416; INFO/CARD #173.

Crystal Technology's surface acoustic wave filters can be used for IF filtering, timing extraction, and general spectral shaping in a wide variety of applications, including TV and CATV, satellite receiver, telecommunications, radar, and telemetry systems. They provide greater selectivity, reproducibility, and stability than either LC or helical filters, especially at UHF or L-band frequencies. Out-of-band rejection of 70 dB can be realized with a single filter, and over 100 dB can be achieved by cascading two units. **Crystal Technology, Inc., Palo Alto, CA 94303. Booth #412; INFO/CARD #172.**

The Dow-Key 402 series SPDT "Smart Switches" use the latest MIC detector and solid-state CMOS driver technology internally to detect power and VSWR changes and switch automatically when preset conditions are met. They feature high power handling (350 W at 1 GHz) and low insertion loss (0.5 dB at 12 GHz). The



Dow-Key Microwave

"Smart Switches" are designed for redundant transmitter applications where automatic switching is required if the power decreases in one channel (amplifier failure) or the antenna pattern is disturbed (disconnected or damaged). **Dow-Key Microwave Corp., Carpinteria, CA 93013. Booth #105; INFO/CARD #171.**

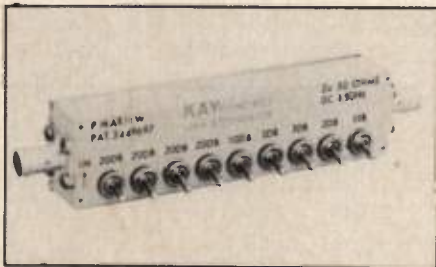
The TSO500 miniature thin film chip attenuators are available from EMC Technology in 1 to 20 dB values, for the frequency range from DC to 18 GHz. At-



EMC Technology

tenuation accuracy is ± 0.25 dB. Impedance is 50 ohms and power dissipation is 0.1 W. The attenuators operate from -55° to 150°C . Measuring only 0.075" x 0.060" with 0.025" terminals, these automatically trimmed attenuators are suitable for circuits of all types where packaging density and improved high frequency performance are important considerations. **EMC Technology, Inc., Cherry Hill, NJ 08034. Booth #309; INFO/CARD #170.**

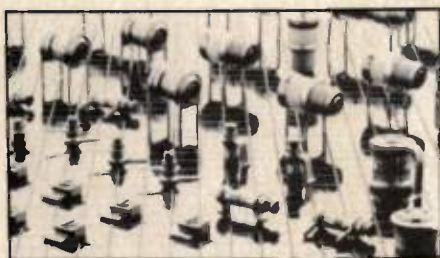
The Model 439 from Kay Elemetrics is a miniature bench attenuator designed to provide a frequency range of DC to 1500 MHz. Attenuation range is 0 to 101 dB in



Kay Elemetrics

1 dB steps. VSWR is 1.2 below 500 MHz and 1.4 above 500 MHz. Insertion loss is 0.2 dB below 500 MHz, 0.5 dB between 500 and 1000 MHz, and 0.8 dB above 1000 MHz. The 439 is available with BNC connectors, with SMA or TNC available as options. **Kay Elemetrics Corp., Pine Brook, NJ 07058. Booth #423; please circle INFO/CARD #169.**

The "A" and "E" line of internally sealed air trimmers offer ten full turns of adjustment, long life, Qs over 5000, internal stops, extended shaft options, and tuning ranges of either 0.8 to 10 pF or 0.8



Voltronics

to 14 pF. Their non-rotating piston glass trimmers offer much higher capacitance values, exceeding 250 pF. The non-rotating design provides excellent linearity, high current capacity, low RF loss, high Q, and long life. The "M" series of sapphire trimmers are usable to 3 GHz while the "CP" series of surface-mounted trimmers are usable up to 5 GHz. Voltronics Corp., East Hanover, NJ 07936. Booth #613; INFO/CARD #168.

Systems

The Austron Model 2110 is a microprocessor-controlled disciplined frequency standard that automatically locks the frequency of its precision ovenized crystal oscillator to that of an externally applied reference having superior long-term stability. Using a third-order servo tech-



Austron

nique, the instrument is able to correct the frequency offset and aging of the internal oscillator. If the external reference is removed or fails, the 2110 will continue to apply corrections to the oscillator to hold it on frequency. Typically the unit can limit the frequency offset to a few parts in 10^{12} for several days following the loss of the reference. Austron Inc., Austin, TX 78761. Booth #602; INFO/CARD #167.

Designed to be part of a larger multi-kilowatt RF power amplifier system, the Erbtec RF Amplifier Controller incorporates the intelligence and all the necessary electronics to monitor, control, and properly drive external high power vacuum tube amplifiers. Its modular architecture includes a RS-232 interface enabling all functions to be completely controlled and monitored by a remote computer. The instrument has very few manual adjustments, and no special tools are required for maintenance. Erbtec, Inc., Boulder, CO 80301. Booth #316; INFO/CARD #166.

Using MOSFET technology, the Intech COM 1000 provides 1000 watts over a frequency range of 1.6 to 30 MHz. The harmonic distortion is at least 73 dB below the fundamental at rated output power. The COM 1000 incorporates a "soft fail" mode in which operation is impaired but not inhibited upon failure of one or more FETs. In this mode the output is less than 3 dB down. Intech, Inc., Santa Clara, CA 95050. Booth #502; INFO/CARD #165.

Test Equipment

A solid-state, cavity-tuned, RF power signal source, the RPS 3000 from American Microwave Technology produces 10 watts of CW output from 3.0 to 3.5 GHz. The output is isolated to safely provide

High Quality Attenuators at Low Prices!



High quality attenuators don't necessarily have to include high quality prices. Kay attenuators are designed and manufactured with high quality components but we do not subject our buyers to high prices. The Model 439 was designed to offer all of the superior specifications of the Model 432D but at a reduced cost, providing a \$36.00 savings to the customer. Kay is able to produce low priced attenuators with superior specification by using teflon, gold and silver component in our custom developed and in-house manufactured switches. Listed below are some of the more common attenuators. Check the prices for yourself.

ATTENUATOR TYPE	MODEL NO.	IMPEDANCE	FREQ. RANGE	ATTEN RANGE	STEPS	INSERTION LOSS AT 1GHz	PRICE*
Standard	432D	50Ω	DC- 1GHz	0-101dB	1dB	.7dB	\$265
In-Line	442D	75Ω	DC- 1GHz	0-101dB	1dB	.4dB	\$265
Miniature	439A	50Ω	DC-1.5GHz	0-101dB	1dB	.5dB	\$229
In-Line	449A	75Ω	DC- 1GHz	0-101dB	1dB	.4dB	\$229
Rotary	500A	50Ω	DC- 2GHz	0- 10dB	1dB	.2dB	\$175
	510A	75Ω	DC-1.5GHz	0- 10dB	1dB	.2dB	\$175
Rotary Bench:	5050	50Ω	DC- 1GHz	0- 81dB	.1dB	.8dB	\$589
Programmable	4440	50Ω	DC-1.5GHz	0-130dB	10dB	.2dB	\$299
	4457	75Ω	DC- 1GHz	0-127dB	1dB	.3dB	\$375

*Single Quantities. Discounts for Quantity Orders.

If you don't see an attenuator that fits your requirements call us for information on our complete line of standard products. Kay can also design an attenuator to fit your specific needs. We have designed over 250 different special attenuators in the past.

We also offer a very substantial discount schedule for quantity purchases. For a complete catalog or to place an order call Chris Meagher at (201) 227-2000, ext. 105.

KAY

Kay Elemetrics Corp

12 Maple Avenue

Pine Brook, NJ 07058-9797

USA

Tel: (201) 227-2000

TWX: 710-734-4347

INFO/CARD 27

maximum power operation into any VSWR. Actual power output can be monitored on the front panel. **American Microwave Technology, Inc., Fullerton, CA 92631. Booth #520; please circle INFO/CARD #164.**

A new series of five plug-in elements from Bird Electronic converts the company's THRULINE wattmeter into an extraordinarily sensitive instrument. The elements offer bi-directional RF power measurement from 20 mW to 100 W at



Bird Electronics

±5% accuracy of reading, in frequency bands from 25 to 1000 MHz. Full rated accuracy is maintained over the 5000 to 1 power range with temperature extremes between 0° and 50°C. The entire complement of elements enable the THRULINE to cover frequencies from 200 kHz to 1000 MHz and power from 20 mW to 10 kW. **Bird Electronic Corp., Solon, OH 44139. Booth #307; INFO/CARD #163.**

Four surface acoustic wave resonator oscillators form the heart of the Hewlett-Packard 8642A/B signal generators. These extremely high-Q devices operating near 800 MHz provide low SSB phase noise at offsets beyond 10 kHz. The 8642A covers the range of 100 kHz to 1057.5 MHz while the 8642B doubles the upper limit to 2115 MHz. Both models offer undererrange to 10 kHz and a resolution of 1 Hz, 0.1 Hz with a special function. The

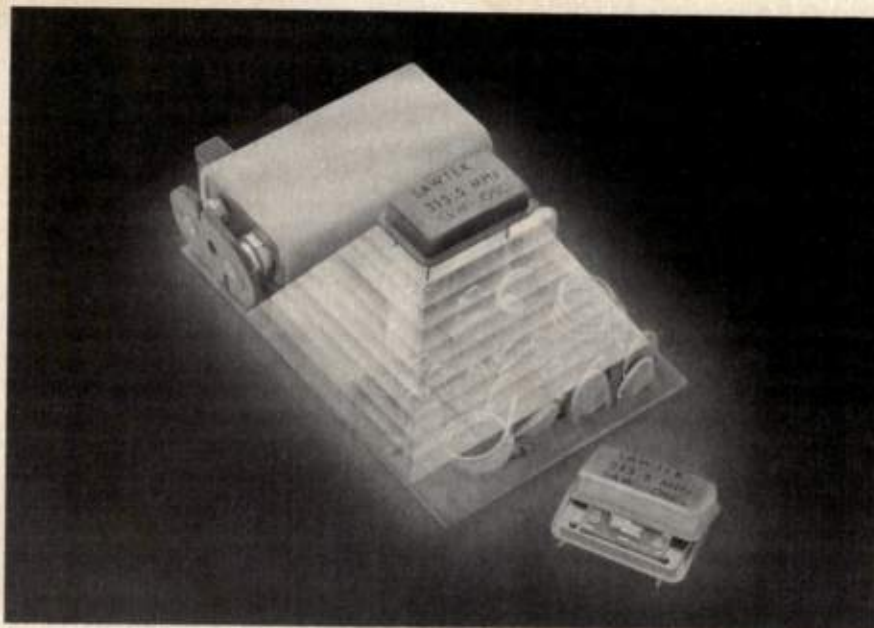


Hewlett Packard

RF Design

output ranges from +20 to -140 dBm with a resolution of 0.1 dB. AM, FM, ϕ M, and PM allow the 8642A/B to accurately simulate signals used for most types of RF communication systems. On demand, the generators can switch in a separate heterodyne output section to provide improved modulation performance for carrier frequencies below 132.2 MHz. **Hewlett-Packard, Palo Alto, CA 94303. Booth #522; INFO/CARD #161.**

Weighing in at 7.5 kg, the Marconi 2022 signal generator has a frequency range of 10 kHz to 1000 MHz, with a resolution of 10 Hz below 100 MHz and 100 Hz above 100 MHz. Output amplitude is +6 to -127 dBm with a resolution of 0.1 dB. Amplitude, frequency, and phase can be modulated externally or internally. Two elapsed time indicators — usage since last resetting and usage since manufacture — aid in analyzing reliability and cost-



SAW Oscillators

Sawtek's Surface Acoustic Wave oscillators for military and commercial applications simplify design and improve noise performance. High-Q SAW resonators offer quartz stability at fundamental frequencies from 100 MHz to 1000 MHz. Hybrid oscillators in hermetic packages are available for reduced size and increased reliability. FM or pulse code modulation capability is optional.

Sawtek maintains a large selection of frequencies from an inventory of pre-tooled resonator crystals and new designs can be tooled rapidly. Our engineers also offer assistance in oscillator design for low-cost consumer applications and are prepared to help evaluate the suitability of SAW oscillators for your requirements.

In addition to oscillators and resonator products, Sawtek produces other high performance SAW components including bandpass filters, delay lines, and pulse compressors for cable television, satellite communications, modems, radar, EW, and many other signal processing applications. And, if what you need is not among our hundreds of standard products, we can provide technical assistance and rapid response to new design and production requirements. Quality and performance have made Sawtek the industry leader in SAW technology; you can rely on us for the total engineering support you need.

When your system demands the advantages of SAW Technology ... Demand SAWTEK.

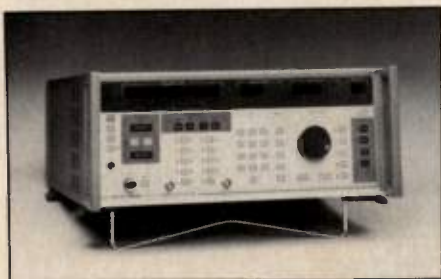
SAWTEK
INCORPORATED

P.O. BOX 18000, DEPT. MRF, ORLANDO, FL 32860, (305) 886-8860

INFO/CARD 28

of-ownership. Marconi Instruments, Allendale, NJ 07401. Booth #507; please circle INFO/CARD #160.

For testing of communications systems, one of the most important parameters for a signal generator is its phase noise performance. The new FCC proposals to reduce channel spacings to as low as 7.5 kHz place stringent requirements on instruments used to test the new systems. The Racal-Dana 9087 generates signals with noise as low as -142 dBc/Hz at only 3 kHz offset from the carrier. With a frequency range of 10 kHz to 1300 MHz with a resolution of 1 Hz, the 9087 covers all HF, VHF, and UHF telecommunications bands as well as the LF and MF bands often used for radio navigation. The signal may be swept. The output is variable from $+19$ to -140 dBm (2 V to 0.0224 μ V rms into 50 ohm) with a resolution of 0.1 dB. A GPIB interface provides for full programmability. In addition, its fast switching speed of 500 μ s makes the 9087 suitable for FSK (frequency shift keying) simulation and the testing of electronic warfare systems. The 9087 offers total modulation



Racal-Dana

versatility, including AM, FM, ϕ M, and PM from a combination of internal and external sources. Simultaneous AM+FM, AM+ ϕ M, FM+PM, and ϕ M+PM allows accurate simulation of ECM/ECCM and "chirp" signals. Racal-Dana, Irvine, CA 92713. Booth #405; INFO/CARD #158.

The Polarad SMPD synthesized signal generator covers the frequency range of 5 kHz to 1 GHz with a resolution of 1 Hz.



Polarad Electronics

The output level range is $+13$ to -143 dBm with a resolution of 0.1 dB. Amplitude, Frequency, phase, and pulse may be modulated. Linear and logarithmic frequency

sweeps are available, with both the sweep width and sweep time being freely selectable. The SSB phase noise is <-143 dBc/Hz at 20 kHz from the carrier (at 100 MHz). Polarad Electronics, Lake Success, NY 11042. Booth #311; Info/card #177.

Option 07 gives the Tektronic 496 and 496P portable spectrum analyzers 75



Tektronics

ohm measurement capability in addition to the standard 50 ohm measurement. Calibration is provided so that it is no longer necessary for the user to convert the units or account for external losses when changing from 50 ohm to 75 ohm. Option 07's frequency range of 5 MHz to 1 GHz, and 300 kHz resolution provide measurement capability for all cable and broadcast systems. The 496/496P offer spectrum analysis and measurements in the 1 kHz to 1.8 GHz range with 80 dB dynamic range. Tektronix Inc., Beaverton, OR 97077. Booth #504; please circle INFO/CARD #157.

The HPIL (Hewlett-Packard Interface Loop) available as an option on the Texscan SSG-1000 and SSG-2000 signal generators enable a low-cost hand-held computer, such as the HP-41C, to control the instrument. The SSG-1000 covers the frequency range of 100 kHz to 1000 MHz with a resolution of 10 Hz. The SSG-2000 extends the range to 2000 MHz, with a resolution of 20 Hz above 1000 MHz. Spurious noise is below -60 dBc (-54 dBc above 100 MHz), and harmonics are below -30 dBc. AM, FM, and PM are available. Texscan Instruments Corp., Indianapolis, IN 46226. Booth #417; please circle INFO/CARD #156.

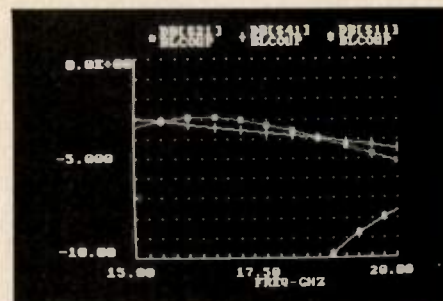
RF Software

The growing popularity of the IBM PC led Compact Software to develop a version of SUPER-COMPACT for the PC. SUPER-COMPACT PC models circuits as a series of two-ports. Up to fifteen variables may be optimized simultaneously. An important capability is the easy interface to the mainframe versions of the program. The initial analysis can be performed on the PC, and then uploaded to a faster mainframe for the "number-crunching." Compact Software. Booth

#100, 101; INFO/CARD #155.

CADEC from Communications Consulting allows circuit analysis and optimization in the linear frequency domain. The circuit, described using the nodal method, is converted internally to a series of two-ports. The program includes a fast Fourier transformation of calculated frequency points to a large variety of user defined waveforms. CADEC is available for IBM PCs and compatibles and the Hewlett-Packard Series 200. Communications Consulting Corp., Upper Saddle River, NJ 07458. Booth #515; please circle INFO/CARD #154.

Touchstone/RF is a version of EEsof's Touchstone program that has been specially tailored for RF work. The costly microwave circuit models such as microstrips and striplines have been eliminated, reducing the cost by about a half. Touchstone/RF is available for the HP Series 200 computers and the IBM PCs and



EEsof

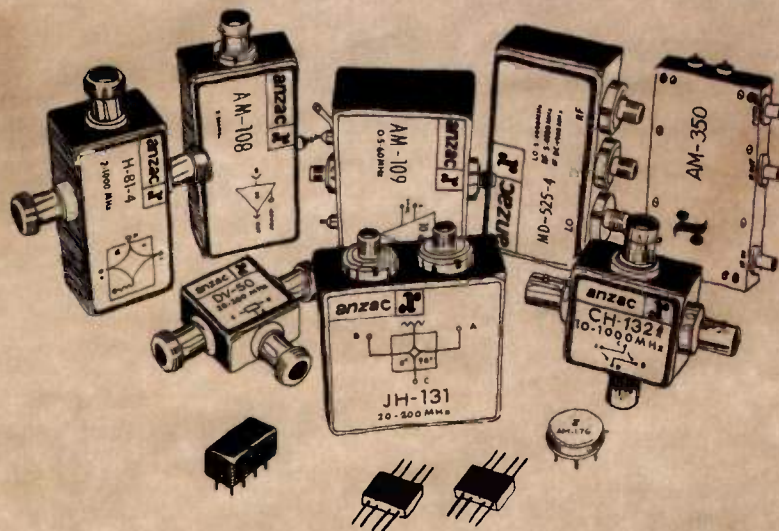
compatibles. The program is compatible with their MICAD circuit layout program. EEsof, Inc., Westlake Village, CA 91362. Booth #610; INFO/CARD #153.

EMC/EMI

Compared to ordinary adhesive-bonded gaskets, Chomerics' vulcanized assemblies provide the following advantages: improved reliability, uniform sealing, simpler installation, and easier maintenance. Conductive, non-conductive, and non-conductive/conductive Combo elastomer gaskets can be vulcanized or bonded directly onto metal covers and enclosure panels. Chomerics Shielding Technology, Woburn, MA 01888. Booth #318; INFO/CARD #152.

Keene Corp., Ray Proof Division offers RF shielded rooms for secure communications, RF secure conference rooms, secure computer rooms, RF rooms for TEMPEST and testing, anechoic chamber systems, microwave/millimeter wave absorbers, EMI power line filters, and special purpose filters. Keene Corp., Ray Proof Division, Norwalk, CT 06856. Booth #401; INFO/CARD #151.

WANTED



THE ANZAC GANG

For various counts of fast delivery, operating reliably, exceptional performance, and taking a tough stand on quality.

AMPLIFIERS

Sneaky critters. Don't make hardly any noise. Use a variety of disguises: flatpack, relay header, TO-8, even connectorized boxes. Operate all over the range—from 0.5 to 5200 MHz. Known to hang out with the notorious LOG AMP, a non-linear operator with a reputation for mighty wide dynamic range—some say 80 dB!

CONTROL DEVICES

a.k.a. (also known as) SWITCHES—trigger-happy showoffs, some as fast as 50 ns!, MODULATORS—sharpies that're really up on the Code of the West, ATTENUATORS—tough guys that'll step you right down, and, watch out for these guys, PHASE SHIFTERS!

MIXERS

More socially acceptable, double-balanced and all, but tough customers nonetheless. TIM,* a particularly ornery type, will go with anything—doesn't care how he's loaded. Very much home on the range from a lowdown 0.02 MHz way up to 18 GHz! That's microwave, pardner.

*Termination Insensitive Mixer

PASSIVES

Don't be fooled by their name. These are tough hombres. Some of these hybrids will turn on you—90, even as much as 180 degrees! DIVIDERS, COUPLERS, (DIRTY) DOUBLERS, TRANSFORMERS, and that paragon of respectability, the old timer and favorite of the dance hall darlin', IMPEDANCE BRIDGE.

SUBSYSTEMS

Alias for a powerful bunch of multiple personalities that will do anything for a buck. Their specialty is custom jobs. And they've got the most advanced tools and techniques of the trade. Fearless and experienced, they've even stood up to MIL-STD 883B!

REWARD

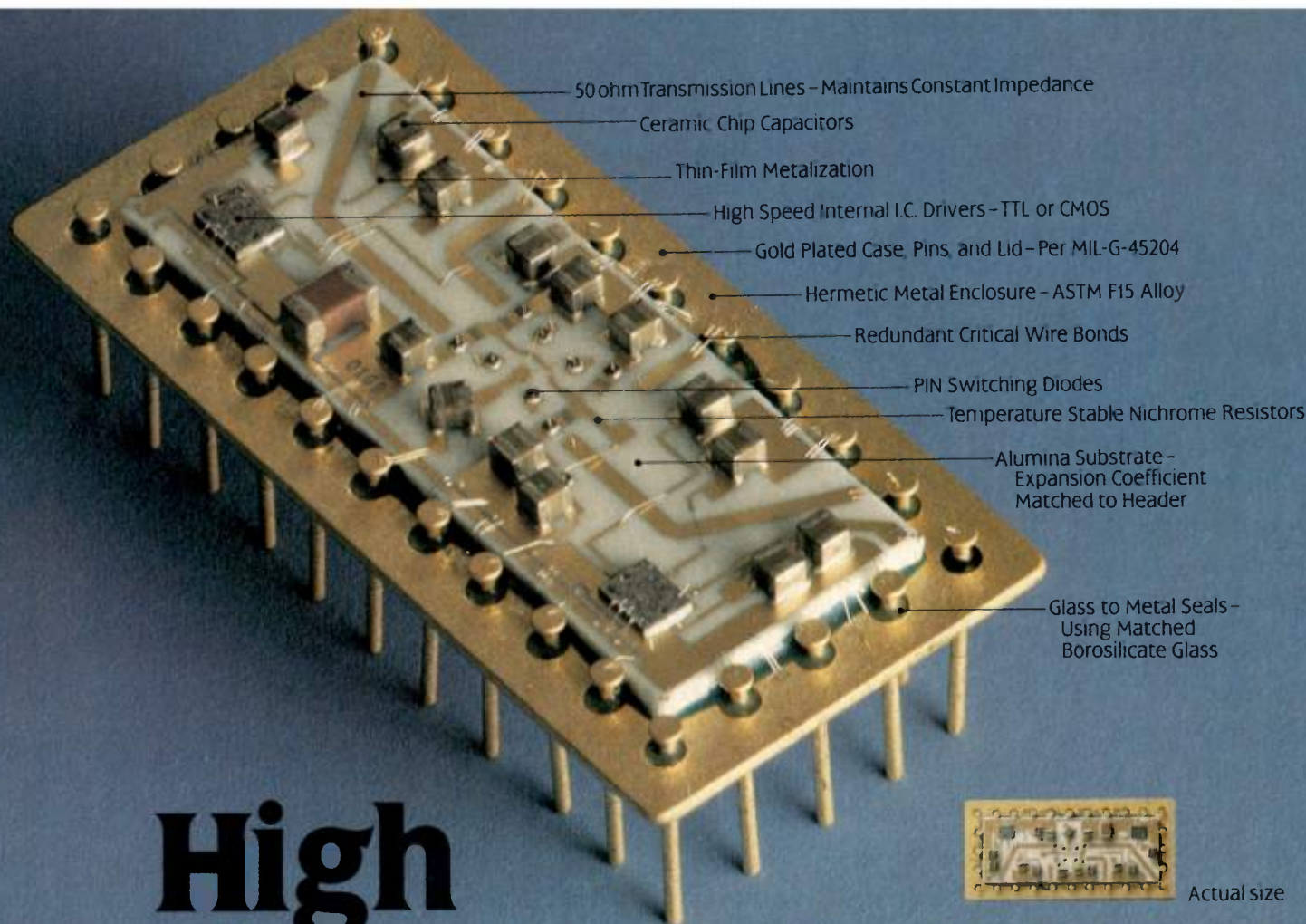
Interested parties will be rewarded with complete specifications. Actual buyers will be specially rewarded with top performance. Contact your local sheriff or us back home.

Adams Russell
ANZAC DIVISION

80 Cambridge Street • Burlington • MA 01830 • (617) 273-3333 • TWX 710-332-0258

INFO/CARD 29

See us at RF Tech Expo, L&M Engineering Booth #319, 321, 323.



High Reliability RF MICs

DAICO High Reliability RF Microwave Integrated Circuit Components

are products of state-of-the-art thin-film technology. Quality screened components, manufactured and tested to rigid Daico standards and numerous in-process quality tests, assures each device meets applicable MIL STD Specifications. Quantitative 100%

final electrical tests are made with HP8505 Analyzers and HP9825 Computer controlled automatic systems. These data assure Daico High Reliability RF MIC components meet all critical design parameters, thus saving costly incoming testing.



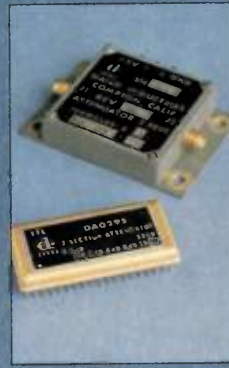
MIC SWITCHES

- Thin-film MIC construction.
- DC - 4GHz
- SPST - SP24T
- Speeds < 5nS (10-90% RF)
- Internal TTL or CMOS drivers
- Internal 50 ohm terminations
- PC Board mount, Stripline or Connectorized



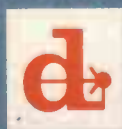
MIC VOLTAGE CONTROLLED ATTENUATORS

- Thin-film MIC construction
- Linear attenuation to 60dB
- Linearity to ± 0.75 dB
- Internal drivers
- Constant 50 ohm impedance
- PC Board mount, Stripline or Connectorized



MIC STEP ATTENUATORS

- Thin-film MIC construction
- Steps - 1 through 7
- Attenuation to 63.5dB
- Speeds < 5nS (10-90% RF)
- Internal TTL or CMOS drivers
- PC Board mount or Connectorized



DAICO INDUSTRIES, INC.

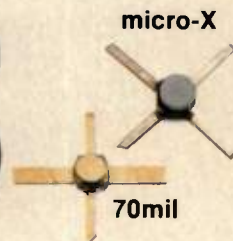
2351 East Del Amo Blvd. Compton, Calif. 90220
Telephone: (213) 631-1143 • TWX 910-346-6741

INFO/CARD 30

© 1982 Daico Industries, Inc. Imp 82411



MONOLITHIC MICROWAVE MODAMPS



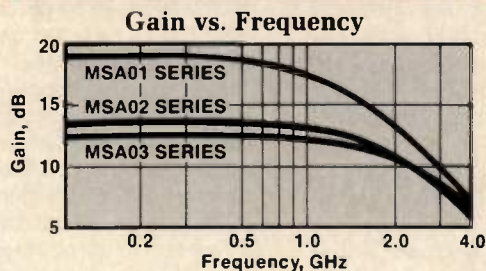
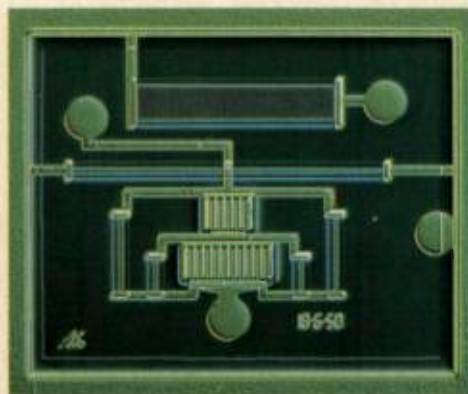
Now! MMICs out of the lab and onto the shelf.

Avantek® MODAMP™ silicon monolithic microwave amplifiers are the new alternative to hybrid modules—small, highly-reliable cascadable building blocks for frequencies through 3 GHz. And, they are now in production and available from stock.

Available in micro-X and 70-mil transistor packages, MODAMP monolithic amplifiers permit greatly increased circuit and packaging density, while meeting the performance and reliability requirements of both military and commercial applications.

In any application, the MODAMP monolithic amplifier assures highly predictable, reliable performance without fine-grain gain ripple, and with excellent temperature stability.

MODAMP silicon monolithic amplifiers are now available, and priced from \$5.00 to



\$21.80 in 100 piece quantities.*
Contact your nearest Avantek representative or call us for details on this latest family of Avantek modular amplifier products.



No Single Component Tells the Entire Avantek Story

INFO/CARD 31

Visit our Tech Expo Booths #516, 518.

NOW IN DISTRIBUTION

Applied Specialists, Inc.
(Applied Engineering Consultants)
Washington, D.C., Virginia
Maryland (301) 595-5373
Baltimore (301) 792-2211
(800) 638-8555

Component Distributors, Inc. (Beacon)
Ft. Lauderdale, FL (305) 971-4950
Huntsville, AL (205) 883-7501
Raleigh, NC (919) 781-0262

Peak Distributors, Inc. (Dytec Central)
Arlington Heights, IL (312) 255-0707

Pen Stock Company (Cain-White & Co.)
Los Altos, CA (415) 948-6552

Sertek, Inc. (Cain Technology)
Los Angeles, CA (213) 476-2251
(714) 997-7311

Spirit Electronics, Inc. (Thorson)
Scottsdale, AZ (602) 998-1533

Avantek
Semiconductor Marketing
3175 Bowers Avenue
Santa Clara, California 95051
(408) 727-0700

Copyright 1983 Avantek, Inc.
Avantek is a registered trademark of Avantek, Inc.

*U.S. Domestic Prices Only

The SAW Resonator: How It Works

Part I gives an introduction to the Surface Acoustic Wave resonator and a TI-59 program to model device responses.

By Jeff Schoenwald
Contributing Editor

Long-time readers of *RF Design* have encountered the Surface Acoustic Wave (SAW) resonator before^{1,2}. The original concept belongs to Eric Ash, of the Imperial College in London, who made the first attempt to produce a high Q resonant acoustic device that is planar in its fabrication (like all semiconductor circuits today), uses SAW, and can scale the frequency spectrum well beyond the practical limits achievable, then or now, by bulk quartz crystal filters. The first truly successful devices were demonstrated by Texas Instruments, followed soon after by scores of industrial, government and university laboratories in the United States, Europe and Japan. The theory, fabrication and performance of the SAW resonator is well chronicled in some detail and variation in the proceedings of the IEEE Ultrasonics Symposium going back to 1974.

In this article I have tried to provide the RF engineer with a useful tool — a model with which he can simulate the many different device responses the SAW resonator has been found able to produce. In Part I the theory of the model is presented, along with a listing for the TI-59 calculator equipped with a printer. In Part II we manipulate the model to produce various devices and develop a good feeling for how performance depends on design and material parameters.

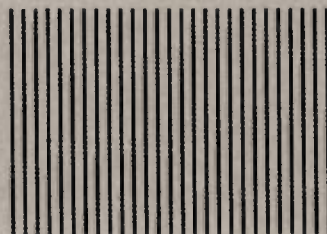
The first SAW resonator was a single pole device — a pair of reflecting structures forming a single cavity. Each reflecting structure consists of a repetitive set of lines and gaps — a grating. The grating is formed in various ways but always involves the use of vacuum deposition of metal (mostly aluminum) or occasionally a dielectric, and photolithographic exposure, developing and etching. Sometimes the stripes of the reflector are patterned in etched aluminum; the more reliable technique used today is one in which grooves are plasma etched directly out of

the quartz substrate. Each line and groove is one quarter wavelength long in the direction of propagation of the wave, and is typically 50-200 wavelengths wide, at the designated center frequency. Each pair of line and groove has a very low coefficient of reflection, purposely: too large a coefficient and the surface wave would quickly scatter into the bulk and dissipate. A distributed reflector consisting of several hundreds of lines (sometimes more than a thousand) produces a very efficient phase matched coupling between a SAW wave traveling in one direction and a reflected wave. As we shall see in some of the examples in Part II, the reflectivity can be very nearly 100%. Two such reflectors can form a cavity whose length is an integer number of half wavelengths. This is a Fabry-Perot cavity, and is the fundamental structure known as the single pole resonator. Place an interdigital transducer in the cavity (at the proper position, of course) and we have a way to dump electrical energy into this acoustic cavity through the piezoelectric coupling coefficient of the substrate. Remember that crystal quartz, lithium niobate, zinc oxide and many other materials are piezoelectric. Read my two previous articles^{1,2} for a bit more background, or plow through the rich literature on the subject if you have a few years.

We needn't stop with a single pole resonator. Refer to Fig. 1. A third reflective array properly placed in line with the other two forms a second cavity — the two-pole SAW resonator. This may be continued indefinitely. The calculator is dumb and will not mind. But we, as engineers, can play the program included here like an arcade game and produce interesting and varied results. First, I'll describe the theory behind the program. Second, familiarize yourself with initial data entry procedures and device design. Then, next month, we'll start to build a succession of



$M = 1$



$M = 2$



$M = 3$

FIGURE 1. Basic structures for SAW resonators using cascaded reflector arrays forming a single array ($M = 1$), ($M = 2$) single pole and ($M = 3$) two pole resonator.

devices and look at the power transmission and reflection characteristics of each one and, for a few selected cases, the change in performance of a single design as we make small changes in one of the parameters.

The program comes in two versions. The first one produces a listing of transmitted and reflected power as a function of frequency. The second version, which is run by replacing the last part of the program, will list the phase of the transmitted and reflected waves versus frequency. Unfortunately the TI-59 does not have enough memory to compute both and still be "user friendly" enough to handle all the I/O commands for data entry

and listing on the printer. As a serious TI-59 programmer, you could generate more available memory by loading all the data off-line, eliminating the print commands to list them (jot them down elsewhere), and leave only the appropriate RUN/STOP commands to read important computed parameters as the program generates them at the beginning — you'll understand what I mean when we cover data entry. If you do all this, there should be enough memory space left to compute magnitude *and* phase of transmitted and reflected waves. I have chosen instead to rely on the automation features available on the TI-59 when used with the printer.

An Overview of the Program Architecture

After initial data entry, the program accomplishes its task by transmission line matrix computation methods. The 2x2 transmission matrix ($T[1]$) of a single line and gap segment is computed. The eigen values of this matrix are determined and the matrix $T[N]$ of an array of N such segments is computed using Sylvester's Theorem (3). This theorem states that if T is a $j \times j$ matrix (in this case 2x2), then any polynomial matrix expression in powers of T may be written as:

$$P(T) = \sum_{r=1}^j \left\{ P(\lambda_r) \prod_{s=1, s \neq r}^j \left(\frac{T - \lambda_s I}{\lambda_r - \lambda_s} \right) \right\}, I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (1)$$

where I is the 2x2 identity matrix, λ_r is the r 'th eigenvalue of the matrix T , and $P(\lambda_r)$ is the same polynomial as before, but in powers of λ_r , instead of the matrix T . For our 2x2 situation, $j=2$, T is the matrix of one section (a line and a gap), and $P(T) = T_N$. Then:

$$T^N = \lambda_1^N \left(\frac{T - \lambda_2 I}{\lambda_1 - \lambda_2} \right) + \lambda_2^N \left(\frac{T - \lambda_1 I}{\lambda_2 - \lambda_1} \right) \quad (2)$$

$$= T \left(\frac{\lambda_1^N - \lambda_2^N}{\lambda_1 - \lambda_2} \right) + I \left(\frac{\lambda_1 \lambda_2^N - \lambda_1^N \lambda_2}{\lambda_1 - \lambda_2} \right)$$

The eigenvalues λ_1 and λ_2 are found by setting the determinant of $T-I$ equal to zero and solving Eq. 2. This approach enables the closed-form, single pass calculation which is independent of the number of sections N in the grating array. The original version of this calculation did not use Sylvester's Theorem and relied instead on a recursive calculation which consumed time proportional to the size of the grating number $N(4)$.

The matrix $T[g]$ representing the gap of length l_g (normalized relative to the wavelength at the specified reference frequency f_0) is computed and the structure cascaded by multiplication of the two matrices

$$T[N] \times T[g] = T[N+g] \quad (3)$$

The composite matrix is then solved for its eigenvalues and Sylvester's Theorem is used again to find the net transmission matrix of M such sections, which form $M-1$ cavities, or an $(M-1)$ — pole resonator:

$$(T[N+g])^M = T[M] \quad (4)$$

Again, we must compromise because of the calculator's capacity. A practical device could have several cavities with different values of l_g , and the grating arrays between these cavities, referred to as coupling reflectors, might have different sizes. Nevertheless, the symmetric devices we are able to design are instructive, and represent the great majority of designs that have been practically implemented over the past 10 years.

The program assumes the transmission line structure is lossless, i.e., the impedance values are not complex. Making provisions for a complex impedance requires an ability to manipulate them in matrix multiplication, which the TI-59 does not do directly, or doubling the dimension of matrices and increasing the size

of the calculation, which we can't afford. We also assume that the characteristic impedance of the source and load at either end of the grating are the same, and equal to that of the gaps between lines in a grating and between grating arrays where we have formed cavities, i.e., $Z(\text{load}) = Z(\text{source}) = Z(\text{gap}) = 1$.

Data entry procedures are summarized in the flow diagram in Table 1. After l_1 , l_2 , n_2 and f_0 are entered, f_c , the "center frequency" at which the first maximum in reflectivity occurs, is computed:

$$f_c = \frac{f_0}{2(l_1 + n_2 \cdot l_2)} \quad (5)$$

Other reflectivity maxima occur at odd harmonics of f_c . The fractional "phase length" of a strip relative to a strip gap pair is

$$t = \frac{n_2 \cdot l_2}{l_1 + n_2 \cdot l_2} \quad (6)$$

If $t = 0.5$, $l_1 = n_2 \cdot l_2$ and each segment has equal "optical," or phase thickness. The fractional difference in phase thickness between a gap and a strip is $1-2 \cdot t$.

Armed with this input and a starting frequency, we may proceed to compute the transmission matrix of a strip-gap pair:

$$T[1] = \begin{bmatrix} A1 & B1 \\ C1 & D1 \end{bmatrix} \quad (7)$$

where

$$A1 = \frac{(Z+1)\cos y}{2} - \frac{(Z-1)\cos(1-2t)y}{2} \quad (7a)$$

$$B1 = \left(\frac{(Z+1)\sin y}{2} - \frac{(Z-1)\sin(1-2t)y}{2} \right) \quad (7b)$$

$$C1 = \left(\frac{(Z+1)\sin y}{2Z} + \frac{(Z-1)\sin(1-2t)y}{2Z} \right) \quad (7c)$$

$$D1 = \frac{(Z+1)\cos y}{2Z} + \frac{(Z-1)\cos(1-2t)y}{2Z} \quad (7d)$$

and

$$y = \pi \cdot f / f_c \quad (8)$$

Once $T[1]$ is obtained, we must find its eigenvalues in order to compute $T[1]^N = T[N]$, the equivalent of cascading N sections. We define the quantity θ ,

$$\cos \theta = \frac{A1 + D1}{2} \quad (9)$$

$$\lambda_1 = \cos \theta + \sqrt{\cos^2 \theta - 1}$$

$$\lambda_2 = 1/\lambda_1$$

If $\cos^2 \theta - 1$ is zero or positive, the eigenvalues of $t[1]$ are real. However, it is entirely possible that $(A1 + D1)/2 < 0$, in which case the eigenvalues are a complex conjugate pair. The distinction is made because the program branches to handle each case differently. If the eigenvalues are real, we obtain:

$$[TN] = \begin{bmatrix} AN & BN \\ CN & DN \end{bmatrix} \quad (10)$$

where

$$AN = A_1 \frac{\lambda_1^N - \lambda_2^N}{\lambda_1 - \lambda_2} - \frac{\lambda_1^{N-1} - \lambda_2^{N-1}}{\lambda_1 - \lambda_2} \quad (11a)$$

$$BN = jB_1 \frac{\lambda_1^N - \lambda_2^N}{\lambda_1 - \lambda_2} \quad (11b)$$

$$CN = jC_1 \frac{\lambda_1^N - \lambda_2^N}{\lambda_1 - \lambda_2} \quad (11c)$$

$$DN = D_1 \frac{\lambda_1^N - \lambda_2^N}{\lambda_1 - \lambda_2} - \frac{\lambda_1^{N-2} - \lambda_2^{N-2}}{\lambda_1 - \lambda_2} \quad (11d)$$

If the eigenvalues are complex, we have instead

$$AN = \frac{D \sin N\theta}{\sin \theta} - \frac{\sin (N-1)\theta}{\sin \theta} \quad (12a)$$

$$BN = \frac{jB_1 \sin N\theta}{\sin \theta} \quad (12b)$$

$$CN = \frac{jC_1 \sin N\theta}{\sin \theta} \quad (12c)$$

$$DN = \frac{D_1' \sin N\theta}{\sin \theta} - \frac{\sin (N-1)\theta}{\sin \theta} \quad (12d)$$

where θ is obtained from (9).

Having constructed a grating array [TN], we must now compute the transmission line that will make up the cavity between two reflectors. The matrix for this section is simple:

$$[Tg] = \begin{bmatrix} \cos \gamma & jZ_1' \sin \gamma \\ j \sin \gamma & \cos \gamma \end{bmatrix} \quad (13)$$

where

$$\gamma = 2\pi \left(\frac{f_1}{f_c} - lg \right) \quad (14)$$

and $Z_1 = 1$.

The matrix for the cascaded reflector and gap is simply obtained using (1). The same calculation is applied to $T[N+g]$ to find its eigenvalues, and then the composite structure is cascaded M times to build a transmission line with M reflectors and $M-1$ cavities. Note that the tail end of the structure contains a length of transmission line l_g . This will have no effect on the

Program Structure
Data Entry
($l_1, l_2, n_2, f_0, Z, f_1, df, f_2, M, lg$)

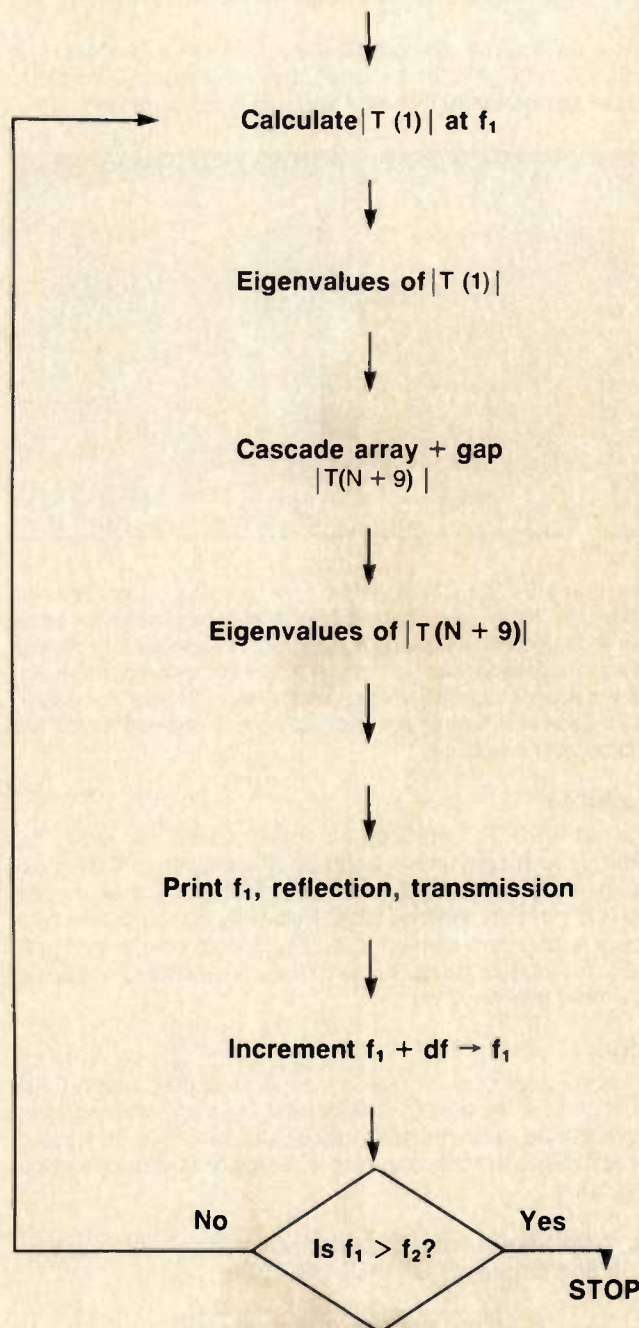


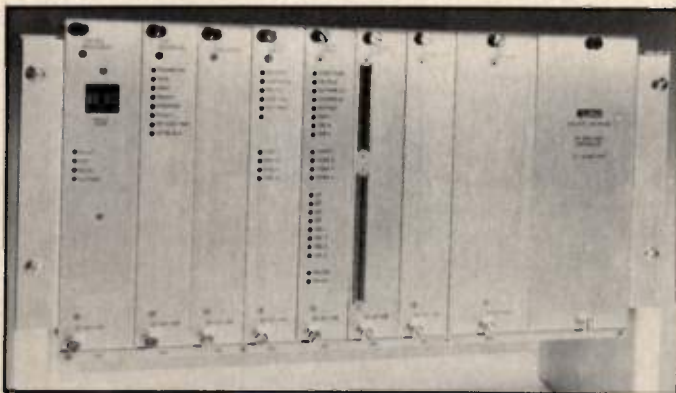
TABLE 1

EXCELLENCE IN DESIGN AND PRODUCTION

Experience

At ERBTEC we specialize in products which marry state-of-the-art digital and RF technologies. In the past ten years we have produced systems for a number of Fortune 500 companies. Systems for Data Acquisition, Telemetry, Instrumentation, Voice Communications, and HF Pulse Doppler Radar, to mention only a few.

And we have produced products such as this High Power RF Amplifier Controller. This modular, rack-mounted unit monitors, controls and drives high-power vacuum tube amplifiers.



Like many ERBTEC products it incorporates a high level of intelligence. To you this means capabilities such as true ease of use — No complex training is required. No special adjustment tools are necessary. (Microprocessors do most of the grunt work). It means simple communication with a remote host computer. It also means comprehensive self-testing with sophisticated fault detection and reporting.

Reliability

Like all ERBTEC products, it has field-proven reliability. Reliability that means stable, trouble-free operation in close proximity to multi-kilowatt RF amplifiers. Reliability that means durability and long-term operation. Reliability that originates with our very strong commitment to quality in both design and production. If a product should fail, our modular architecture assures fast, simple maintenance.

Support

We take great pride in making good customer support our number one priority. We put considerable effort into creating complete, accurate, and readable documentation. We constantly strive to achieve the fastest possible response to your questions or problems.

We can provide a highly cost-effective solution to your application. To find out how, CONTACT US TODAY.



5680 Valmont Rd., Boulder, CO 80301
(303) 447-8750, Telex: 386 292

magnitude of the power transmitted or reflected, but only a phase shift in the transmitted wave.

Once the transmission of matrix T of the entire structure has been computed, the normalized transmission and reflection amplitudes Tf and Rf are easily computed:

$$Tf = \frac{2}{A' + B' + C' + D'} \quad (15a)$$

$$Rf = \frac{A' + B' - C' - D'}{A' + B' + C' + D'} \quad (15b)$$

Since the device is assumed to be lossless only one coefficient need be calculated, say Tf, and

$$Rf^2 = 1 - Tf^2 \quad (16)$$

Using the Program for Design and Analysis

The program is listed in Table II. Partition the TI-59 for 30p17 (719.29) and load the program. Two magnetic cards are needed to store it. Enter the data as shown in Table III. Each input parameter is printed as it is entered. After f_0 is entered and printed, f_c is computed and it too is printed. This is done to aid the user in choosing an appropriate frequency range for analysis. After all input data has been entered, calculation commences, resulting in a listing of the frequency and corresponding normalized reflected and transmitted power (in dB). A complete cycle takes about 20 seconds. The computation is then repeated at the next frequency until the entire frequency domain has been examined. While the program chugs away, take a break.

The user may FIX the number of decimal places desired at the beginning or at any point during data entry, since, for example, the reflection or transmission loss may only be interesting to 0.1 dB accuracy. Care must be taken, however, since the printed listing of input parameters or frequency may appear truncated to less accuracy than was originally specified.

Join us next month for Part II. We will use the program to examine the properties of reflective arrays, single and multiple cavities. As an added bonus, a BASIC version is also provided for the growing number of microcomputer users.

References

1. J. Schoenwald, "Surface Acoustic Waves for the R.F. Design Engineer," *r.f. design*, pp. 11-16, March/April 1981.
2. J. Schoenwald, "Surface Acoustic Waves for the R.F. Design Engineer: The Interdigital Transducer," *r.f. design*, pp. 25-33, July/August, 1981.
3. J. Irving and N. Mullineau, *Mathematics In Physics and Engineering*, pp. 285-288, Academic Press, New York, N.Y. (1959).
4. E.K. Sittig and C.A. Caquin, "Filters and Dispersive Delay Lines Using Repetitively Mismatched Ultrasonic Transmission Lines," *IEEE Transactions on Sonics and Ultrasonics*, Vol. SU-15, pp. 111-119, (1968).

TABLE III
Data Entry

Parameter	Enter	Press
gap length	l_1	A
line length	l_2	R/S
velocity Index	n_2	R/S
reference frequency	f_0	R/S
impedance ratio	Z	B
number of sections	N	R/S
start frequency	f_1	C
frequency increment	df	R/S
stop frequency	f_2	R/S
number of reflectors	M	R/S
cavity size	lg	R/S

000	76	LBL	065	69	69	130	99	PRT
001	50	I x I	066	43	RCL	131	91	R/S
002	43	RCL	067	04	04	132	76	LBL
003	12	12	068	92	RTN	133	12	B
004	22	INV	069	53	(	134	42	STO
005	39	COS	070	43	RCL	135	10	10
006	42	STO	071	00	00	136	99	PRT
007	04	04	072	55	÷	137	91	R/S
008	43	RCL	073	02	2	138	42	STO
009	11	11	074	54	)	139	11	11
010	42	STO	075	32	X ↔ T	140	42	STO
011	00	00	076	53	(	141	29	29
012	71	SBR	077	43	RCL	142	99	PRT
013	38	SIN	078	00	00	143	53	(
014	42	STO	079	55	÷	144	43	RCL
015	27	27	080	02	2	145	06	06
016	53	(	081	54	)	146	65	x
017	43	RCL	082	59	INT	147	43	RCL
018	11	11	083	67	EQ	148	07	07
019	75	—	084	00	00	149	55	÷
020	01	1	085	90	90	150	53	(
021	54	)	086	43	RCL	151	43	RCL
022	42	STO	087	04	04	152	05	05
023	00	00	088	94	+/-	153	85	+
024	71	SBR	089	92	RTN	154	53	(
025	38	SIN	090	43	RCL	155	43	RCL
026	42	STO	091	04	04	156	06	06
027	28	28	092	92	RTN	157	65	x
028	61	GTO	093	76	LBL	158	43	RCL
029	18	C'	094	11	A	159	07	07
030	76	LBL	095	42	STO	160	54)
031	38	SIN	096	05	05	161	54)
032	53	(	097	99	PRT	162	54)
033	53	(	098	91	R/S	163	42	STO
034	43	RCL	099	42	STO	164	12	12
035	00	00	100	06	06	165	53	(
036	65	x	101	99	PRT	166	43	RCL
037	43	RCL	102	91	R/S	167	10	10
038	04	04	103	42	STO	168	85	+
039	54	)	104	07	07	169	01	1
040	38	SIN	105	99	PRT	170	54)
041	55	÷	106	91	R/S	171	42	STO
042	43	RCL	107	42	STO	172	16	16
043	04	04	108	08	08	173	53	(
044	38	SIN	109	99	PRT	174	24	CE
045	54	)	110	55	÷	175	75	—
046	92	RTN	111	53	(	176	02	2
047	76	LBL	112	02	2	177	54)
048	45	Y*	113	65	x	178	42	STO
049	53	(	114	53	(	179	17	17
050	43	RCL	115	43	RCL	180	53	(
051	01	01	116	05	05	181	01	1
052	50	I x I	117	85	+	182	75	—
053	45	Y*	118	53	(	183	02	2
054	43	RCL	119	43	RCL	184	65	x
055	00	00	120	06	06	185	43	RCL
056	54	)	121	65	x	186	12	12
057	42	STO	122	43	RCL	187	54)
058	04	04	123	07	07	188	42	STO
059	43	RCL	124	54	)	189		



PRECISION CRYSTAL OSCILLATORS SERIES 8000

STANDARD FREQUENCY 5.0 MHz

AGING RATE _____ MODEL ER8001 $1 \times 10^{-9}/\text{day}$
MODEL ER8003 $1 \times 10^{-10}/\text{day}$
MODEL ER8005 $5 \times 10^{-11}/\text{day}$

PHASE NOISE _____ SSB 1 Hz BW at 10 Hz offset
MODEL ER8001 . . . 124 db
MODEL ER8003 . . . 135 db

INPUT VOLTAGE _____ 12 VDC \pm 10% STANDARD

OUTPUT _____ SINE-WAVE 1VRMS INTO 50
ohm LOAD

SIZE _____ MODEL ER8001 and
MODEL ER8003
2" x 2" x 4" H
MODEL ER8005
2.25" x 2.25" x 4.25" H

OPTIONS _____ MANY OPTIONS ARE AVAIL-
ABLE TO INTERFACE WITH
YOUR REQUIREMENTS

ELECTRONIC RESEARCH COMPANY SERIES 8000 PRECISION OVENIZED CRYSTAL OSCILLATORS ARE THE ULTIMATE CHOICE WHERE PROVEN RELIABILITY AND FREQUENCY STABILITY IS REQUIRED. THESE OSCILLATORS ARE IDEAL FOR APPLICATIONS WHERE A PRECISION TIME BASE IS TO BE MULTIPLIED OR SYNTHESIZED REQUIRING A LOW PHASE NOISE SOURCE. ALL ELECTRONIC RESEARCH COMPANY'S OSCILLATORS UTILIZE QUARTZ CRYSTALS MANUFACTURED BY ERC FOR MAXIMUM CONTROL ON ALL PARAMETERS TO INSURE PERFORMANCE SPECIFICATIONS. IF YOUR APPLICATION REQUIRES SUPERIOR OSCILLATOR PERFORMANCE CALL US OR WRITE FOR OUR COMPLIMENTARY CATALOGUE.

For information and prices, send your specifications to:

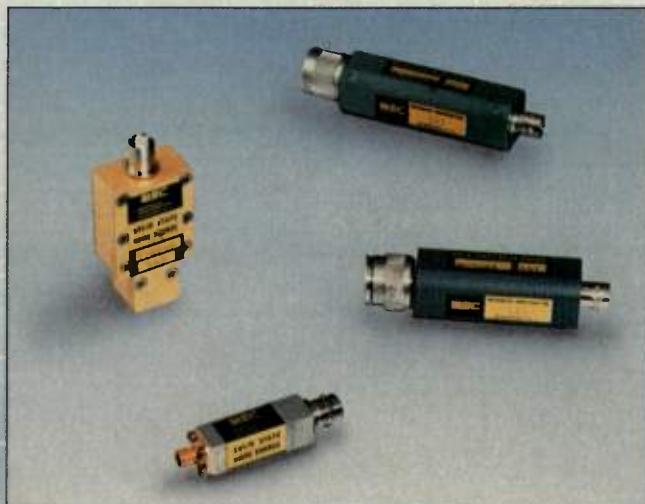
erc **FREQUENCY CONTROL PRODUCTS**
electronic research company
7618 Wedd Overland Park Kansas 66204
TWX: (910) 749-6477
Telephone: (913) 631-6700

Wideband, mm-wave, high-level... MSC's got a nose for noise.

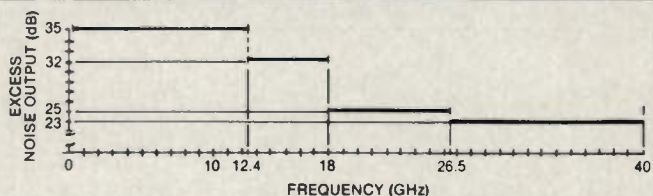
MSC's Solid State Noise Source product line results from our advanced microwave power semiconductor technology. Hybrid IC construction yields mechanical integrity capable of withstanding the most severe environmental conditions without sacrificing reliability and long-term stability.

Solid State Noise Sources are available with excess noise ratios (ENR) of 15.5 dB as direct replacements for gas discharge tube noise sources. Sources with higher level ENR allow noise to be injected into receiver front-ends via a directional coupler.

System Noise Sources are specifically designed for "BITE" applications for monitoring of parameter changes and system performance. ENR outputs of up to 35dB allow detection of receiver deterioration and developing faults.



TYPICAL EXCESS NOISE OUTPUT



WIDEBAND COAXIAL SOURCES 10 TO 18000 (MHz)

MODEL NUMBER	FREQUENCY RANGE	ENR	FLATNESS	POWER REQ. MAX.
MC 1000	10 - 1500	35.0dB	± 0.50dB	+ 28V, 10mA
MC 1100	10 - 1500	15.5dB	± 0.50dB	+ 28V, 10mA
MC 1040/1040P	10 - 4000	25.5dB/15.5dB	± 0.50dB	+ 28V, 15mA
MC 5112/5112P	1000 - 12400	25.5dB/15.5dB	± 0.50dB	+ 28V, 15mA
MC 5118/5118P	1000 - 18000	25.5dB/15.5dB	± 0.50dB	+ 28V, 15mA
MC 50018/50018P	10 - 18000	25.5dB/15.5dB	± 0.75dB	+ 28V, 15mA

WAVE GUIDE BAND SOURCES (GAS TUBE REPLACEMENTS)

MC 51218W	12400 - 18000	15.0dB	± 0.50dB	+ 28V, 15mA
MC 51826W	18000 - 26500	25.0dB	± 2.00dB	+ 28V, 20mA
MC 52640W	26500 - 40000	23.0dB	± 3.00dB	+ 28V, 20mA

HERMETIC NOISE SOURCES

MC 7090H	8325 - 9675	35.0dB	± 0.50dB	+ 28V, 15mA
MC 7146H	13500 - 15700	30.0dB	± 0.50dB	+ 28V, 15mA

Microwave Semiconductor Corp.
100 School House Rd., Somerset, N.J. 08873
A Siemens Company
(201) 469-3311 TWX(710) 480-4730 TELEX 833473

MSC

NOISE SOURCES

Short on CAD Software?

Get the **POWER** of
SUPER-COMPACT
on your **IBM P.C. !**

SUPER-COMPACT PC is the most sophisticated Microwave CAD tool available for personal computers today. A powerful aid in the design of high frequency & microwave integrated circuits, SUPER-COMPACT PC is compatible with industry standard, SUPER-COMPACT.

SUPER-COMPACT PC's full screen editor makes it easy to use, enabling microwave engineers to quickly realize improvements in

productivity, product design and performance. SUPER-COMPACT PC runs on IBM PC-XT, IBM-AT and compatibles.

In addition to INPUT FILE COMPATIBILITY with SUPER-COMPACT, SUPER-COMPACT PC gives you:

- **SCREEN EDITING CAPABILITIES**
- **TWEAK FEATURE**
- **DUAL SCREEN DISPLAY**
- **SYNTAX CHECKING**
- **OPTIONAL COMMUNICATIONS MODULE**

- **Powerful**
- **Fast**
- **Accurate**
- **Reliable**
- **Affordable**



**SUPER-COMPACT PC now gives you
FULL MODELING CAPABILITIES offered in
the Industry Standard SUPER COMPACT. Plus . . .
an UPDATED AND COMPLETE ELEMENT LIBRARY.**

Have a Hands On Experience at R.F. Technology Expo, Booth 100 & 101

COMPACT SOFTWARE

A
**COMSAT TECHNOLOGY
PRODUCTS COMPANY**

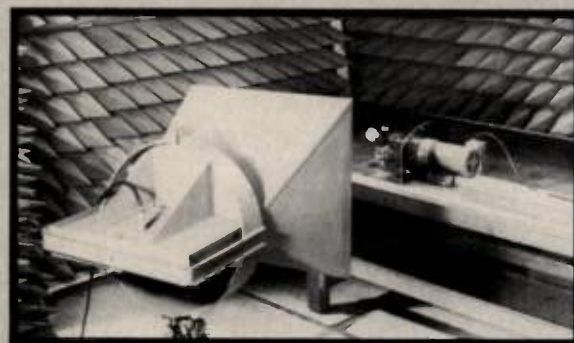
1131 San Antonio Road, Palo Alto, CA 94303, Telephone: 415-965-6440, TWX: 910-373-0048, FAX: 415-962-0542, Telex: 171427.
2700 Prosperity Avenue, Fairfax, Virginia 22031, Telephone: 703-698-0215.
1314 San Basile Circle, Suite F, Round Rock, Texas 78664, Telephone: 512-255-9064.
COMSAT (U.K.) Ltd., 8-10 Grafton Street, London W1X 3LA, England, Telephone: 011-44-1-480-6183, TELEX: 851-265883

[illegible]

585	43	RCL	650	85	+	652	43	RCL
586	24	24	651	43	RCL	653	07	07
587	54	)	652	07	07	654	54)
588	42	STO	653	54	)	655	55	÷
589	06	06	654	33	x ²	656	53	(
590	53	(	655	95	=	657	43	RCL
591	43	RCL	656	35	1/x	658	05	05
592	21	21	657	65	x	659	33	x ²
593	65	x	658	04	04	660	85	+
594	43	RCL	659	95	=	661	43	RCL
595	24	24	660	42	STO	662	06	06
596	85	+	661	28	28	663	33	x ²
597	43	RCL	662	94	+/-	664	75	-
598	22	22	663	85	+	665	43	RCL
599	65	x	664	01	1	666	07	07
600	43	RCL	665	95	=	667	33	x ²
601	25	25	666	28	LOG	668	75	-
602	54	)	667	65	x	669	43	RCL
603	42	STO	668	01	1	670	08	08
604	07	07	669	00	0	671	33	x ²
605	53	(	670	95	=	672	54)
606	43	RCL	671	99	PRT	673	54)
607	22	22	672	43	RCL	674	22	INV
608	65	x	673	28	28	675	30	TAN
609	43	RCL	674	28	LOG	676	95	=
610	24	24	675	65	x	677	99	PRT
611	75	-	676	01	1	678	53	(
612	43	RCL	677	00	0	679	43	RCL
613	20	20	678	95	=	680	06	06
614	65	x	679	99	PRT	681	85	+
615	43	RCL	680	98	ADV	682	43	RCL
616	25	25	681	43	RCL	683	07	07
617	54	)	682	13	13	684	54)
618	42	STO	683	32	X↔T	685	55	÷
619	08	08	684	43	RCL	686	53	(
620	43	RCL	685	26	26	687	43	RCL
621	05	05	686	67	EQ	688	05	05
622	42	STO	687	19	D'	689	85	+
623	19	19	688	43	RCL	690	43	RCL
624	43	RCL	689	29	29	691	08	08
625	06	06	690	42	STO	692	54)
626	42	STO	691	11	11	693	94	+/-
627	20	20	692	61	GTO	694	22	INV
628	43	RCL	693	14	D	695	30	TAN
629	07	07	694	76	LBL	696	95	=
630	42	STO	695	19	D'	697	99	PRT
631	21	21	696	43	RCL	698	98	ADV
632	43	RCL	697	26	26	699	43	RCL
633	08	08	698	91	R/S	700	13	13
634	42	STO	699	00	0	701	32	X↔T
635	22	22				702	43	RCL
636	71	SBR	638	60	DEG	703	26	26
637	49	PRD	639	53	(	704	67	EQ
638	53	(	640	02	2	705	19	D'
639	43	RCL	641	65	x	706	43	RCL
640	05	05	642	53	(	707	29	29
641	85	+	643	43	RCL	708	42	STO
642	43	RCL	644	08	08	709	11	11
643	08	08	645	65	x	710	61	GTO
644	54	)	646	43	RCL	711	14	D
645	33	x ²	647	06	06	712	76	LBL
646	85	+	648	75	-	713	19	D'
647	53	(	649	43	RCL	714	43	RCL
648	43	RCL	650	05	05	715	26	26
649	06	06	651	65	x	716	91	R/S

Largest Independent Lab In The West

Faster Turnaround EMI/EMC Testing Two Weeks or Less!



200 V/m Testing to 18 GHz Receiving Capability to 40 GHz

With seven large shielded enclosures, 25 years of EMI/EMC experience, and a highly trained staff, Genisco has the "right stuff" to solve all of your susceptibility and emissions testing problems. Talk to us about much-shorter lead times before you schedule your next test. We can even set up a two-or-three shift operation for you to meet urgent scheduling requirements!

- MIL-STD 461A/B, medical and commercial specs
- Radiated susceptibility testing: 10kHz-18 GHz
- Enclosure treated with RF anechoic material
- Emissions testing: 20 Hz to 40 GHz
- Modern semi-automatic swept EMI receivers
- Automated analysis; x-y plots to 40 GHz
- Mobile EMI vans for remote-site testing
- EMC consulting and custom EMI filter designs

Current Capabilities Include:

Frequency	Field Intensity	Modulation	Antennas
10 kHz - 30 MHz	200 V/m	CW, AM, FM or β M	IFI EFG-3, AR AT3000, parallel plate
30 MHz - 150 MHz	200 V/m	CW, AM, FM, β M or pulse mod.	IFI EFG-3
150 MHz - 375 MHz	200 V/m	CW, AM, FM, β M or pulse mod.	IFI EFG-3, AR AT1000
375 MHz - 1 GHz	200 V/m	CW, AM, FM, β M or pulse mod.	AR AT1000, Stoddart 92270-1 Horn
1 GHz - 18 GHz	200 V/m	CW, AM or pulse mod.	Standard gain horns, and ridged-guide horns
18 GHz - 40 GHz	200 V/m	CW, AM or pulse mod.	(Available by August 1985)

Call Bill Parker at (213) 537-4750

GENISCO
TECHNOLOGY CORPORATION
EMC Engineering Services Division
18435 Susana Rd., Rancho Dominguez, CA 90221
(213) 537-4750, TWX: 910-346-6773

The Phase/Frequency Detector

An analysis of phase-locked loop design employing phase frequency detectors.

By James Crawford

The controversial subject of "Divider Time Delay"¹ in recent *RF Design* issues has prompted the following discussion which was presented at a Hughes Aircraft Co. in-plant class on phase-locked loop design. The following analysis is an endorsement of Dr. Egan's explanation² where he states that the appearance of the delay-like term is due to the sampling process which is taking place in the phase-locked loop, not the transport delay or any other delay through the divider.

The delay-like terms which was mentioned above is shown in equations (3) and (4) of reference [3]. In this reference it is suggested that "the discrepancy between theory and experiment (in phase-locked loop design) was found to be attributed to divider delay which caused a decrease in phase margin significant enough in many cases to cause unstable loop performance." A decrease in loop phase margin does indeed occur in these phase-locked loops but the sole mechanism is a result of the sampling process which is taking place in the closed loop.

A rigorous analysis of phase-locked loop design employing phase-frequency detectors necessitates a detailed examination of the operation fundamentals. Rather than deal immediately with the specifics of phase-locked loop design using the phase/frequency detector, the problem will be dealt with using the following approach:

1) A general discussion of sampling phase-locked loops will be given which will display some of the differences between the true open-loop gain function, and the commonly used continuous approximation to the open-loop gain function.

2) With the sampling basics now developed, the transfer function for the phase/frequency detector will be found in some detail.

3) The phase/frequency detector transfer function is used to write an accurate impulse for the open-loop gain function. Given this function, a band-limited approximation of the open-loop gain function will be found using Z-transforms. The final band-limited expression can be used with conventional continuous transform (Laplace transforms) design methods for phase-locked loops.

Sampling Phase-Locked Loop Fundamentals

In contrast to the continuous mixer-type phase detector, the phase/frequency detector is a sampling phase detector. Phase error information is available at discrete time intervals which are spaced at exact intervals of T seconds, where T is the period of the reference frequency. The phase error at each instant is in the form of an impulse function whose area is proportional to the phase error. In reality, the impulses out of a phase-frequency detector such as the Motorola 4344 are of finite amplitude, but this fact is completely negligible in light of the RC filter time constants which follow the device. The phase detector output pulses may be mathematically viewed as ideal

impulse functions of appropriate area. For the time being, the concept of the phase/frequency detector as an ideal impulse sampler will be deferred and developed momentarily.

The phase-frequency detector is modeled in Figure 1 as an ideal impulse sampler. The function $H(s)$ represents some form of analog "hold" function such as the RC lowpass filters that customarily follow a phase-frequency detector. The function $G(s)$ represents the normal loop filter transfer function.

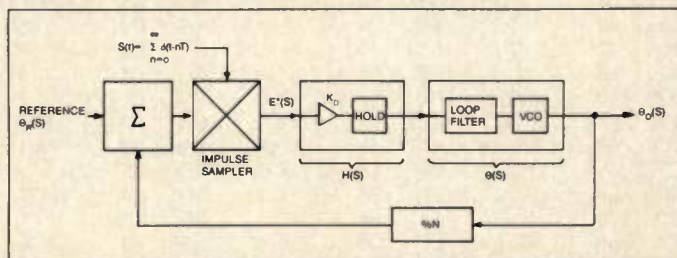


Figure 1. The general Sampled phase-locked loop employs an ideal impulse sampler which must be followed by some form of "hold" device. (HS).

Before jumping into the loop details, as an aside, consider the time function $f(t)$ which is sampled by an ideal impulse sampler. The sampled time function can be written as in (1) where the asterisk (*) represents the time-sampled form of the function.

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

From Laplace platform and convolution theory, (1) may be written in Laplace transforms as in (2) where $F^*(s)$ and $f^*(t)$ are Laplace transform pairs. Note that $F(s)$ and $f(t)$ are also Laplace transform pairs.

$$F^*(s) = F(s) \star L \left\{ \sum_{n=0}^{\infty} \delta(t - nT) \right\} \quad (2)$$

The \star in (2) represents convolution in the frequency domain. Equation (1) may be used with the definition of the forward one-sided Laplace transform to give yet another interpretation of the time-sampled function form in the frequency domain.

$$F^*(s) = \int_0^{\infty} f^*(t) \exp(-st) dt \quad (3)$$

$$= \int_0^{\infty} f(t) \sum_{n=0}^{\infty} \delta(t - nT) \exp(-st) dt$$

$$F^*(s) = \sum_{n=0}^{\infty} \int_0^{\infty} \delta(t - nT) \exp(-st) dt \quad (4)$$

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

Equation (5) is actually the defining relationship for the Z-transform of $f(t)$. This fact will be used later in this article for easy calculation of $F^*(s)$.

A very powerful relationship may be found by continuing the convolution calculation in (2). Since the convolution must be performed in the frequency domain, we must know the Laplace transform of the infinite series of impulse functions which are performing the sampling operation. Since

$$\delta(t) \leftrightarrow 1 \quad (6)$$

$$\begin{aligned} \text{then} \\ L \{ \sum_{n=0}^{\infty} \delta(t-nT) \} &= 1 + \exp(-sT) + \exp(-2sT) + \dots \\ &= \frac{1}{1 - \exp(-sT)} \end{aligned} \quad (7)$$

The convolution of (2) may be rewritten as

$$\begin{aligned} F^*(s) &= F(s) \star \frac{1}{1 - \exp(-sT)} \\ &= \int \frac{F(u) du}{1 - \exp(sT - uT)} \\ &= \int \frac{F(Z)}{1 - \exp(sT/Z)} \frac{dz}{T Z} \end{aligned} \quad (8)$$

where $Z = \exp(uT)$ and $du = dZ/(TZ)$.

Taking this process one step further and using the Residue theorem, this integral may be evaluated as in (9).

$$\begin{aligned} &= \frac{1}{T} \int \frac{F(Z) dZ}{Z - \exp(-sT)} \\ &= \frac{1}{T} \sum_{n=-\infty}^{\infty} F(s + j n W_s) \end{aligned} \quad (9) \quad \text{where } W_s = 2\pi/T.$$

Equation (9) is a valuable result and although it involves an infinite summation, it may be used to evaluate $F^*(s)$.

These previous transform tools will appear much more valuable if we now return to a discussion of Figure 1. As in classical PLL analysis, the most expedient first step in the loop analysis is to solve for the error function $E^*(s)$. We may write

$$\begin{aligned} E^*(s) &= (\Phi_r - \Phi_o)^* \\ &= \Phi_r^* - \Phi_o^* \\ &= \Phi_r^* - [E^*(s) H(s) G(s)]^* \end{aligned} \quad (10)$$

Those unfamiliar with sampled systems will find [4] particularly useful and easy to understand. As developed in Chapter 4 of [4], the sampling operation in (10) may be brought within the brackets because $E(s)$ is already a sampled function. The sampled error function is then given by

$$E^*(s) = \Phi_r^* - E^*(s) HG^*(s) \quad (11)$$

We finally obtain the desired result for the sampled loop error function.

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

In most cases, $\Phi_r(s)$ can be assumed to be effectively bandlimited and aliasing of noise products can be neglected. This gives some simplification to (12) as given in (13).

$$E^*(s) = \frac{\Phi_r(s)/T}{1 + HG^*(s)} \quad (13)$$

where $\Phi^*(s) \sim \Phi_r(s)/T$.

The asterisks would be absent in classical analysis of a phase-locked loop which neglected sampling effects. With rare exception, most systems which use the phase/frequency detector have a small bandwidth compared to the reference frequency in order to obtain reasonably low "sampling spurs." For this reason, the higher order terms (terms other than $n=0$) in equation (9) can largely be ignored for low bandwidth situations. This is precisely why classical analysis ignoring sampling effects still provides excellent results in small bandwidth situations. As the loop bandwidth is increased compared to the reference frequency, however, the higher order terms cannot be ignored.

For large loop bandwidth situations (bandwidth $> 0.1 F_{ref}$), Z-transform techniques should be used to include the higher order effects. If there are true transport time delays within the loop, modified Z-transforms should be used. If the loop bandwidths remain small (say $< 0.1 F_{ref}$), bandlimited forms of the open-loop gain function may be found which very accurately describe sampling effects without resorting to Z-transform analysis. Equation (9) which is repeated below as equation (14) will provide the menu for arriving at a bandlimited form of the open-loop gain function including sampling effects. The continuous Laplace transform impulse response, $G(s)$, must first be found. The continuous open-loop gain function will be re-expressed in terms of Z-transforms and the assumption of small loop bandwidth imposed. The final result will be the bandlimited form of the open-loop gain function with first order sampling effects.

$$F(Z) = \frac{1}{T} \sum_{n=-\infty}^{\infty} F(s + j n W_s) \quad (14)$$

It will be shown that the so called "divider time delay" appears during this step and is solely a result of sampling.

Impulse Response of the Phase/Frequency Detector

A simplistic equivalent circuit of the phase/frequency detector is provided in Figure 2. No attempt has been made here to describe the frequency discriminator mode of operation. In many applications, the phase detector remains in its linear range of operation, because although the phase error may be very large at the VCO, it is reduced by N at the phase detector.

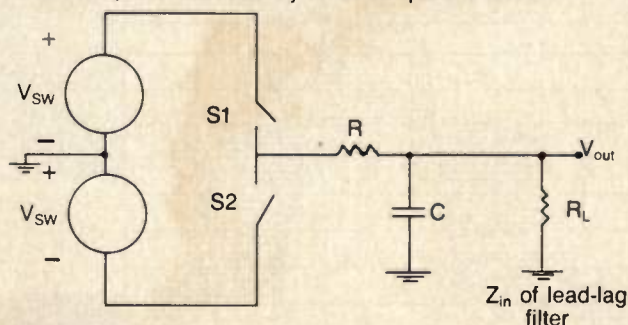


Figure 2

In steady-state operation, the switches in Figure 2 are open 95 percent of each reference period, only closing long enough to replenish the small discharge in capacitor C each reference period. (Since the 4344 type phase detector cannot resolve absolute time difference between the divider and reference pulse trains less than its own internal time delay, some built in offset is needed to avoid the detector's "dead zone" of operation at zero time difference between the two waveform trains.) During the period of frequency acquisition, the proper polarity switch is closed for a length of time which is defined by the time difference between the leading edge of the divide-by-N signal. This signal relationship is shown in Figure 3. The phase detector output pulse width is directly proportional to the phase error within the loop.

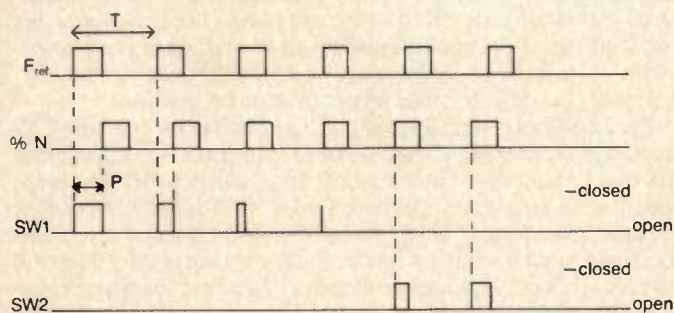


Figure 3

$$\phi_e = \frac{P}{T} 2\pi \quad (15)$$

$$\text{or} \\ p = \frac{T}{2\pi} \phi_e$$

The pulse widths out of the phase detector, p , are very small with respect to the reference period because a Type II loop is always used (zero steady-state phase error) and the VCO phase error is reduced by the divider ratio, N .

We are primarily interested in the impulse response of the phase detector/lowpass filter combination. The transfer function for the lowpass filter alone is given by (16).

$$FL(s) = \frac{R1}{R1 + R} \frac{1}{1 + s \tau 1} \quad (16)$$

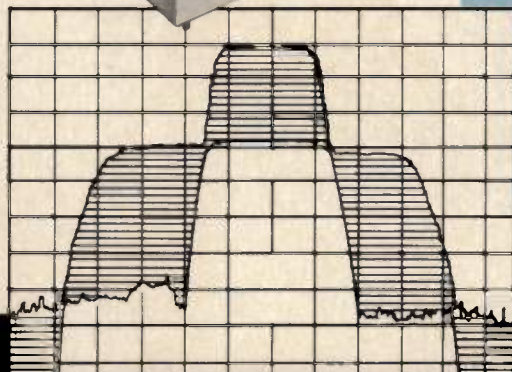
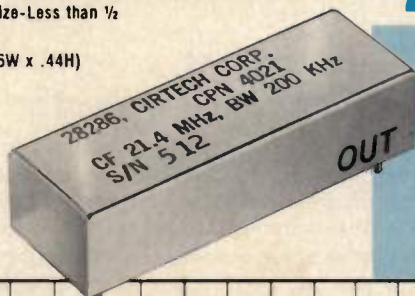
$$\text{where } \tau 1 = \frac{R1 R C}{R1 + R}$$

A typical pulse response of the circuit in Figure 2 is presented in Figure 4. The rising edge is very linear because $p \ll \tau 1$. The output voltage, V_{out} , can be easily found from Figure 4. The output voltage during the next reference period is given by (17).

$$V_{out}(t) = V_o \exp(-t/\tau 1) + \frac{R1}{R1 + R} V_{sw}(1 - \exp(-t/\tau 1)) \quad (17)$$

THINK SMALL

Package Size-Less than 1/2 cubic inch
(1.75L x .6W x .44H)



NEVER HAVE WE PUT SO MUCH PERFORMANCE IN SUCH A SMALL PACKAGE!



CIRTECH

21.4 Mhz LC and Crystal Family

CPN	3db Bandwidth	Ripple	Insertion Loss	Shape Factor 60:3	Spurious Response
4021	200 Khz.	.75db	7db	2.5:1	55db
4022	400 Khz.	1db	6db	3.5:1	55db
4023	600 Khz.	1db	8db	4:1	60db
4024	4 Mhz.	1db	3db	3:1	60db
4025	2 Mhz.	1db	5db	3:1	60db
4026	1 Mhz.	1db	7db	3.5:1	60db
4027	500 Khz.	1db	7db	4:1	60db
4028	3.2 Khz.	.5db	4.5db	2.5:1	65db
4029	300 Khz.	1db	9db	2.5:1	55db
4030	50 Khz.	1db	3db	2.5:1	65db
4031	100 Khz.	1db	8db	2.5:1	55db
4032	10 Khz.	1db	3db	2.5:1	65db
4033	20 Khz.	1db	3db	2.5:1	65db

Cirtech's usual high rel process of thermal shock and accelerated aging mean superior reliability. The size uniformity on the 21.4 Family is ideal for applications offering customers optional bandwidths. Conforms to MIL-STD-202 Method 204, Condition B. **FOR BROCHURE WRITE:**

CIRTECH CORPORATION

P.O. BOX 23096 • 15237 CHERRY ST. • STANLEY, KANSAS 66223
913-681-2801 • TWX 910-749-6806

Now, HP packs more value into its economical RF spectrum analyzers with digital display and rugged portability.



Measuring RF signals? HP's economy RF spectrum analyzers now give you even more value for your money. We've added digital display, versatile data I/O and rugged portability to the excellent performance and operating simplicity of these popular spectrum analyzers. The new HP 853A digital display spectrum analyzer mainframe with the HP 8557A (10 kHz-350 MHz) or 8558B (100 kHz-1500 MHz) spectrum analyzer plug-in combines accurate performance and simple three-knob operation to meet a wide range of RF measurement applications.

Digital display adds clarity and convenience.

The HP 853A provides two independent 480-by-800-point resolution traces for flexibility in storing trace data and monitoring signal changes. You get a crisp, flicker-free, easy-to-read display. And the microprocessor-managed display system includes maximum hold for storing peak signal values, digital averaging over successive sweeps to reduce noise effects, and trace normalization to help detect signal changes in a crowded spectrum.

Rugged portability lets you take it almost anywhere.

The 853A is designed for transportable use in rigorous environments. Weighing less than 48 lbs., the analyzers can be taken outdoors for field test use, or easily moved around lab and production sites. The 853A comes with a tilt-bail handle, rubber bumpers, and a drip-proof front panel cover. What's more, the HP 853A with plug-in installed is type-tested to meet shock, vibration and driptest

levels specified under MIL-T-28800 C Type III, Class 3, Style C performance tests.

A choice of RF plug-ins covers your applications.

Notable performance specifications of the 8557A and 8558B plug-ins include 70 dB dynamic measurement range, 1 kHz to 3 MHz variable resolution, full range frequency response of ± 1 dB and 70 dB IF substitution amplitude accuracy of ± 1 dB. Basic measurements require only a three-knob sequence: TUNE to a signal and read frequency from the LED display, narrow the FREQUENCY SPAN for closer analysis and adjust REFERENCE LEVEL to read amplitude directly. Resolution and sweep speed are automatically adjusted.

U.S.A. list prices for the plug-ins are: HP 8557A (350 MHz) \$6,520; HP 8558B (1500 MHz) \$7,925. The new 853A display mainframe is listed at \$5,550*



DESIGNED FOR
HP-IB
SYSTEMS

trace I/O as well as operator prompts on the CRT.

For a permanent record or comparison of many displays, the 853A push-button controls can directly operate an HP-IB plotter for hard copy data recording. Or connect the 853A to a computer (like the HP-85) via HP-IB and get

To add portability and digital display convenience to your RF spectrum analysis applications, call your nearest HP sales office and ask for "Instruments." For the same simplicity and performance in microwave applications, ask about HP's economical microwave plug-in for the 853A. For more information about these instruments, write Hewlett-Packard, 1820 Embarcadero Road, Palo Alto, CA 94303.

5301201

*U.S.A. list prices only



**HEWLETT
PACKARD**

INFO/CARD 43

WRH

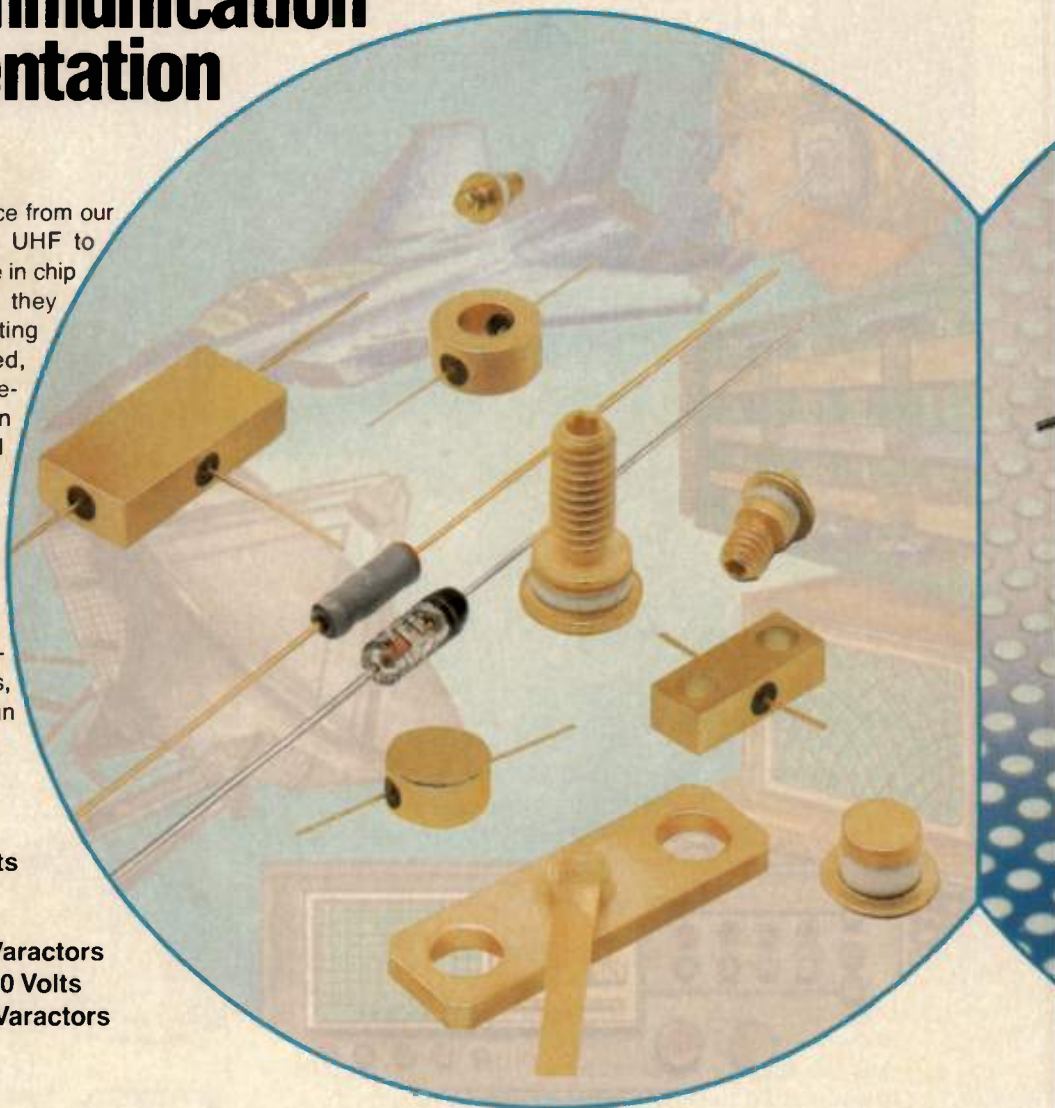
THE "CAN DO" COMPONENT COMPANY

Semiconductors for Defense, Communication and Instrumentation

You can select with complete confidence from our full line of semiconductors for your UHF to millimeter applications. Whether they be in chip form, glass or ceramic configuration, they have one thing in common — operating reliability. Each has been designed, processed, measured, tested and re-tested to provide optimal performance in some of the most advanced RF and microwave circuits. We produce them by the dozens or thousands to match strict specification requirements, as well as the equally important parameters of price and delivery.

Many of our high performance products are available as standard products, or call to discuss your special design 617-256-8101.

- Silicon Abrupt Junction Tuning Varactors, 30V to 90 Volts
- FLTVAR — Frequency Linear Tuning Varactors
- VHF/UHF Hyperabrupt Tuning Varactors
- GaAs Tuning Varactors 15V to 60 Volts
- Power Generation — Multiplier Varactors
- Step Recovery Diodes
- Harmonic Generator Varactors
- Multi-Chip High Power Generator Varactors
- Noise Diodes
- Gunn Diodes
- Parametric Amplifier Varactors
- Control Devices — PIN and NIP Diodes
- UHF/VHF PIN Diodes
- Power RF Switching
- Small Signal RF Diodes
- HF Power PIN Diodes
- Limiter Diodes
- Chip Capacitors



FREQUENCY SOURCES

SEMICONDUCTOR DIVISION

A SUBSIDIARY OF LORAL CORPORATION

16 Maple Road
Chelmsford, MA 01824
(617) 256-8101
TWX (710) 343-0404

INFO/CARD 39

While it's true that Telonic Berkeley did introduce the first tubular bandpass filters over 20 years ago, we're also a leading creator of a multitude of other unique RF and microwave filters. Our diplexers and triplexers are just an example of our broad capabilities.

Coaxial or waveguide...DC to 18GHz and above...ground to outer space. We can provide filters to meet your size and frequency specifications.

Our Engineering, Program Management, Quality and Production departments are organized to respond rapidly to support your needs. With an eye for critical design parameters such as corona, multipaction and sealing, and difficult environmental requirements,

Telonic Berkeley's engineers design filters, diplexers and multiplexers that withstand the most stringent temperature, shock and vibration requirements. We have the technology to provide state-of-the-art

**...And you
thought
we only made
tubular
filters.**

designs, plus the organizational depth to support sophisticated programs with program management, design reviews and reliability analyses.

Looking for a company that can handle your filter project from concept through delivery? Look no further. Contact Telonic Berkeley today with your RF and microwave filtering requirements.

TELONIC BERKELEY INC.
2825 Laguna Canyon Road
P.O. Box 277

Laguna Beach, CA 92652

TLX 18-2720 Domestic

TLX 47-20277 Foreign

Our Toll Free Telephone (800) 854-2436

(Except CA)

In California (714) 494-9401



TELONIC/BERKELEY

INFO/CARD 40

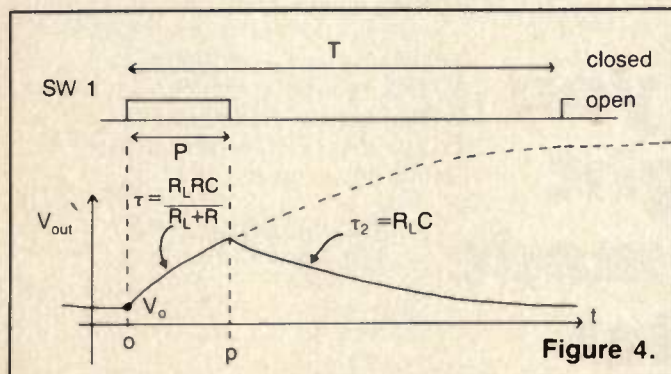


Figure 4.

for $0 < t \leq p$

$V_{out}(t) = V_{out}(p) \exp(-t/\tau_2)$ for $p < t < T$.

In a properly designed Type II loop under normal linear operation, $p \ll \tau_1$ and equation (17) may be written in a more simple form without the first exponentials.

$$V_{out}(t) \sim V_o + \frac{R_1}{R_1 + R} V_{sw}(t/\tau_1) \quad (18)$$

for $0 < t \leq p$

$V_{out}(t) = V_{out}(p) \exp(-t/\tau_2)$ for $p < t < T$.

It is important to note once more that V_o represents the initial capacitor voltage due to any previous phase sample, Φ_e .

The Laplace transform transfer function can be found by using the above equations directly.

$$V_{out}(s) = L\left\{V_o + \frac{R_1}{R_1 + R} V_{sw} \frac{p}{\tau_1} \exp(-t/\tau_2)\right\} \quad (19)$$

$$= \frac{V_o}{s + 1/\tau_1} + \frac{R_1 V_{sw} \Phi_e T}{(R_1 + R) \tau_1 2\pi (s + 1/\tau_2)}$$

where the phase error is $\Phi_e = 2\pi p/T$.

As stated earlier, V_o is a direct result of earlier samples of the phase error, Φ_e . Using this fact, it is possible to show that the output voltage as a function of the input phase error is given by (20).

$$V_{out}(s) = \frac{K_d T}{(R_1 + R)/R_1 + sRC} \frac{1}{1 - \exp(-sT) \exp(-T/\tau_2)} \quad (20)$$

where $K_d = V_{sw}/(2\pi)$

This is the final result for the phase detector impulse response. The factor T is a direct result of the sampling operation. Notice that if T/τ_2 is not large, the second multiplicative factor cannot be ignored. In this case, the output voltage is a function of the present phase detector error as well as the previous error samples and Z-transform analysis is required. Since the intent of this analysis has been to eventually arrive at a band-limited form of the open-loop gain function, in that vein, T/τ_2 will be assumed to be $\gg 1$ such that Z-transform analysis will not be required in the final end result.

AMERICA'S BIGGEST ELECTRONICS COMPANIES ARE PAYING US TO KEEP QUIET.

It's no secret that nobody can keep something sealed and secured like SRS. That's why companies like McDonnell Douglas, Westinghouse, Hughes, ITT and many others trust their EMI/RFI, EMP shielding, and environmental sealing problems to us. You see, we developed SRBOND™ fabrication services, a special EMI/RFI gasket technology designed so we can fully configure, cure and bond elastomers to both metallic and non-metallic surfaces, prevent over-deflection of materials, and give up to 100% db attenuation and 100% protection from hostile environments.

Whether you need an individual com-

ponent part, or the fabrication of a complete assembly, call SRS and we'll show you how we can engineer a solution to fit any form, and any surface, on your product. Or write us for our new design guide at Dept. F. When it comes to db attenuation, we don't think any company has more to say about keeping quiet.



SRS Industries

DIVISION OF KEENE CORPORATION

903 South Alta Vista Avenue
Monrovia, CA 91016

(818) 357-3287 TWX: 910-585-3486

INFO/CARD 41

February 1985

Derivation of the Continuous Band-Limited Open-Loop Gain Function with Sampling

The phase-frequency detector is always used in a Type II phase-locked loop in order to realize reasonable spurious performance and tuning range. In order to simplify the mathematics involved, however, an example using a Type I system will be used. Our approach will be to calculate $Gol(Z)$ and compare it to the continuous form of $Gol(s)$. This will reveal the effects of sampling upon the otherwise continuous open-loop gain expression.

In order to make any connection between an impulse sampled system and a continuous system, the sampled loop must have some form of "hold" device which effectively converts the phase detector impulse functions into smooth time waveforms which have a finite width in time, and a finite height. If the "hold device" is not present, the loop *must* be analyzed as a sampled system. No equivalent continuous system would exist for that case.

The "hold" device may be as simple as an RC lowpass filter, or as complicated as a true 0-order sample/hold. Consider a continuous Type I phase-locked loop with a low pass "hold" as given in (21).

$$Gol(s) = \frac{K_d K_v}{N s} \rightarrow \frac{W_n}{s} \frac{1}{1+s\tau} \quad (21)$$

where

K_d =phase detector gain

K_v =VCO sensitivity

N =feedback divider ratio

τ =low pass filter time constant representing the "hold."

As shown earlier, the sampling effects upon a continuous function may be included by taking the Z-transform of the time function provided that the continuous function is correct of course. In the previous section, it was shown that the impulse response of the phase/frequency detector followed by a simple RC lowpass filter is given by (20). Therefore, assuming that $T \gg \tau$ in equation (20), equation (21) must be multiplied by T to have proper form. Using a table of Z-transforms, equation (21) may be easily converted into $Gol(Z)$.

$$\frac{W_n T}{s(1+s\tau)} \rightarrow W_n (1 - \exp(-t/\tau)) T \quad (22)$$

$$\rightarrow \frac{W_n Z T}{Z-1} - \frac{W_n Z T}{Z-A}$$

Collecting terms in (22), the Z-transform for the Type I system is simply given by (23).

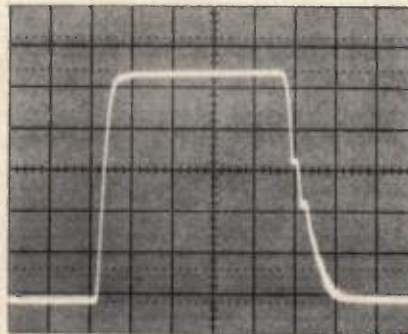
$$Gol(Z) = \frac{W_n Z (1-A) T}{(Z-1)(Z-A)} \quad (23)$$

We can effectively remove any significant effects of the "hold" device upon the system by allowing $\tau \rightarrow 0$, i.e., $A \rightarrow 0$. This is equivalent to making the RC filter time constant negligible compared to the reference period, T . In the limit as $A \rightarrow 0$,

$$Gol(Z) = \frac{W_n Z T}{(Z-1)(Z-0)} = \frac{W_n T}{(Z-1)} \quad (24)$$

Equation (24) may be expressed in terms of the more familiar complex frequency, s , by noting that $Z = \exp(sT)$. Doing so, we obtain (25).

NEED FAST LOG RESPONSE?



LOG TECH HAS THE SOLUTION

DO YOU NEED HIGH FIDELITY LOGGED RF OR IF RESPONSE? THEN STUDY THIS ACTUAL PHOTOGRAPH SHOWING THE LOGGED RESPONSE OF A ONE MICROSECOND PULSE USING THE CLA SERIES OF LOG AMPLIFIERS.

THE CLA SERIES OFFERS STATE OF THE ART RISE AND FALL TIMES TO PROVIDE A "HIGH FIDELITY" LOG RESPONSE.

SPECIFICATIONS:

Frequency Range
30MHZ—1.2GHZ

Input Dynamic Range
30 to 80 db (Selectable)

Meets Environmental Requirements of MIL-E-5400

WE INVITE INQUIRIES
CONCERNING YOUR SPECIAL
REQUIREMENTS.



LOG TECH, INC.

3529 Old Conejo Rd.
Suite 123
Newbury Park, Ca. 91320
(805) 499-6462

Number of harmonic terms included in summation 5
 Loop reference frequency 10000
 Type I loop Wn 2000
 Loop LPF time constant, nsec 5000
 APPROXIMATION TO SAMPLED OPEN-LOOP GAIN FUNCTION

Summation of Gol Terms			Continuous Gol Exp(-ST/2)	
F	Gol,dB	Ang,Deg		
100	10.06	-91.20	10.06	-91.98
150	6.53	-91.08	6.54	-92.97
200	4.03	-92.40	4.04	-93.96
300	0.51	-93.61	0.51	-95.94
400	-2.00	-94.01	-1.98	-97.92
500	-3.94	-96.03	-3.92	-99.90
700	-6.09	-98.47	-6.05	-103.86
1000	-10.03	-102.21	-9.95	-109.00
1500	-13.65	-108.72	-13.47	-119.70
2000	-16.28	-115.74	-15.98	-129.60
3000	-20.07	-132.17	-19.52	-149.30
4000	-22.55	-153.18	-22.05	-169.16

Number of harmonic terms included in summation 10
 Loop reference frequency 10000
 Type I loop Wn 2000
 Loop LPF time constant, nsec 5000
 APPROXIMATION TO SAMPLED OPEN-LOOP GAIN FUNCTION

Summation of Gol Terms			Continuous Gol Exp(-ST/2)	
F	Gol,dB	Ang,Deg		
100	10.06	-91.46	10.06	-91.98
150	6.54	-92.19	6.54	-92.97
200	4.04	-92.93	4.04	-93.96
300	0.51	-94.39	0.51	-95.94
400	-1.98	-95.86	-1.98	-97.92
500	-3.92	-97.33	-3.92	-99.90
700	-6.04	-100.30	-6.05	-103.86
1000	-9.94	-104.79	-9.95	-109.00
1500	-13.45	-112.49	-13.47	-119.70
2000	-15.92	-120.54	-15.98	-129.60
3000	-19.24	-138.14	-19.52	-149.36
4000	-21.15	-150.08	-22.05	-169.16

Number of harmonic terms included in summation 5
 Loop reference frequency 1000
 Type II loop Wn 2000
 Loop damping factor, eta .707
 APPROXIMATION TO SAMPLED OPEN-LOOP GAIN FUNCTION

Summation of Gol Terms			Continuous Gol Exp(-ST/2)	
F	Gol,dB	Ang,Deg		
100	20.95	-156.41	20.90	-158.03
150	14.77	-147.09	14.67	-149.29
200	10.75	-139.68	10.60	-142.34
300	5.68	-129.45	5.46	-132.82
400	2.48	-123.29	2.22	-127.29
500	0.16	-119.51	-0.11	-124.14
700	-3.13	-115.77	-3.41	-121.69
1000	-6.45	-114.59	-6.72	-122.49
1500	-10.16	-117.17	-10.37	-128.23
2000	-12.79	-122.18	-12.92	-136.02
3000	-16.50	-136.40	-16.49	-153.68
4000	-18.04	-155.59	-19.03	-172.38

Number of harmonic terms included in summation 10
 Loop reference frequency 1000
 Type II loop Wn 1000
 Loop LPF time constant, nsec 5000
 APPROXIMATION TO SAMPLED OPEN-LOOP GAIN FUNCTION

Summation of Gol Terms			Continuous Gol Exp(-ST/2)	
F	Gol,dB	Ang,Deg		
100	10.70	-139.13	10.60	-140.36
150	5.60	-120.39	5.46	-129.85
200	2.38	-121.69	2.22	-123.33
300	-1.73	-114.49	-1.93	-116.51
400	-4.46	-111.20	-4.67	-113.64
500	-6.51	-109.71	-6.72	-112.59
700	-9.53	-109.20	-9.75	-112.99
1000	-12.68	-111.03	-12.90	-116.22
1500	-16.21	-116.62	-16.46	-123.99
2000	-18.67	-123.59	-18.98	-132.82
3000	-21.97	-139.95	-22.53	-151.53
4000	-23.05	-150.98	-25.06	-170.77

(25)

$$Gol(s) = \frac{1}{j2} \frac{Wn \exp(-sT/2)}{\sin(\omega T/2)}$$

For frequencies which are small compared to the reference frequency, $F_{ref} = 1/T$, the $\sin(x) \sim x$ approximation may be made, reducing (25) to finally (26). This is equivalent to the initial premise that the loop bandwidth is much less than the reference frequency.

(26)

$$Gol(s) = \frac{Wn \exp(-sT/2)}{s}$$

The final result for the bandlimited form of the open-loop gain function is given in (27). This expression includes the first order sampling effects. The appearance of the so-called time delay exponential occurred without introducing any transport time delay whatsoever, only the sampling effects.

(27)

$$Gol(s) = \frac{\exp(-sT/2) Wn}{s}$$

Generalizing, first order sampling effects for phase-locked loops which have a small percentage bandwidth compared to the reference frequency can be analyzed using classical Laplace transform methods provided the new "delay term" is included in the phase detector transfer function.

$$Kd \exp(-sT/2) \quad (28)$$

Further Proof

As further proof of our result above, we may compare this result with that obtained using (9). Only the first few terms of the infinite summation in (9) will be included. The computer program and sample run appear in Appendix I. Notice that the inclusion of the added exponential term of (28) with the normal Type I open-loop gain results in very good agreement between the two mathematical models for frequencies well within the closed-loop bandwidth. The phase of the open-loop gain function would be very inaccurate had the exponential term been left out. As the loop bandwidth increases with respect to the reference frequency, the approximation shows more and more deviation from the true open-loop gain calculated by (9). [Note that for all cases, $T/\tau_1 \gg 1$ has been assumed with loop bandwidth $\ll F_{ref}$.]

In order to be complete, the same calculation was performed for the Type II phase-locked loop with a phase-frequency detector and small RC lowpass filter "hold." The continuous form of the open-loop gain function is given in (29) where T is due to the phase detector transfer function.

(29)

$$Gol(s) = \frac{Kd T}{1 + s\tau} \frac{1 + s\tau_2}{s\tau_1} \frac{Kv}{N s}$$

Our approximation to $G^*ol(s)$ is found using equation (28).

(30)

$$G^*ol(s) \sim \exp(-sT/2) \frac{Kd}{1 + s\tau} \frac{1 + s\tau_2}{s\tau_1 N} \frac{Kv}{s}$$

The true function $G^*ol(s)$ is found again from substituting equation (29) into (9).

(31)

$$G^*ol(s) = \frac{1}{T} \sum_{n=-\infty}^{\infty} \frac{Kd T}{1 + u\tau} \frac{1 + u\tau_2}{u\tau_1} \frac{Kv}{N u}$$

where $u = s + jnW_s$

February 1985

Reiterating, the T following K_d is due to the phase detector transfer function, (20), whereas the $1/T$ is due to the leading coefficient in (14).

A second computer program and sample run are provided in Appendix I for this Type II phase-locked loop case. Once again, the bandlimited gain expression in (30) closely approximates the true gain function (31) for frequencies well within the closed-loop bandwidth.

In concluding this article, several statements stand out.

- In order to make any correlation between sampled and continuous systems, some form of analog "hold" device impulse response of the hold device is the interpolating waveform between sample points in the time domain.
- The appearance of sampling in any loop with the accompanying "hold" device, causes an exponential phase term to appear, $\exp(-sT/2)$.
- Sampling effects in small percentage bandwidth loop (wrt. F_{ref}) may be quite accurately described by the normal continuous open-loop gain function provided that the additional exponential term is included.

Sampling effects cause the appearance of the exponential delay-like term whenever quantities within the loop are only available at discrete instants in time. Digital dividers within the feedback loop in an otherwise continuous loop will still cause the exponential term to appear. If digital feedback dividers and a digital phase/frequency detector are used within the phase-locked loop together, only one $\exp(-sT/2)$ term results (the continuous first order approximation remains unchanged). True

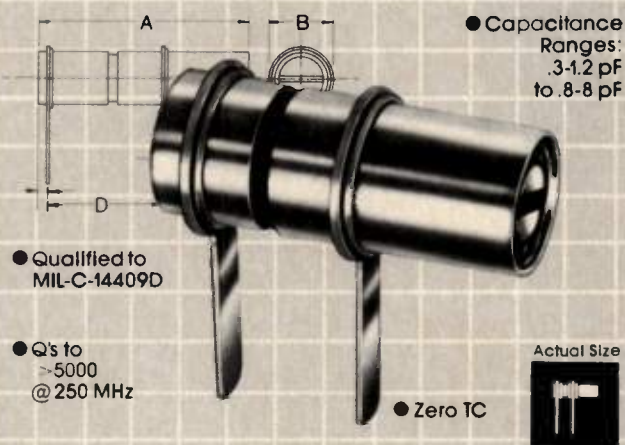
transport delay within the loop is accounted for by another exponential delay term. (Here, true transport delay refers to delay through op-amps and propagation delay refers to delays through other components, including dividers. These quantities are available in component data books.)

Analysis of the phase/frequency detector in a phase-locked loop can be considerably more complex than the usual continuous analysis which is generally employed. If the loop bandwidth is, say, $< F_{ref}/40$, the loop can be considered continuous for all practical purposes. For higher percentage bandwidths, attention should be given to the added "delay-like" term shown in equation (28) and care should be given to insure that T/τ_2 is > 3 in equation (20). [If $T/\tau_2 < 3$, another integrator in the form of a time variable filter is created which makes the situation much more complex. Of course, keeping $T/\tau_2 > 3$ will result in higher spurs and notch filtering will undoubtedly be required. The time variable filter increases the gain within the loop bandwidth and adds substantial phase as well which can easily lead to instability. For best results, choose $T/\tau_2 > 3$.]

Although the cautious aspects of sampled phase-locked loop design have been brought out for the phase/frequency detector, sampled systems harbor much more capability than first glance indicates. For instance, a Type I sampled loop which employs a zero order sample and hold rather than the phase/frequency detector will theoretically perform phase-lock in only one sample period! An ideal Type II phase-locked loop with a zero order sample and hold phase detector is capable of performing phase-lock in only two sample periods. These speed-optimized phase-locked loops must be analyzed using Z-transforms.⁵

GIGA·TRIM®

VARIABLE CAPACITORS Sapphire Dielectric



Electronic Accuracy Through Mechanical Precision

Johanson

Manufacturing Corporation

400 Rockaway Valley Road, Boonton, New Jersey 07005
201-334-2676 • TWX 710-987-8367

CONSULTING, DESIGN, and FABRICATION

★ EM SENSORS

Current Probes
Antennas
FCC & CISPR LISNs

★ NANOSECOND TRANSIENT SUPPRESSORS

Coaxial Lines
Power Lines
Telephone Circuits
I/O Semiconductor Circuits

Fischer Custom Communications, Inc.

P.O. Box 581 Dept. J
Manhattan Beach, Ca. 90266
(213) 545-4617

INFO/CARD 72

INFO/CARD 71

References

1. *RF Design*, "PLL Primer, Part III," A.B. Przedpelski, July/August 1983, pp. 48-58.
2. *RF Design*, Letters to the Editor, Dr. William F. Egan, March/April 1984, pp. 9A-12A.
3. *RF Design*, "Divider Delay: The Missing PLL Analysis Ingredient," Stan Goldman, March/April 1984, pp. 58A-66A.
4. *Digital Control of Dynamic Systems*, Gene F. Franklin, J. David Powell, Addison-Wesley.
5. *Microwaves & RF*, "Sampling Phase-Locked Loops for Frequency Synthesis," J.A. Crawford (to be published).

Appendix I

FILE: SAMPL1 71

PAGE 001

```

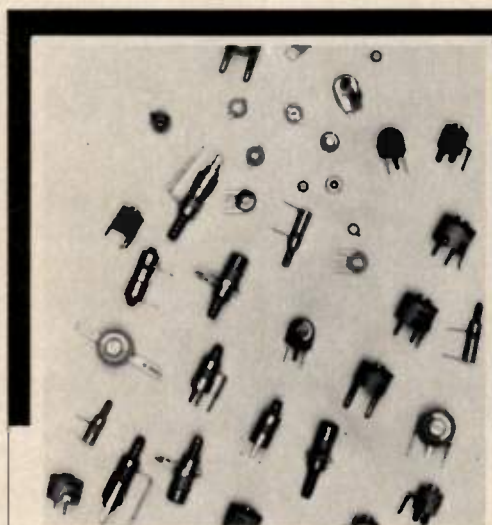
10 *****
20 '
30 ' Comparison of Sum( Fts + jnHs ) with Z-transforms
40 '
50 *****
60 DIM PTS(20),MAG(20),ANG(20)
62 PI=3.1415926540
70 FOR I%=1 TO 17
80 READ PTS(I%)
90 NEXT I%
100 DATA 100,150,200,300,400,500,700,1000,1500,2000,3000,4000,5000,7000
110 DATA 0000,9000,10000
120 '
130 INPUT "NUMBER OF HARMONICS TO INCLUDE ";NHARM;
135 INPUT "INPUT REFERENCE RATE, HZ ";FREF
136 INPUT "INPUT THE TYPE I LOOP WN ";WN

```

```

137 INPUT "INPUT THE LOW-PASS FILTER TIMECONSTANT, NSEC";TAU
138 TAU=TAU*9.999999E-10
140
150 FOR I%=1 TO 17
160 SUMR=0
170 SUMI=0
180 FOR J%=1 TO NHARM:
190 F=PTS(I%)+J%*FREF
200 GOSUB 1000
210 SUMR=SUMR+FR
220 SUMI=SUMI+F1
230 F=PTS(I%)-J%*FREF
240 GOSUB 1000
250 SUMR=SUMR+FR
260 SUMI=SUMI+F1
270 NEXT J%
280 F=PTS(I%)
290 GOSUB 1000
300 SUMR=SUMR+FR
310 SUMI=SUMI+F1
320 MAG(I%)=4.34294*LOG( SUMR^2+SUMI^2 )
330 ANG(I%)=ATN(SUMI/(SUMR+1E-08))
340 IF SUMR<0 THEN ANG(I%)=ANG(I%)-PI
350 NEXT I%
351 PRINT CHR$(26)
352 LPRINT "Number of harmonic terms included in summation ";NHARM;
353 LPRINT "Loop reference frequency ";FREF
354 LPRINT
355 LPRINT "Type I loop WN ";WN
356 LPRINT
357 LPRINT "Loop LPF time constant, nsec ";TAU*1E+09
358 LPRINT
359 LPRINT "APPROXIMATION TO SAMPLED OPEN-LOOP GAIN FUNCTION"
360 LPRINT "
370 LPRINT " Summation of Gol Terms Continuous Gol
371 LPRINT " Exp( -ST/2 ) "
372 LPRINT "
373 LPRINT " Gol,dB Ang,Deg "
374 LPRINT "===== "
375 LPRINT "
376 LPRINT "
377 LPRINT "
378 LPRINT "
379 LPRINT "
380 LPRINT "
381 LPRINT "
382 LPRINT "
383 LPRINT "
384 LPRINT "
385 LPRINT "
386 LPRINT "
387 LPRINT "
388 LPRINT "
389 LPRINT "
390 LPRINT "
391 LPRINT "
392 LPRINT "
393 LPRINT "
394 LPRINT "
395 LPRINT "
396 LPRINT "
397 LPRINT "
398 LPRINT "
399 LPRINT "
400 LPRINT "
401 LPRINT "
402 LPRINT "
403 LPRINT "
404 LPRINT "
405 LPRINT "
406 LPRINT "
407 LPRINT "
408 LPRINT "
409 LPRINT "
410 LPRINT "
411 LPRINT "
412 LPRINT "
413 LPRINT "
414 LPRINT "
415 LPRINT "
416 LPRINT "
417 LPRINT "
418 LPRINT "
419 LPRINT "
420 LPRINT "
421 LPRINT "
422 LPRINT "
423 LPRINT "
424 LPRINT "
425 LPRINT "
426 LPRINT "
427 LPRINT "
428 LPRINT "
429 LPRINT "
430 LPRINT "
431 LPRINT "
432 LPRINT "
433 LPRINT "
434 LPRINT "
435 LPRINT "
436 LPRINT "
437 LPRINT "
438 LPRINT "
439 LPRINT "
440 LPRINT "
441 LPRINT "
442 LPRINT "
443 LPRINT "
444 LPRINT "
445 LPRINT "
446 LPRINT "
447 LPRINT "
448 LPRINT "
449 LPRINT "
450 LPRINT "
451 LPRINT "
452 LPRINT "
453 LPRINT "
454 LPRINT "
455 LPRINT "
456 LPRINT "
457 LPRINT "
458 LPRINT "
459 LPRINT "
460 LPRINT "
461 LPRINT "
462 LPRINT "
463 LPRINT "
464 LPRINT "
465 LPRINT "
466 LPRINT "
467 LPRINT "
468 LPRINT "
469 LPRINT "
470 LPRINT "
471 LPRINT "
472 LPRINT "
473 LPRINT "
474 LPRINT "
475 LPRINT "
476 LPRINT "
477 LPRINT "
478 LPRINT "
479 LPRINT "
480 LPRINT "
481 LPRINT "
482 LPRINT "
483 LPRINT "
484 LPRINT "
485 LPRINT "
486 LPRINT "
487 LPRINT "
488 LPRINT "
489 LPRINT "
490 LPRINT "
491 LPRINT "
492 LPRINT "
493 LPRINT "
494 LPRINT "
495 LPRINT "
496 LPRINT "
497 LPRINT "
498 LPRINT "
499 LPRINT "
500 LPRINT "
501 LPRINT "
502 LPRINT "
503 LPRINT "
504 LPRINT "
505 LPRINT "
506 LPRINT "
507 LPRINT "
508 LPRINT "
509 LPRINT "
510 LPRINT "
511 LPRINT "
512 LPRINT "
513 LPRINT "
514 LPRINT "
515 LPRINT "
516 LPRINT "
517 LPRINT "
518 LPRINT "
519 LPRINT "
520 LPRINT "
521 LPRINT "
522 LPRINT "
523 LPRINT "
524 LPRINT "
525 LPRINT "
526 LPRINT "
527 LPRINT "
528 LPRINT "
529 LPRINT "
530 LPRINT "
531 LPRINT "
532 LPRINT "
533 LPRINT "
534 LPRINT "
535 LPRINT "
536 LPRINT "
537 LPRINT "
538 LPRINT "
539 LPRINT "
540 LPRINT "
541 LPRINT "
542 LPRINT "
543 LPRINT "
544 LPRINT "
545 LPRINT "
546 LPRINT "
547 LPRINT "
548 LPRINT "
549 LPRINT "
550 LPRINT "
551 LPRINT "
552 LPRINT "
553 LPRINT "
554 LPRINT "
555 LPRINT "
556 LPRINT "
557 LPRINT "
558 LPRINT "
559 LPRINT "
560 LPRINT "
561 LPRINT "
562 LPRINT "
563 LPRINT "
564 LPRINT "
565 LPRINT "
566 LPRINT "
567 LPRINT "
568 LPRINT "
569 LPRINT "
570 LPRINT "
571 LPRINT "
572 LPRINT "
573 LPRINT "
574 LPRINT "
575 LPRINT "
576 LPRINT "
577 LPRINT "
578 LPRINT "
579 LPRINT "
580 LPRINT "
581 LPRINT "
582 LPRINT "
583 LPRINT "
584 LPRINT "
585 LPRINT "
586 LPRINT "
587 LPRINT "
588 LPRINT "
589 LPRINT "
590 LPRINT "
591 LPRINT "
592 LPRINT "
593 LPRINT "
594 LPRINT "
595 LPRINT "
596 LPRINT "
597 LPRINT "
598 LPRINT "
599 LPRINT "
600 LPRINT "
601 LPRINT "
602 LPRINT "
603 LPRINT "
604 LPRINT "
605 LPRINT "
606 LPRINT "
607 LPRINT "
608 LPRINT "
609 LPRINT "
610 LPRINT "
611 LPRINT "
612 LPRINT "
613 LPRINT "
614 LPRINT "
615 LPRINT "
616 LPRINT "
617 LPRINT "
618 LPRINT "
619 LPRINT "
620 LPRINT "
621 LPRINT "
622 LPRINT "
623 LPRINT "
624 LPRINT "
625 LPRINT "
626 LPRINT "
627 LPRINT "
628 LPRINT "
629 LPRINT "
630 LPRINT "
631 LPRINT "
632 LPRINT "
633 LPRINT "
634 LPRINT "
635 LPRINT "
636 LPRINT "
637 LPRINT "
638 LPRINT "
639 LPRINT "
640 LPRINT "
641 LPRINT "
642 LPRINT "
643 LPRINT "
644 LPRINT "
645 LPRINT "
646 LPRINT "
647 LPRINT "
648 LPRINT "
649 LPRINT "
650 LPRINT "
651 LPRINT "
652 LPRINT "
653 LPRINT "
654 LPRINT "
655 LPRINT "
656 LPRINT "
657 LPRINT "
658 LPRINT "
659 LPRINT "
660 LPRINT "
661 LPRINT "
662 LPRINT "
663 LPRINT "
664 LPRINT "
665 LPRINT "
666 LPRINT "
667 LPRINT "
668 LPRINT "
669 LPRINT "
670 LPRINT "
671 LPRINT "
672 LPRINT "
673 LPRINT "
674 LPRINT "
675 LPRINT "
676 LPRINT "
677 LPRINT "
678 LPRINT "
679 LPRINT "
680 LPRINT "
681 LPRINT "
682 LPRINT "
683 LPRINT "
684 LPRINT "
685 LPRINT "
686 LPRINT "
687 LPRINT "
688 LPRINT "
689 LPRINT "
690 LPRINT "
691 LPRINT "
692 LPRINT "
693 LPRINT "
694 LPRINT "
695 LPRINT "
696 LPRINT "
697 LPRINT "
698 LPRINT "
699 LPRINT "
700 LPRINT "
701 LPRINT "
702 LPRINT "
703 LPRINT "
704 LPRINT "
705 LPRINT "
706 LPRINT "
707 LPRINT "
708 LPRINT "
709 LPRINT "
710 LPRINT "
711 LPRINT "
712 LPRINT "
713 LPRINT "
714 LPRINT "
715 LPRINT "
716 LPRINT "
717 LPRINT "
718 LPRINT "
719 LPRINT "
720 LPRINT "
721 LPRINT "
722 LPRINT "
723 LPRINT "
724 LPRINT "
725 LPRINT "
726 LPRINT "
727 LPRINT "
728 LPRINT "
729 LPRINT "
730 LPRINT "
731 LPRINT "
732 LPRINT "
733 LPRINT "
734 LPRINT "
735 LPRINT "
736 LPRINT "
737 LPRINT "
738 LPRINT "
739 LPRINT "
740 LPRINT "
741 LPRINT "
742 LPRINT "
743 LPRINT "
744 LPRINT "
745 LPRINT "
746 LPRINT "
747 LPRINT "
748 LPRINT "
749 LPRINT "
750 LPRINT "
751 LPRINT "
752 LPRINT "
753 LPRINT "
754 LPRINT "
755 LPRINT "
756 LPRINT "
757 LPRINT "
758 LPRINT "
759 LPRINT "
760 LPRINT "
761 LPRINT "
762 LPRINT "
763 LPRINT "
764 LPRINT "
765 LPRINT "
766 LPRINT "
767 LPRINT "
768 LPRINT "
769 LPRINT "
770 LPRINT "
771 LPRINT "
772 LPRINT "
773 LPRINT "
774 LPRINT "
775 LPRINT "
776 LPRINT "
777 LPRINT "
778 LPRINT "
779 LPRINT "
780 LPRINT "
781 LPRINT "
782 LPRINT "
783 LPRINT "
784 LPRINT "
785 LPRINT "
786 LPRINT "
787 LPRINT "
788 LPRINT "
789 LPRINT "
790 LPRINT "
791 LPRINT "
792 LPRINT "
793 LPRINT "
794 LPRINT "
795 LPRINT "
796 LPRINT "
797 LPRINT "
798 LPRINT "
799 LPRINT "
800 LPRINT "
801 LPRINT "
802 LPRINT "
803 LPRINT "
804 LPRINT "
805 LPRINT "
806 LPRINT "
807 LPRINT "
808 LPRINT "
809 LPRINT "
810 LPRINT "
811 LPRINT "
812 LPRINT "
813 LPRINT "
814 LPRINT "
815 LPRINT "
816 LPRINT "
817 LPRINT "
818 LPRINT "
819 LPRINT "
820 LPRINT "
821 LPRINT "
822 LPRINT "
823 LPRINT "
824 LPRINT "
825 LPRINT "
826 LPRINT "
827 LPRINT "
828 LPRINT "
829 LPRINT "
830 LPRINT "
831 LPRINT "
832 LPRINT "
833 LPRINT "
834 LPRINT "
835 LPRINT "
836 LPRINT "
837 LPRINT "
838 LPRINT "
839 LPRINT "
840 LPRINT "
841 LPRINT "
842 LPRINT "
843 LPRINT "
844 LPRINT "
845 LPRINT "
846 LPRINT "
847 LPRINT "
848 LPRINT "
849 LPRINT "
850 LPRINT "
851 LPRINT "
852 LPRINT "
853 LPRINT "
854 LPRINT "
855 LPRINT "
856 LPRINT "
857 LPRINT "
858 LPRINT "
859 LPRINT "
860 LPRINT "
861 LPRINT "
862 LPRINT "
863 LPRINT "
864 LPRINT "
865 LPRINT "
866 LPRINT "
867 LPRINT "
868 LPRINT "
869 LPRINT "
870 LPRINT "
871 LPRINT "
872 LPRINT "
873 LPRINT "
874 LPRINT "
875 LPRINT "
876 LPRINT "
877 LPRINT "
878 LPRINT "
879 LPRINT "
880 LPRINT "
881 LPRINT "
882 LPRINT "
883 LPRINT "
884 LPRINT "
885 LPRINT "
886 LPRINT "
887 LPRINT "
888 LPRINT "
889 LPRINT "
890 LPRINT "
891 LPRINT "
892 LPRINT "
893 LPRINT "
894 LPRINT "
895 LPRINT "
896 LPRINT "
897 LPRINT "
898 LPRINT "
899 LPRINT "
900 LPRINT "
901 LPRINT "
902 LPRINT "
903 LPRINT "
904 LPRINT "
905 LPRINT "
906 LPRINT "
907 LPRINT "
908 LPRINT "
909 LPRINT "
910 LPRINT "
911 LPRINT "
912 LPRINT "
913 LPRINT "
914 LPRINT "
915 LPRINT "
916 LPRINT "
917 LPRINT "
918 LPRINT "
919 LPRINT "
920 LPRINT "
921 LPRINT "
922 LPRINT "
923 LPRINT "
924 LPRINT "
925 LPRINT "
926 LPRINT "
927 LPRINT "
928 LPRINT "
929 LPRINT "
930 LPRINT "
931 LPRINT "
932 LPRINT "
933 LPRINT "
934 LPRINT "
935 LPRINT "
936 LPRINT "
937 LPRINT "
938 LPRINT "
939 LPRINT "
940 LPRINT "
941 LPRINT "
942 LPRINT "
943 LPRINT "
944 LPRINT "
945 LPRINT "
946 LPRINT "
947 LPRINT "
948 LPRINT "
949 LPRINT "
950 LPRINT "
951 LPRINT "
952 LPRINT "
953 LPRINT "
954 LPRINT "
955 LPRINT "
956 LPRINT "
957 LPRINT "
958 LPRINT "
959 LPRINT "
960 LPRINT "
961 LPRINT "
962 LPRINT "
963 LPRINT "
964 LPRINT "
965 LPRINT "
966 LPRINT "
967 LPRINT "
968 LPRINT "
969 LPRINT "
970 LPRINT "
971 LPRINT "
972 LPRINT "
973 LPRINT "
974 LPRINT "
975 LPRINT "
976 LPRINT "
977 LPRINT "
978 LPRINT "
979 LPRINT "
980 LPRINT "
981 LPRINT "
982 LPRINT "
983 LPRINT "
984 LPRINT "
985 LPRINT "
986 LPRINT "
987 LPRINT "
988 LPRINT "
989 LPRINT "
990 LPRINT "
991 LPRINT "
992 LPRINT "
993 LPRINT "
994 LPRINT "
995 LPRINT "
996 LPRINT "
997 LPRINT "
998 LPRINT "
999 LPRINT "

```



SPECIFY THE BEST- SPECIFY STETTNER TRIMMERS

Just in case you haven't heard: Stettner Electronics is recognized as one of the most versatile manufacturers of variable ceramic capacitors (trimmers) in the world. In Europe Stettner is Number One!

Stettner stocks a wide variety of variable and fixed

ceramic capacitors for prompt delivery, and can cross reference to most manufacturers.



**STETTNER
ELECTRONICS, INC.**

6135 Airways Blvd.
Chattanooga, Tennessee 37421
Phone: (615) 892-0291
Call Toll Free: 1-800-251-4558

Is there life after cancer?

Some people think that even when a cancer is cured, the patient will never live a normal life again.

The American Cancer Society knows better.

It helps people return to their homes and their jobs.

There is life after cancer. Two million people are living proof. If you or anyone close to you needs help, call us.



American Cancer Society

This space contributed as a public service.

February 1985



QUALITY & RELIABILITY that stand the test of time

AROUND THE GLOBE...

Along with offering the best performance/price in the industry, our goal at PTS has always been reliability. We believe, that with a yearly failure rate of 4%, we do indeed produce the most reliable synthesizer line.

It's easy to talk about a commitment to quality; at PTS we are actually doing something about it. We are backing that commitment by extending our warranty . . . **NOW TWO YEARS!**

Models covering 40MHz, 160MHz, 200MHz, 500MHz
Choice of resolution; low phase noise, fast switching,
fully programmable, BCD or IEEE BUS



NEW: Choice of table-look-up resolution with steady-phase switching.


PTS 500 shown with 0.1 Hz resolution,
frequency standard, 3×10^{-9} /day: \$7,300

PTS
PROGRAMMED TEST SOURCES, INC.

Littleton, MA, (617) 486-3008

INFO/CARD 48





To detect noise, you need silence.

You can't detect spurious RF signals from your product if your measurement is being affected by noise.

You need silence—total silence.

For over 50 years Ray Proof has been a single-source supplier of noise-free RF enclosures for electronic test and measurement. In fact, we've designed, manufactured, installed and guaranteed more shielded enclosures for more applications than any other company in the world.

Ray Proof shielded enclosures meet or exceed government and commercial specifications concerning the design, construction and testing of RF-free enclosures. In fact, our System 100 design has pushed the standard to 100 GHz.

We work with you on your requirement from initial design right through final test and certification. And then we stay with you to provide every level of support and training you'll ever need.

So if your product or system specifications call for a demanding, noise-free test environment, call Ray Proof. You'll find that we can make a pretty loud statement about silence.

Keene Corporation
Ray Proof Division
50 Keeler Avenue, Norwalk, CT 06856
Toll Free: 800-243-5704
In Connecticut: 203-838-4555

KEENE
CORPORATION
RAY PROOF DIVISION



WE CREATE SILENCE.

INFO/CARD 49

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

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

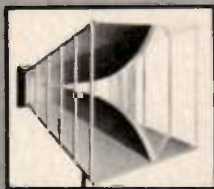
The Electro-Mechanics Company has been designing and manufacturing EMI/RFI Test Accessories for over 25 years.

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.



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 50

"Hush-Hush" Technology Comes Out of the Closet

Keene Corp., Shielding Division

Electronic soundproofing," once a low key technology used for security of government facilities, is coming out of the closet. Hastening its "coming out" is the boom in consumer electronics, medicine's fast-growing MRI* (Magnetic Resonance Imaging) miracle machine, and an expected change of heart by the FCC.

"The market has grown 25% a year since '79 and the pace is increasing," says Arnold Zais of Keene Corporation's Shielding Division. "In '84, the total market should top the \$200 million mark. Our own sales should be up 20% this year."

Sometimes built invisibly within walls so outsiders don't know it's there, RF shielding blocks passage of radio waves like insulation blocks heat loss in your home. So it stifles deliberate electronic bugging and accidental radio interference. In RF shielded rooms, even the power lines and air vents are specially treated so stray radio waves don't pass through.

"For years, our main customers were government agencies and the aerospace industry, for security reasons," says Zais. "And secondarily, from industry for quality control testing."

But in the past five years, this has completely changed around. "Non-government/military sales now represent the majority of the business and is the fastest-growing segment," says Zais. "Part of the reason is that 'electronic hash' is growing at 50% a year.

"Literally, there's no end in sight — unless people like you and me give up on computers, video games and our electronic way of life."

One main impetus for growth of RF shielding is MRI. That's the \$1 million-a-copy medical "imaging" tool that's said to be the most powerful diagnostic device ever developed. Some observers expect it to eclipse X-rays and CAT scanners. It shows more and eliminates the radiation hazard.

Every MRI must be installed in a shielded room to get high quality images. Recently, for instance, the University of Pennsylvania started up the nation's most advanced MRI clinical research facility — all enveloped in a \$1.5 million special room cocooned with \$100,000 worth of Keene shielding.

"Our MRI business tripled in '83," says

Zais. "And this year, the FDA is expected to approve MRI as an accepted imaging modality. As a result, this business segment, which has nothing to do with security or defense, should continue to grow exceptionally for the foreseeable future."

New FCC Product Safety Test

Also contributing to Keene Shielding's growth is the continuing boom in electronics and computers. Reason: before any electronic device can be marketed in the U.S., the FCC requires a test to ensure that it doesn't give off harmful or interfering emissions. Europe's Electromagnetic Compatibility Compliance testing requirements parallel the FCC's.

"Electronic manufacturers run emissions tests for their own purposes as well," says Zais. "They want to make sure their new product won't be 'zapped' by a passerby with a CB or an automatic garage door opener or a local TV transmitter or a faulty arcing neon sign."

This year, many industry observers expect the FCC to change its longstanding regulation and give shielded anechoic test chambers a shot in the arm. For years, the FCC mandated "open site" testing for compliance testing — tests run out in the country, away from everything, where the environment is electronically "clear" but generally not. Recently, the major computer and electronics firms are buying shielded anechoic chambers for FCC testing. Although such chambers from Keene cost over \$1 million they are more efficient, reliable and accurate than outdoor sites.

Everybody Wins

"This would benefit everybody," says Zais. "Shielded chamber testing is obviously more efficient and economical than trekking out to the desert with a truckload of equipment. Ironically, it also creates an electronically 'cleaner' environment because there's so much electronic clutter everywhere outdoors. So chamber test results are more reliable. I believe the FCC is simply letting the evidence and experience accumulate. And now that it has, they'll probably accept chamber testing as fully equivalent to open site testing. It



A typical testing application in a Keene shielded chamber.

could be much more cost effective for the electronics industry, with no tradeoff whatsoever to anybody. It's simply an idea whose time has come."


Invisible Intruder, Invisible Barrier

Electronic RF shielding consists of constructing a complete metal room of thin metal panels. The panels are walls, floor and ceiling before the decorative surface is applied. Around all doors is an arrangement of interlocking metal linings that look like brass weatherstripping. Special RF filters go into all electrical and power lines. Air vents are designed to keep radio waves from getting through, too.

When the door closes on an RF-shielded room or chamber, the interior is cocooned in a continuous film of sheet metal. If there's even the tiniest breach, unwanted radio waves can leak through just like liquid finds the smallest leak in any container. MRI shielded rooms are made of special non-magnetic materials to block the radio waves with a structure that will not affect the MRI magnet field.

"Concern over electronic pollution, and even industrial espionage, has prompted some executives to cocoon their R&D labs, conference rooms, and computer centers in RF shielding," says Zais. One hotel in the Washington, DC area even considered shielding some meeting rooms to offer "something extra" in a security conscious age.

Keene's Shielding Division is also benefiting from development of "stealth" technology. Their recently-acquired subsidiary, Advanced Absorber Products, Amesbury, MA, makes absorber material that traps and attenuates radio waves.

"As long as electronics is here to stay, our 'invisible' business should do well," says Zais. 

*Editor's note: MRI (Magnetic Resonance Imaging) is the new industry terminology for what was called NMR (Nuclear Magnetic Resonance).

Serial RS-232 to GPIB Interface

Erbtec Engineering, Inc.

This application note describes a method for interfacing serial RS-232 compatible signals with the IEEE-488 bus (GPIB).

This capability can be used to satisfy the needs of a variety of applications such as:

- Interface of RS-232C compatible devices
- Bus extension
- Factory data collection
- Data communications and distributed systems
- Use in noisy environments

Two approaches to baud rate selection are described. One approach provides convenient selection of any commonly used baud rate from 50 to 9600. The second method provides a single baud rate which can be set by the user to any desired value.

The user can also select number of bits, odd/even or no parity and number of stop bits via a DIP switch.

Receipt of a general or device RESET command will cause the interface circuitry to be reset.

Hardware Description

The serial RS-232 to GPIB interface is implemented with a UART coupled with Erbtec's general purpose IEEE-488 bus interface module (EPI-120). The UART used in this design is the General Instruments AY-3-1015D. Any similar UART could be used in its place.

For optimum data transfer Port A of the EPI-120 is used for data input to the bus. Port B is used for parallel data transfer from the bus to the RS-232 serial output. Input handshakes are accommodated by directly tying the HSA-IN line on the EPI-120 to the Data Available line on the UART. The HSA-OUT line is tied to the RDAV line on the UART. Similarly, output handshakes are accommodated by directly tying HSB-IN to EOC and HSB-OUT to

DTSTB. The RESET line on the EPI-120 is tied to the external reset (XR) on the UART through an inverter. Also the REMOTE line is tied to the RDE line on the UART through an inverter. Thus, receipt of a "GO TO LOCAL" command or loss of the REMOTE ENABLE signal will disable the UART.

Serial output from the UART is passed through a 1488 to establish proper RS-232 drive levels. Output from the 1488 is normally tied to pin 3 of a DB25 connector. Serial input from pin 2 is passed through a 1489 RS-232 receiver to the UART. The Request to Send (RTS) and Data Terminal Ready (DTR) lines are pulled up to +15 V through a 3.3K resistor.

The UART requires a clock pulse of 16 times the selected baud rate.

For optimum versatility a dual baud rate generator chip such as the AY-5-8116 can be used. An external DIP switch permits selection of any of the commonly used baud rates. Separate rates can be selected for receive and for transmit.

The second method uses a 555 timer chip as a simple clock generator. It generates a single common clock for both receive and transmit. Clock frequency must be adjusted by the user to 16 times the desired baud rate.

Software Description

A sample program which illustrates how very simple it can be to communicate between a bus control computer and an RS-232 terminal device is provided in Figure 1. The sample program is written using HP's BASIC for the HP85.

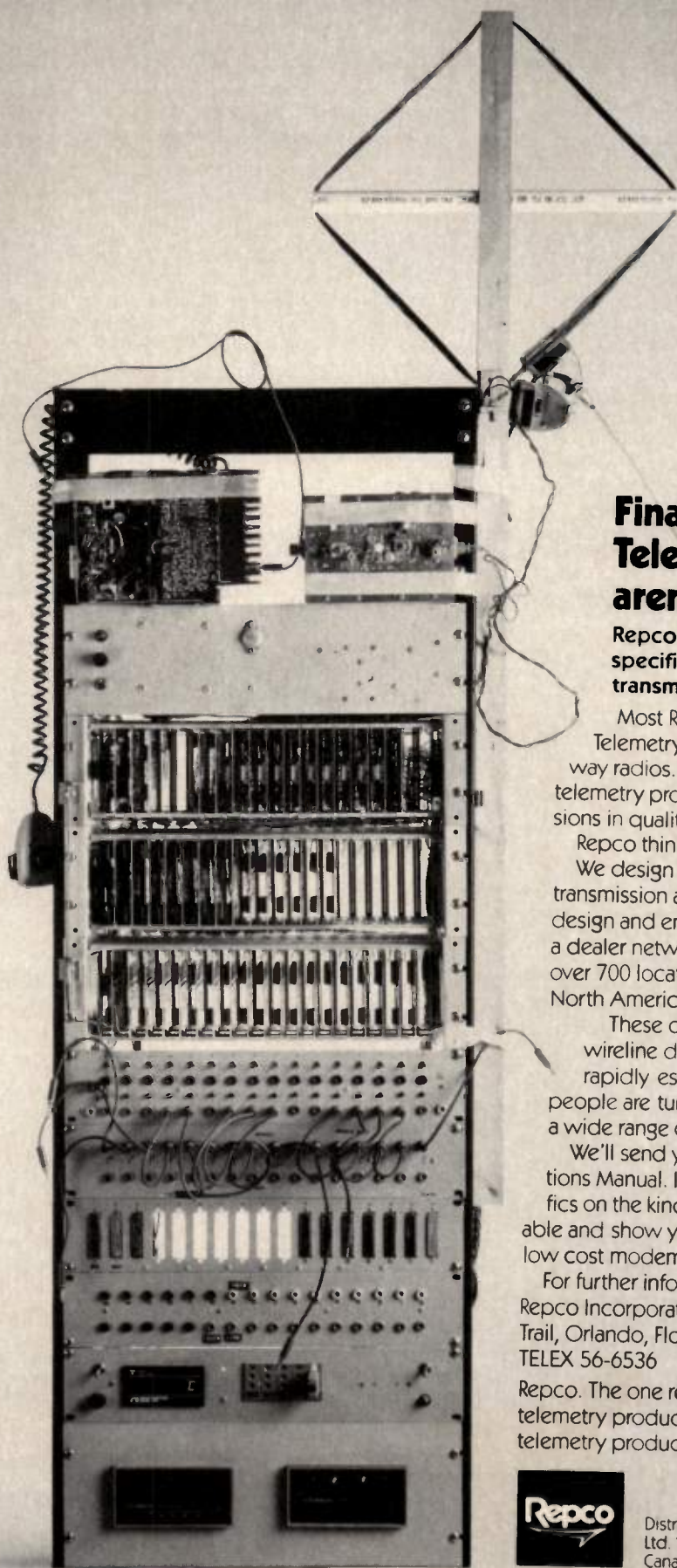
Line 130 sends the string A\$ to device 01 on the Bus (select code 7). Assuming the EPI has its address select switches set to 1 it will be configured by the command string A\$ as follows:

- A1 — Accept data from Port A in 8 bit format and transfer to the GPIB unchanged

- A9 — Interpret Port A logic levels as high true
B2 — Transfer data from the GPIB to Port B in 8 bit binary format.
B9 — Interpret Port B logic levels as high true
C4 — HSA-IN is high true; HSA-OUT is low true
D4 — HSB-IN is high true; HSB-OUT is low true
N2 — End of transfer condition signalled by two characters (when not specified they will default to carriage return and line feed)
Y1 — Enable next sequential address feature (Data on device address +1)
The command at line 210 sends the string "ENTER YOUR NAME" to the terminal device. Note the address is 702. This was enabled by the Y1 command in the initialization string A\$.
The command at line 230 addresses the EPI as a talker and reads in the response from the RS-232 device.
Line 250 causes the message USER NAME IS XXXXXX to be displayed on the bus control computer — where XXXXXX is the data entered at the remote RS-232.

Figure 1

```
100 ! CONFIGURE INTERFACE
110 DIM A$(23)
120 A$="A1, A9, B2, B9, C4, D4, N2, Y1"
130 OUTPUT 701 USING "K"; A$
200 !
210 OUTPUT 702; "ENTER YOUR NAME"
220 !
230 ENTER 701; N$
240 !
250 DISP "USER NAME IS"; N$
900 !
999 END
```

Finally. Telemetry products that aren't hand-me-downs.

Repco designs RF Links products specifically for monitor and data transmission applications.

Most RF Links products available to the Telemetry market were modifications of two-way radios. Then they were adapted as telemetry products, possibly with some concessions in quality and compromises in function.

Repco thinks you deserve better.

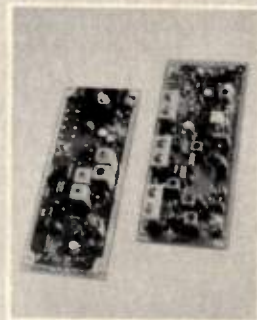
We design products exclusively for your data transmission and monitoring needs. We offer design and engineering services. And, we have a dealer network to support your RF needs in over 700 locations throughout North America.

These days, with the cost of wireline data transmission rapidly escalating, a lot of people are turning to wireless for a wide range of applications.

We'll send you our free Applications Manual. It'll give you the specifics on the kinds of products available and show you how RF Links and low cost modems will work for you.

For further information call or write: Bob Lowell, Repco Incorporated, 2421 North Orange Blossom Trail, Orlando, Florida 32804, (305) 843-8484 TELEX 56-6536

Repco. The one resource you can depend upon for telemetry products that were designed to be telemetry products.



Distributed in Canada by Repco Radio Canada, Ltd. 1750 Plummer St., Unit 20 Pickering, Ontario, Canada L1W3L7, (416) 839-5911

INFO/CARD 51

A One Transistor FM Transmitter

*By William Rynone
Pegasus Data Systems*

Last summer, I was requested to design a simple FM transmitter to meet the requirements for a convenient, low cost method of testing a large number of vendor supplied FM receivers that were to be incorporated into a digital data transmission system. The test that had to be performed was intended to make a subjective check of the accuracy of the tuning dial setting and the sensitivity of each receiver unit. Since it might become necessary to perform field tests, interconnecting various pieces of bulky and heavy test equipment was considered to be an undesirable alternative.

To meet the requirement, the transistor circuit shown below was designed, built and tested. The 2N2222 circuitry is a three element phase shift oscillator circuit, designed to yield a 1000 Hz sine wave. The 1000 Hz sine wave is then applied to the TCG-610 varactor diode (6 pF at 4 volts) which changes the tank capacitance, thus varying the RF oscillator frequency at a 1000 Hz rate. The 1000 ohm potentiometer in the collector circuit may be adjusted to enable desired frequency modulation level.

The Hartley RF oscillator, which is designed around a readily available MPF-

102 JFET, has an output that should be relatively stable if it is not enclosed (but without an antenna). When enclosed, a BNC or F connector can be used to feed the RF to a small loop. If you decide to build this unit, be careful. The FCC has regulations regarding the radiation of RF.

One of my colleagues, Bohden Stryzak, modified the transmitter by eliminating the sine wave oscillator portion and replaced it with a carbon microphone as shown below. His children then had a three dollar portable transmitter that could be used with any portable FM receiver as a walkie-talkie.

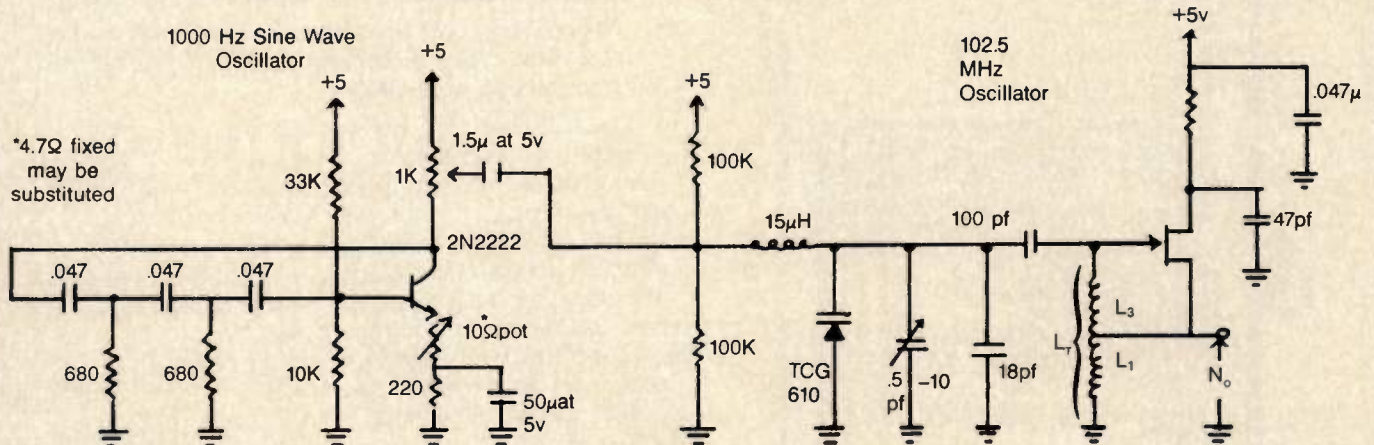


Figure 1

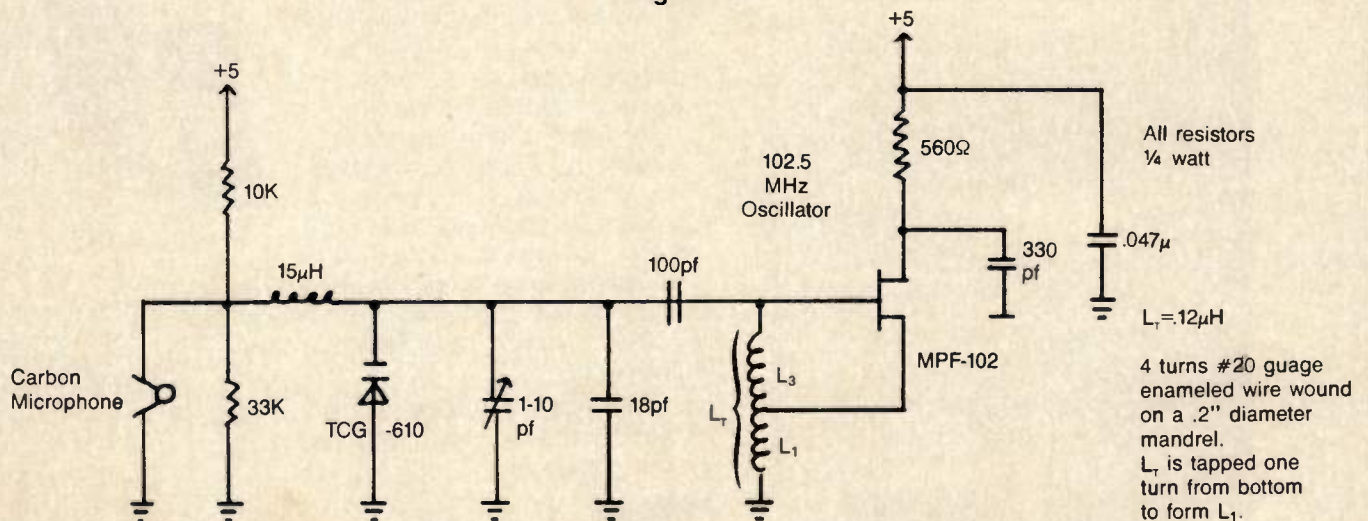


Figure 2.

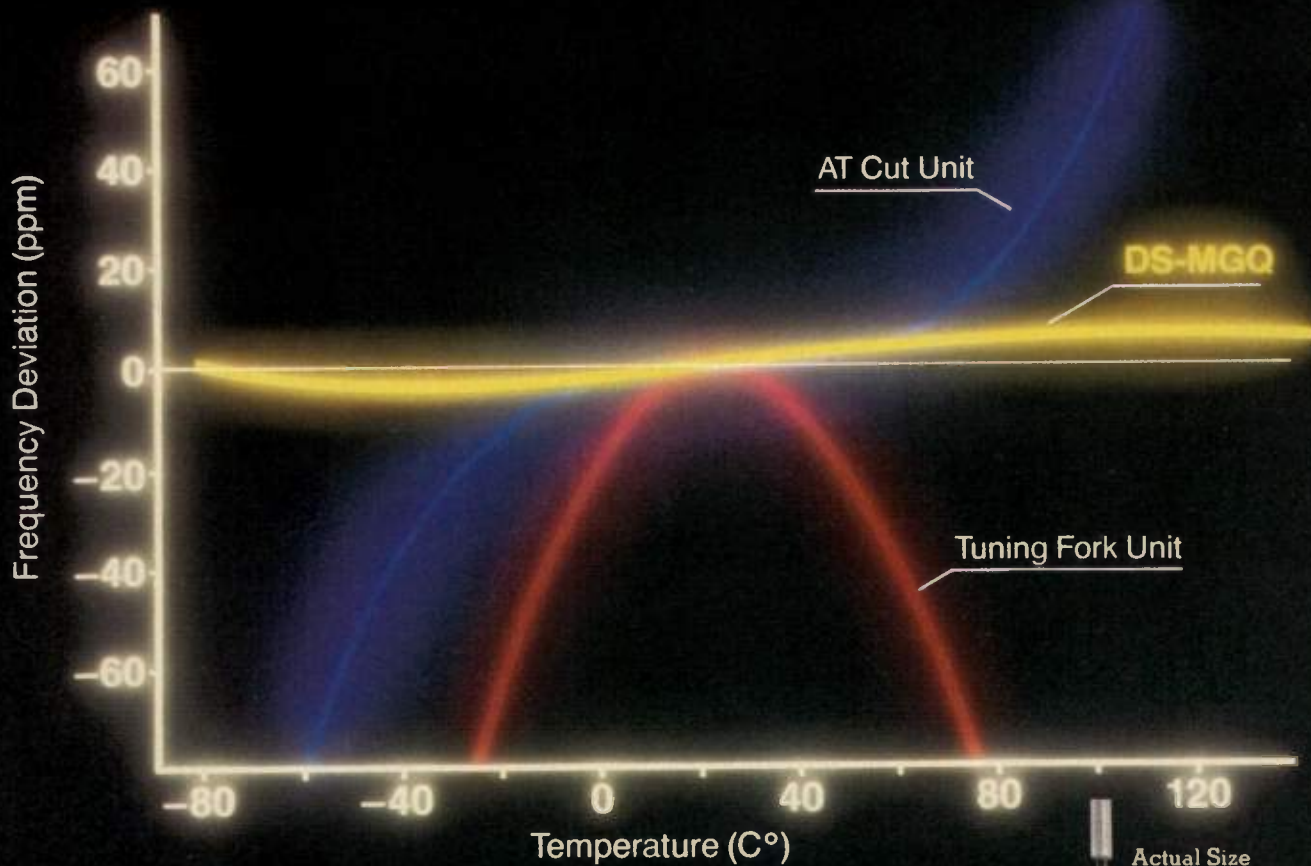
***In April, Racal-Dana
will put universal counters
in a whole new light.***



***Any purchase before then
could leave you in the dark.***

RACAL-DANA

Our Figures Speak For Themselves.



The DS-MGQ Quartz Crystal From Seiko Instruments.

Exceptional stability over a wide temperature range puts these DS-MGQ crystals in a class by themselves. So does the world's smallest package.



In fact, our ultra-miniatures use 95% less real estate than a standard HC-33 enclosure. Combine this with low power consumption and high resistance to shock and you have an ideal crystal that meets all your design requirements.

These high-reliability crystals come in a choice of 20 off-the-shelf frequencies. Custom frequencies are also available on request. Imagine

the exciting possibilities in your present and planned products. Then write or call today for specifics.

KEY SPECIFICATIONS

Frequency Range	1.0 to 3.0 MHz
Load Capacitance	10pf standard (other settings on request)
Quality Factor	150,000 to 300,000*
Effective Series Resistance	35Ω to 100Ω*
Frequency Temperature Stability (-30°C to +70°C)	± 5ppm to ± 100ppm
Drive Level (Max)	3 to 20μW*
Aging (First Year + 25°C)	1.0ppm (typical)

*Depending on Frequency

SEIKO INSTRUMENTS U.S.A., INC.

2990 West Lomita Blvd., Torrance, CA 90505
 Telephone: (213) 530-8777, FAX: (213) 539-8621
 TWX: 910-347-7307 SEIKO INST. TRNC.

SEIKO INSTRUMENTS

Power Generator

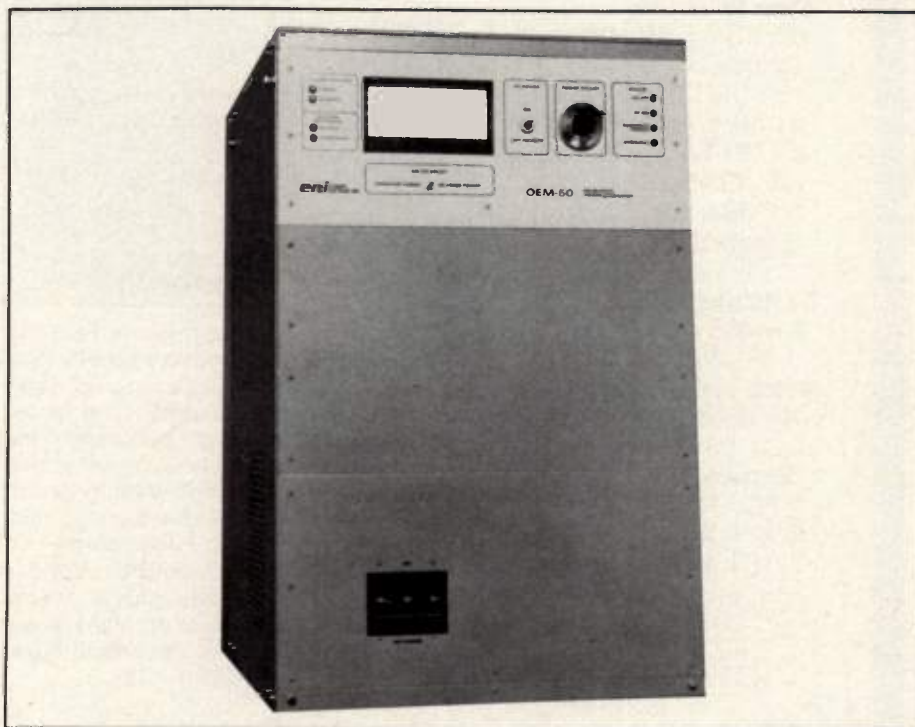
With its 5000 watt power output at 13.56 MHz, the OEM-50 is the highest power all solid state generator in the world. Although the OEM-50 is an order of magnitude smaller (5.5 cubic feet) than its vacuum tube counterparts, nothing has been left out in terms of operating features and versatility. All solid state, high reliability, accurate RF power control, fast pulse operation, stable RF power with line voltage variations, linear analog power meter with compatible digital readout, full remote control functions and built-in diagnostic test equipment are just some of the outstanding attributes of the OEM-50. If your semiconductor processing, sputtering or industrial application calls for the state-of-the-art in a 5 kilowatt source, the OEM-50 was designed just for you.

Automatic Power Control

The reliable operation of any solid state power generator is directly influenced by the sophistication of its power control circuitry. The OEM-50 automatic power control module measures forward RF power, reflected RF power and the current draw of each RF power amplifier module. Should any of these parameters exceed a preset limit, the automatic power control will immediately fold back its RF output power so that the components always remain within their safe operating limits. Besides assuring safe operation of the OEM-50, the automatic power control module will provide constant RF power output level to within 3% of the matched power setting regardless of the plasma load VSWR. In addition, the automatic power control eliminates power output drift due to line voltage variations, component aging and reduces output hum and ripple to insignificant levels. An external DC voltage or pulse fed into the rear panel connector will permit the power output of the OEM-50 to be accurately controlled by a computer program that includes end point detection information.

Computer Compatibility

The OEM-50 is provided with an external computer interface bus that is compatible with TTL logic levels. This interface bus permits RF power to be turned on or off, indicates to the computer when



the unit is developing its maximum power and indicates lack of water cooling or RF power. In addition, external analog voltages are available at the interface connector for both forward and reverse power indications. These voltages are calibrated precisely at 1.00 volt per kilowatt and therefore a digital panel voltmeter will read power directly in kilowatts.

Safe Easy Maintenance

The use of conservatively rated solid state components and automatic power control insures the user of reliable and continuous performance with an absolute minimum of maintenance. A built-in diagnostic servicing switch permits the service technician to read out both the voltage and current draw of each individual module directly on the front panel meter. Should service be required, all of the plug-in modules are easily removed for replacement or repair. The very low DC voltages used in the OEM-50 greatly reduce the potential hazards associated with its servicing when compared with vacuum tube equipment.

Use It Anywhere

A wide range of AC line voltages is readily accommodated by the multitap AC line transformer and the connections verified by a built-in test meter indicator. The OEM-50 may be rack mounted, using the rack mounting kit, into any 19 inch relay rack or operated remotely within the plasma system cabinetry.

No RFI Problem

The OEM-50 is provided with an extremely well shielded and filtered power supply virtually eliminating conducted line leakage. An extremely sharp low pass filter at the output of the unit insures that all harmonics are reduced to very low levels. Extensive use of shielding and RF suppression techniques permits the unit to more than meet FCC requirements for ISM equipment at the same time that it eliminates any RF susceptibility problems for associated plasma system circuitry. **ENI Power Systems, Inc., Rochester, NY 14623-2881. INFO/CARD #113.**

PROGRAMMABLE ATTENUATORS FOR OEM

DC to 2 GHz

Configuration:

2, 5 or 8 cells

Wide Selection:

0.5 dB/0.5 dB steps
1.2 dB/0.1 dB steps
12.0 dB/1.0 dB steps
31 dB/1.0 dB steps
63.75 dB/0.25 dB steps
120 dB/10 dB steps
127 dB/1 dB steps
150 dB/10 dB steps

Switching time:

6 msec @ +12 vdc

Rated switch life:

10⁷ operations per cell

Compact size:

1.2 x 1 x 7/8 - 1 cell
4 x 1 x 7/8 - 8 cells
3 x 1 x 7/8 - 5 cells



**WEINSCHTEL
ENGINEERING**

One Weinschel Lane
Gaithersburg, MD 20877
(301) 948-3434

Telex: ITT440702
or WU89-8352
800-638-2048

C-60



3200 Series

INFO/CARD 54

rf products

Electro-Static Interference Simulator

The Model 2600 will simulate Electro-Statics, Electro-Magnetics, Electro-Overstress, and Electro-Impulse, in quantifi-



able, repeatable energy levels. Features include positive or negative polarity from 0-25 kV, and an adjustable ramp up, delay, and ramp down capability. The Model 2600 also features single or multiple pulse selector, pulse interval adjustment, digital voltage meter, handheld pistol grip with built-in tripod and durable carrying case with remote controller. Pulse networks for human or inanimate simulation, E and H field attachments, Ion source attachments, and Electro-Static attachments are available. IMCS Corp., Mountain View, CA 94043. INFO/CARD #137.

Metallized Capacitors

Called the MDD, this series of capacitors is specifically designed for application in blocking, coupling, filter and bypass circuits of the industrial, electronics, telecommunications, and automotive industries. This resin-coated, epoxy-dipped capacitor offers cost savings over pre-



viously available molded plastic-type polyester capacitors. This new metallized polyester film features high insulation resistance, dielectric strength, and resistivity against humidity. Capacitance ranges from .01 mF to 2.2 mF are available in voltages from 100 to 630 volts DC. These are radial lead capacitors with tin-

plated copper wires. Copper-coated iron leads can be made available for automotive requirements. Temperature range -40°C to +85°C. Most products supplied standard with ±10% tolerance. ITT Components, Santa Ana, CA 92705. Please circle INFO/CARD #136.

High Speed SPDT Switch

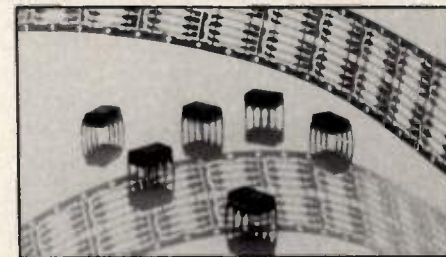
A high speed SPDT switch covers the 10-2000 MHz frequency range in a single unit. The SW-118 provides 50 dB isolation with only 0.8 dB of insertion loss, typical. The switch contains an integral TTL driver and is packaged in an 0.775" x 0.755" x



0.230" plug in package. Adams-Russell Co., Inc., Anzac Div., Burlington, MA 01803. INFO/CARD #135.

Optically-Coupled FET Driver

Without requiring any additional circuitry, the new FDA-200 meets the requirements for isolated FET operations that are demanded by telecommunications, process control, data acquisition,

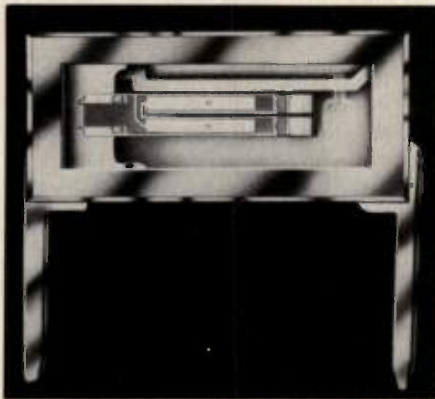


and ATE. In its normal work load, the FDA-200 drives either one large FET or two independent FETs that can work simultaneously, in series, or in anti-parallel for AC loads. Theta-J Corp., Wakefield, MA 01880. INFO/CARD #133.

Miniature Quartz Crystal Resonator

Miniature quartz crystal tuning fork resonators operating in the 10-600 MHz frequency range feature low aging, high stability, low power consumption and high shock resistance. Model CX-LV resonators, designed for use in Pierce oscillators, are available in a rugged

February 1985



ceramic package. Operating parameters include: temperature operating ranges — (industrial) — 40°C to 80°C; (military) — 55°C to 125°C; shock survival 1000-5000g, 1 ms, 1/2 sine; vibration survival 20g, rms 10-2000 Hz. Power consumption is 1mW. **ETA Industries, Inc.**, New York, NY 10020. INFO/CARD #132.

High Pass Coaxial Cable Filters

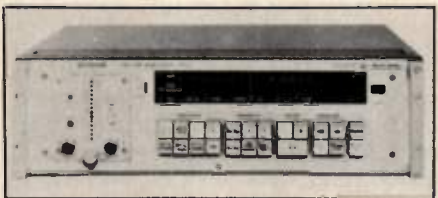
Lower frequency capabilities in semi-rigid coaxial cable are now possible with new High-Pass Filters. The new High-Pass Filters cut off transmissions below



Fc and allow high frequency transmissions to pass. The filters are designed for use with .141 O.D. cable. **Uniform Tubes, Inc.**, Collegeville, PA 19426. Please circle INFO/CARD #134.

10 Hz to 2 GHz Vector Analyzer

Model ZPV Vector Analyzer with 3 new modular plug-in tuners providing frequency coverage from 10 Hz to 2 GHz. Previous models provided coverage from .1 MHz to 2 GHz. The basic unit consists of



a dual-channel vector voltmeter measuring according to magnitude and phase and a microprocessor-controlled analyzer section, weighting, normalizing and converting the measured voltage vectors in-

to the desired complex quantity. **Polarad Electronics, Inc.**, Lake Success, NY 11042. INFO/CARD #131.

Active Bias Source

The BT500 active bias thermal tracking device provides excellent thermal tracking and requires only limited external circuitry for operation. It is the first such device to be available in the standard

hermetic TO-60 package; other packages are also available. The BT500 can be screened to TRW RF Devices Division's new "TX" high reliability screening specifications for MIL-S-19500 applications. The price of the BT500 is \$15.60 each in 100 piece quantities. Availability is immediate. **RF Devices Division, TRW Electronic Components Group**, Lawn-dale, CA 90260. INFO/CARD #178.

HP's Small Wonders

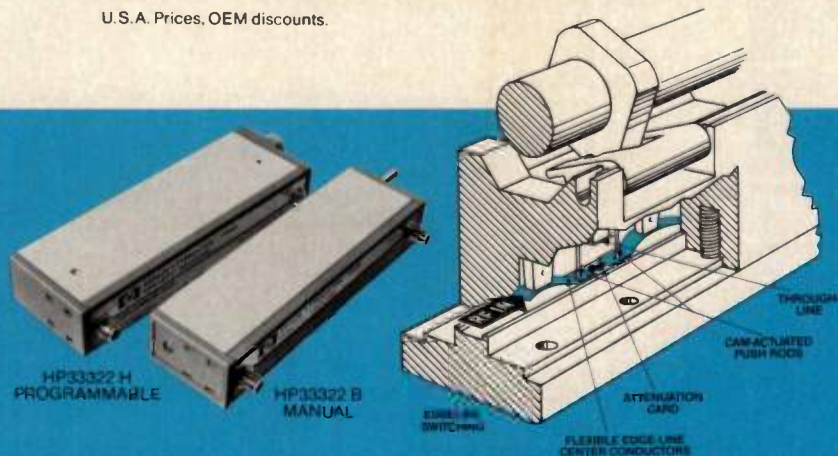
Repeatable attenuation for more than a million steps.

The HP 33320 Series of OEM step attenuators feature a special "edgeline" design. Only the gold-plated center conductor switches between the through-line and the desired attenuation card. This provides a self-wiping action with typical 0.03 dB repeatability at 18 GHz—even after a million steps.

- 0 to 11 dB, 1 dB steps—Model 33320
- 0 to 70 dB, 10 dB steps—Model 33321
- 0 to 90 dB, 10 dB steps—Model 33323
- 0 to 110 dB, 10 dB steps—Model 33322
- DC-4 GHz, DC-18 GHz, or DC-26.5 GHz
- Manual or electrically programmable
- Small size
- Prices from \$480 to \$1785

For more information, call the HP office listed in your white pages and ask for the components representative. Or write Hewlett-Packard, 1820 Embarcadero Road, Palo Alto, CA 94303.

U.S.A. Prices, OEM discounts.



0408410



**HEWLETT
PACKARD**

Push-Pull High Power Bipolar Amplifier

The TPA0102-130 device provides 130 watts of CW linear power in broadband applications. Gain is over 9 dB at 162 MHz and 28 volts. The device is usable over a 30 to 175 MHz frequency range. The price of the TPA0102-130 is \$123.45 each in 100 piece quantities. They are available

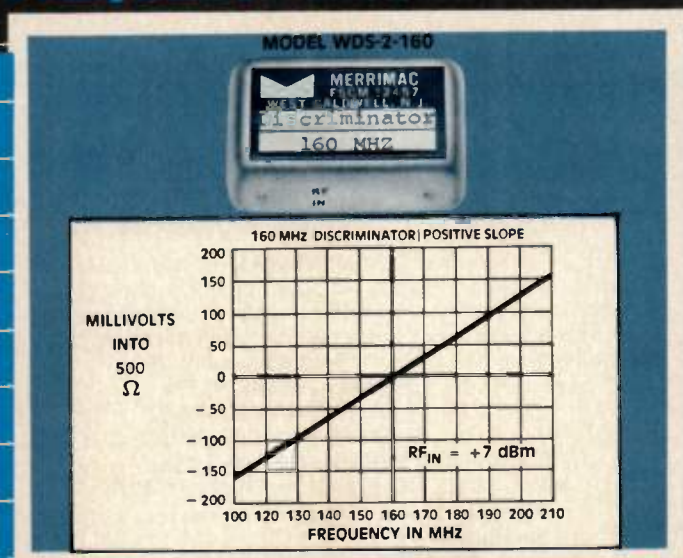
now. RF Devices Division, TRW Electronic Components Group, Lawdale, CA 90260. Please circle INFO/CARD #127.

EM Shielding for Plastics

Known as X-COAT 210-2, the new material typically covers 400 square feet per gallon at thicknesses of 1.5 to 2.5 mils, and adheres readily to most substrates.

X-COAT 210-2 is the most versatile of the company's line of EMI shielding products. It can be cured at elevated temperatures for maximum production rates, or allowed to dry at ambient temperatures. It will adhere to a wide variety of plastics, using specially formulated thinner systems. Electrical resistance of less than one ohm per square assures excellent shielding effectiveness; X-COAT 210-2 is an Underwriters Laboratories recognized component on a wide variety of commonly used plastic substrates. X-COAT 210-2 provides very low cost shielding, as it contains no silver or other precious metals. Typical applications include instruments and computers where RF shielding and electrostatic discharge protection are required. Electro-Kinetic Systems, Inc., Boulder, CO 80302. INFO/CARD #129.

NEW INNOVATIVE IDEAS FROM MERRIMAC WIDE BAND, ULTRALINEAR FREQUENCY DISCRIMINATOR



Specifications:

Center Frequency*(f_c):	160 MHz *
Instantaneous Operating Bandwidth:	up to one octave
Input Impedance:	50 Ω
VSWR:	1.5:1 Max.
RF Input Level:	+7 to +10 dBm
Linearity:	$\pm 5\%$ over one octave
Output Level:	3mV/MHz into 500 Ω load
Output Slope:	Positive Standard: (Negative on request)
Frequency Offset:	External f_c adjustment available on request
Temperature:	-55 to +85 $^{\circ}\text{C}$
Size:	0.5"x1.0"x1.5" nominal
Connections:	Pins
Weight:	<1 oz.

*Models Available at Center Frequencies of 30, 60 and 70 MHz

THE SIGNAL PROCESSING SPECIALISTS



Merrimac
INDUSTRIES, INC.

P.O. BOX 986, 41 FAIRFIELD PLACE, WEST CALDWELL, N.J. 07007-0986 USA
201-575-1300 • TWX 710-734-4314 • CABLE: MERRIMAC W CALDWELL NJ

Zero Bias Coaxial Detector/Mixer

The new RF Detector/Mixer Model DM-51-SMA/M features a replaceable, reversible zero bias Schottky diode, 10 pF output capacity, .5mV/ μV sensitivity, and SMA male to SMA female connectors. It operates over the frequency range of one to 4.2 GHz, and is usable to 10 MHz with external IF bypassing. It has a VSWR of 1.35:1 nominal and 3:1 maximum at 4.2 GHz. Size is .4 in. diameter by 1.6 in. long. Elcom Systems, Inc., Boca Raton, FL 33431. INFO/CARD #130.

Surface Mounted Microcoil Line

Unique to the microcoil design (designated series MC) is a solderable edge that allows visual inspection of the reflow solder joint. The new Surface Mounted Microcoils feature a high self-resonant frequency for use at greater frequencies than currently available in surface mounted coils. Standex Electronics, Cincinnati, OH 45209. INFO/CARD #128.

Hybrid TCXO

The Model ZT-254 holds a stability of $\pm 1 \times 10^{-6}$ over -55 to +85 $^{\circ}\text{C}$ and is packaged in a compact 1.4 x .8 x .35" (only .39 cu. in.) resistance-welded package. Many other stability vs temperature range options are also available. The oscillator is available at any frequency between 1 and 20 MHz and is designed to drive up to 10 CMOS loads. It is also compatible with TTL for 1 or 2 standard loads. The oscillator operates from an input voltage of +8.5 to +16 VDC with a typical input current of 5 mA at 5 MHz. Units plug into standard 24 PIN DIP sockets and meet an



aging rate of better than 1 ppm/yr. Center frequency adjustment is by way of an external potentiometer. **Greenray Industries, Inc., Mechanicsburg, PA 17055. INFO/CARD #179.**

Crystal Oscillators

The XT-1000 is designed for use in microwave systems as a low phase noise reference for phased-locked oscillators. The XT-1000 comes in a rugged aluminum housing that measures 2 in. long x 2 in. wide x $\frac{7}{8}$ in. high (51 x 51 x 22 mm). It has a flush mounting bracket enabling



easy system integration. The XT-1000 can cover 1 MHz to 125 MHz, has +7 dBm output, SMA connector and requires +6 to +15 VDC. Model XT-1000 has a stability of $\leq \pm 15$ ppm over a temperature of 0 to +55 degrees C. Model XT-1000 has $\leq \pm 3$ ppm stability over the same temperature range. Both models exhibit phase noise of > -140 dBc at 10 KHz from carrier. **Microwave Research & Mfg., Upton, MA. 01568. INFO/CARD #126.**

Detector/Preamp Hybrid

The SD-9007 Detector/Preamp Hybrid is offered in a hermetic TO-5 package with internal feedback resistor at under \$25 in quantities over 50. The SD-9007 has a 10 kHz bandwidth and a transfer function of 3×10^7 volts/watt with 940 nm incident radiation. Custom options include bandwidth to 2 MHz and Blue or UV enhancement. **Silicon Detector Corp., Newbury Park, CA 91320. INFO/CARD #125.**

SPDT Coaxial Switch

These SPDT latching or failsafe switches can be mounted conveniently by holes between the ports in the RF portion of the



R.F. Coax Connectors

BNC • F • N • UHF Adaptors

Commercial Grade

High Quality

Fast Delivery

Low Cost

Call
Toll Free

1-800-824-0122
for Quote/Catalog

World Business Corporation

2720 W. Monterey #405
Torrance, CA 90503-7282

Order Desk
(213) 328-6871
In California

INFO/CARD 57

AD-VANCE SHIELDING: THE "NICKEL'S" WORTH

Foil Magnetic Fields with AD-MU Foil...Cut & Apply in Minutes

Solves many magnetic shielding problems for designers, experimenters, production people and relatively small production runs. No waiting; can save days or weeks of valuable time. Eliminates designing, tooling and manufacturing costs for prefabricated shields.

Use a single formula (ask us) to determine thickness or number of layers. Or just use practical trial and error.

Especially good also for hard-to-get-at places and to make assemblies more compact by placing magnetically reacting components closer together without performance degradation.



Ask for NEW 84-PAGE
Time-Saving Reference
Manual/Catalog. Gives
Major Guidelines
for Magnetic Shielding
Design/Procurement



AD-VANCE MAGNETICS, INC.

625 MONROE ST. ROCHESTER, IND. 46975
(219) 223-3158 TWX 810-290-0294

NOW—4 Decades of Magnetic Shielding Leadership

INFO/CARD 58

THE LONG-TERM STABILITY OF A CESIUM. THE SHORT-TERM STABILITY OF A RUBIDIUM.



AUSTRON MODEL 2110 DISCIPLINED FREQUENCY STANDARD

Announcing

THE FIRST MICROPROCESSOR CONTROLLED DISCIPLINED FREQUENCY STANDARD.

Austron's Model 2110 is the first microprocessor controlled Disciplined Frequency Standard. It offers an economical solution to the most difficult and demanding applications.

The Model 2110 automatically locks the frequency of its internal oscillator to an external reference that has superior long-term stability. Through the use of a third-order servo oscillator control technique, the instrument corrects the frequency offset and aging of the internal oscillator. Should the reference fail, the Austron 2110 can limit the frequency offset to parts in 10^{12} for several days.

A SOLUTION FOR DEMANDING APPLICATIONS

- in communications systems where spectral purity and redundancy are of paramount importance
- in metrology where stable frequencies to parts in 10^{12} accuracy are required
- in clock systems where a stable clock with accuracies to ± 100 ns is necessary

- in frequency measurement where there is a need to quickly set oscillators to very high accuracies

OFFERING STATE-OF-THE-ART FEATURES

- microprocessor controlled
- high-stability internal oscillator
- third-order servo oscillator control system
- frequency measurement to parts in 10^{-12} with 100 sec averaging times
- 1 PPS clock output (externally synchronizable)
- spectrally pure output signals
- optional IEEE-488 interface
- optional dual reference frequency input allowing a choice of external references

The Austron Model 2110 microprocessor controlled Disciplined Frequency Standard is a first and it's from Austron. The 2110 can solve your most difficult timing and frequency application problems.

CALL OR WRITE FOR MORE
DETAILED INFORMATION.

LEADERS IN TIMING AND FREQUENCY MANAGEMENT



AUSTRON INC.

P.O. BOX 14766 AUSTIN, TEXAS 78761 • (512) 251-2313 • TWX 910/874-1356

rf products *Continued*

switch. Both inboard and outboard mounting can be provided on the same switch for increased versatility. Teledyne Microwave, Mountain View, CA 94043. Please circle INFO/CARD #121.

Remotely Controlled Signal Source

This signal source for antenna ranges or other uses can be controlled from a hand-held transmitter from distances up to 2,000 feet. The primary remote control transmitter allows selection of frequency and ON/OFF control of the signal output while the auxiliary transmitter provides control of up to 16 housekeeping functions external to the signal source. The frequency synthesized signal source can be provided to cover frequencies from 40 MHz to 200 MHz in steps as small as 10 KHz. Power output is typically 0.5 watt. FM modulation can be provided as an option. Remcon, Oceanside, CA 92054. Please circle INFO/CARD #124.

915 MHz Range Cavity Amplifiers

These two amplifier cavities are designed specifically as inexpensive sources of 915 MHz energy. Characterized by simple electrical and mechanical design, the EIMAC CV-2805 and CV-2811 cavities provide dependable RF power for



scientific, industrial, communication, and medical applications. Both units feature a high-gain design allowing use of solid-state drivers. The amplifier cavities are cathode driven and are forced-air cooled. Relatively compact, the cavities measure approximately 8 inches (20.3 cm.), by 5 inches (12.7 cm.), by 5 inches (12.7 cm.) Varian EIMAC, San Carlos, CA 94070. Please circle INFO/CARD #123.

Spectrum Analyzer With "Signal Search"

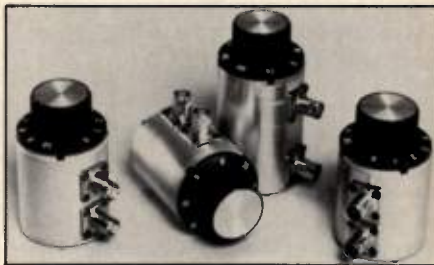
Designated the MS710A, the instrument has a frequency range to 23 GHz and a wide, 100 dB, dynamic range. It is designed for easy operation and features memory presets, GP-IB interface for direct plotting, an internal preselector and dual



ms/div to 10 sec/div (may be selected manually or automatically coupled to frequency span, resolution bandwidth, and video bandwidth); trigger selections, single, free run, line, video and external; average noise level to +30 dBm over the measuring range; sideband noise ≤ -75 dB; CRT display are 80 mm x 100 mm. Anritsu America, Inc., Oakland, NJ 07436. INFO/CARD #122.

Turret Attenuators

Series 5000A and 7500A Turret Attenuators operate over a very broad frequency range and are well suited for bench setups, field use, or incorporated into test instruments. RF system applications include navigation and communication receivers. The Series 5000A Turret At-



memory for trace processing. Special "signal search" functions enable rapid location of the desired signal. The PEAK-CENTER key allows the operator to zero in on the peak value and center it on the screen instantly. With other digital keys, the view can be slowly scanned left or right, or quickly shifted by half-screen increments or one entire span. Specifications include: frequency range 10 MHz to 23 GHz (in two, preselectable ranges, 10 MHz to 2 G, and from 1.7 G to 23 GHz); dynamic range 100 dB (1.7 GHz to 23 GHz), 24-pin GP-IB interface for remote operations (meets IEEE488, IEC625-1); average noise level to +30 dBm over the measuring range; resolution 1 kHz to 3 MHz in a 1, 3, 10 sequence; sweep 2

Intermodulation Problems?

Eliminate them
with M/A-COM

ISOLATORS



HP 8568B
Spectrum Analyzer

Solve your intermodulation problems! M/A-COM has been solving IMD problems longer than anyone in the industry. Call M/A-COM Land Mobile Communications today toll free 800-538-1533 or write:

M/A-COM

**LAND MOBILE
COMMUNICATIONS**

21 Continental Boulevard, Merrimack, NH 03054 USA
800-538-1533 (617) 424-3400 TLX 95-3139

Low Band: 25-50 MHz 406-512 MHz
Mid Band: 66-88 MHz 806-960 MHz
High Band: 146-174 MHz

- Low Insertion Loss
- Maximum Isolation up to 90 dB
- Single, Dual, Triple Junctions
- Constant Transmitter Impedance
- Full Transmitter Protection
- 125-400 Watts

INFO/CARD 60

MIXER PREAMPS FROM SAGE



Designed
for long
lasting performance.

Features:

- Repairable, uncrowded circuit board with low thermal rise, long lasting performance and low production cost
- Low VSWR all ports
- Wide IF bandwidth
- Good gain stability
- Insensitive to power supply voltage variations
- Modularized for various communication bands
- Optional dual IF outputs (as shown in photo)

Typical performance:

Model	RF & LO Frequency (GHz)
FMA 3610-1	0.6-1.1
FMA 3610-2	1.0-1.7
FMA 3610-3	1.7-2.7
FMA 3610-4	4.4-5.0
IF Passband	60-80 MHz
RF - IF gain	20 dB
Noise Figure	7 dB
LO Power	6 mw
VSWR	1.5/1
Power	+28 v @ 60 ma (+20 v optional)

Sage also offers a 70 MHz up-converter in the same package with 0 dBm output at 4.4-5.0 GHz.

70 MHz units can also be used at 40, 50 and 60 MHz IF's.

Call or write for our complete product catalog and price list.

sage

LABORATORIES, INC.

3 Huron Drive • Natick, MA 01760-1382
(617) 653-0844 • TWX: (710) 346-0390

INFO/CARD 61

MINIATURE BANDPASS FILTERS



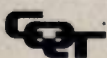
We hold the state-of-the-art filter technology inside the palm of our hand.

State-of-the-art filter technology at its best. Only .325" H x .25" W and as short as 1.25", FBC Cavity filters are setting the standard in communications, aerospace, EW, surveillance and ECM applications.

- 6 GHz—17 GHz
- 3 to 10 Poles
- Typical Butterworth amplitude, phase and group delay responses
- 1 dB BW of 1 to 70% of F_0
- 1.5:1 or less VSWR
- As low as < 0.5 dB Insertion loss
- Up to 10 watts CW
- 50 Ω impedance
- SMA female/male connectors

*Length depends on number of poles and frequency

FBC cavity filters designed to your specifications within 6 to 8 weeks. Small quantities as soon as 2 weeks.



Call (301) 946-1800. Let CIRQTEL, a leader in filter technology for 21 years, solve your filter problems.

Superior Products by Design

CIRQTEL
INCORPORATED

10504 Wheatley Street
Kensington, Maryland 20895
Telephone: (301) 946-1800
TWX: 710-828-0521

INFO/CARD 62

rf products *Continued*

tenuators cover the DC to 2000 MHz frequency range. The positive detent action provides long life for 50 Ω applications such as general purpose test and measurement instrumentation (both military and commercial), Two-Way Communications and general laboratory accessories. DC to 1000 MHz frequency range coverage makes the Series 7500A perfect for CATV and TV applications. Their configuration is identical to the Series 5000A; however, due to the reduction in frequency coverage, some specifications will be improved over the Series 5000A. The Series 5000A and 7500A Turret Attenuators have standard BNC female connectors. Other connectors (such as Type F or female connectors) may be ordered at no additional cost. **Wavetek Indiana, Inc., RF and Microwave Components, Beech Grove, IN 46107. Please circle INFO/CARD #120.**

1.5 GHz Sweep Generator

The LSW-359 sweep generator covers the range of 1 MHz to 1.5 GHz in three bands. The sweeper is designed for laboratory analysis of frequency versus ampli-



tude characteristics for communications, radar, satellite i-f, and telemetry equipment. Featuring full-band sweep, start-stop sweep, delta sweep and CW operating modes, the generator also includes a versatile bypass marker system. A calibrated pulse-type marker, adjustable to any frequency within the selected band, is available in the full-band mode. In addition, birdie (comb-type) markers are available at 1, 10, 50 and 100 MHz spacings. Options include up to three spot-frequency markers and internal 1 kHz sine-wave amplitude modulation. Remote control of primary functions is easily effected, and modulation options make the unit double as a wide range signal generator. **Leader Instruments Corp., Hauppauge, NY 11788. Please circle INFO/CARD #119.**

E's IN IRON POWDER FOR EMI AND POWER FILTERS



Low Cost • High Performance
Iron Powder E Cores

MICROMETALS

IRON POWDER CORES

1190 N. Hawk Circle, Anaheim, California 92807 USA • (714) 630-7420 • TWX 910-591-1690

INFO/CARD 63

Broadband 10 dB Coupler

Offered is a broadband 10 dB coupler ± 1 dB (model CO518-10) with a range from 0.5 GHz to 18 GHz. Insertion loss, excluding coupling loss, is 1.2 maximum over the full frequency range. VSWR is



1.4:1 maximum, while directivity is 15 dB minimum and coupling flatness is ± 0.8 dB. The unit is 4.5" x 0.7" x .38", including SMA connectors and termination. Sage Laboratories, Inc., Natick, MA 01760. Please circle INFO/CARD #118.

Micro-Ohmmeter

The Model 510, a low cost, 4 1/2 digit, micro-ohmmeter is designed to measure the resistances of switch and relay contacts, transformer and motor windings, connectors, or any other low resistance devices. It has five ranges from 19.999 millionohms to 199.99 ohms, full scale, 1

micro-ohm resolution, and a basic accuracy of 0.02%. Three measurement modes are provided. The continuous DC mode is useful for making measurements on inductive components and the switched DC mode removes the effect of thermal voltages, the largest source of error in low resistance measurements. A pulsed mode is provided for thermally sensitive devices such as fuses. The standard unit comes with 4-terminal Kelvin test



clips and a parallel BCD interface. Cambridge Technology, Inc., Cambridge, MA 02140. INFO/CARD #117.

New Crystal Oscillator

The XO-43 crystal oscillator features low profile, resistance welded metal pack-

IF YOU HAVEN'T READ THIS AD YOU PROBABLY DON'T KNOW ABOUT THE MOST EFFICIENT HIGH ANGLE OMNI- DIRECTIONAL ANTENNA EVER DEVELOPED.

There are 280,000 channels in the HF spectrum of 2 to 30 MHz . . . and the Henderson collapsible helical monopole antenna makes them available to you for clear "long haul" communications at any time of night or day. Optional models also cover bands from 1.7 to 30 and from 3 to 30 MHz is preferred. All models actually change their resonant length to any wavelength within their range, without the use of a base tuner/coupler . . . providing gain of at least two power doubles (6dB) . . . and eliminating magnetic emissions. Certified for command control by the USAF and USN . . . suitable for portable, tactical, shipboard, and just plain communications. O.A. length 30'. Installed in 30 minutes. From \$10,000.

Write Al Henderson for further details or circle info/card number below.

SIGNATURE ANTENNA SYSTEMS

921 Martinez Street
San Diego, CA 92106
Phone: (619) 225-8454

LOWEST PRICED, HIGHEST QUALITY ATTENUATORS - BNC \$11.00 1-9 EA., SMA \$8.90 10 EA. AND TERMINATIONS - BNC \$5.60 10 EA., SMA \$5.60 10 EA., MIL. HI-REL. NETWORKS

Model Number (2)	Impedance Ohms (Power W)	Frequency Range	BNC	TNC	N	SMA	UHF	PC
Fixed Attenuators, 1 to 20 dB:								
AT-50(3)	50 (.5W)	DC-1.5GHz	14.00	20.00	20.00	18.00	—	—
AT-51	50 (.5W)	DC-1.5GHz	11.00	15.00	15.00	14.00	—	12.00
AT-52	50 (1W)	DC-1.5GHz	14.50	20.50	20.50	19.50	—	—
AT-53	50 (.25W)	DC-3.0GHz	14.00	17.00	—	15.00	—	—
AT-54	50 (.25W)	DC-4.2GHz	—	—	—	16.00	—	—
AT-55	50 (.25W)	DC-4.2GHz	—	—	—	8.90 (10 Pcs)	—	—
AT-75 or AT-90	75 or 93 (.5W)	DC-1.5GHz (750MHz)	14.00	20.00	20.00	18.00	—	—
Detector, Mixer, Zero Bias Schottky:								
CD-51	50	.01-4.2GHz	84.00	—	—	84.00	—	—
DM-51	50	.01-4.2GHz	—	—	—	84.00	—	—
Relative Impedance Transformers, Minimum Loss Pads:								
RT-50/75	50 to 75	DC-1.5GHz	10.50	19.50	19.50	17.50	—	—
RT-50/93	50 to 93	DC-1.0GHz	13.00	19.50	19.50	17.50	—	—
Terminations:								
CT-50 (3)	50 (.5W)	DC-4.2GHz	11.50	15.00	15.00	17.50	—	—
CT-51	50 (.5W)	DC-4.2GHz	9.50	12.00	12.00	9.50	—	—
CT-52	50 (1W)	DC-1.5GHz	10.50	15.00	15.00	13.00	15.50	—
CT-53/54	50 (.5W)	DC-4.2GHz	5.50 (10 Pcs)	—	—	8.90 (10 Pcs)	—	—
CT-54	50 (2W)	DC-2.0GHz	14.00	15.00	15.00	17.50	—	—
CT-75	75 (.25W)	DC-1.5GHz	10.50	19.50	19.50	13.00	15.50	—
CT-93	93 (.25W)	DC-2.5GHz	13.00	15.00	—	—	15.50	—
Mismatched Terminations, 1.05:1 to 3:1, Open Circuit, Short Circuit:								
MT-51	50	DC-3.0GHz	45.50	—	45.50	45.50	—	—
MT-75	75	DC-1.0GHz	—	—	45.50	—	—	—
Feed thru Terminations, shunt resistor:								
FT-50	50	DC-1.0GHz	10.50	19.50	19.50	17.50	—	—
FT-75	75	DC-500MHz	10.50	19.50	19.50	17.50	—	—
FT-90	93	DC-150MHz	13.00	19.50	19.50	17.50	—	—
Directional Coupler, 30 dB:								
DC-500	50	250-500MHz	80.00	—	—	—	—	—
Relative Decoupler, series resistor or Capacitive Coupler, series capacitor:								
RD or CC-1000	1000 (1000PF)	DC-1.5GHz	12.00	18.00	18.00	17.00	—	—
Adapters:								
CA-50 (N to SMA)	50	DC-4.2GHz	—	—	13.00	13.00	—	—
Inductive Decouplers, series inductor:								
LD-R15	0.17uH	DC-500MHz	12.00	18.00	18.00	17.00	—	—
LD-6R8	8.8uH	DC-35MHz	12.00	18.00	18.00	17.00	—	—
Fixed Attenuator Sets, 3, 6, 10, and 20 dB, in plastic case:								
AT-50-SET (3)	50	DC-1.5GHz	60.00	84.00	84.00	76.00	—	—
AT-51-SET	50	DC-1.5GHz	48.00	64.00	64.00	60.00	—	—
Reactive Multicouplers, 2 and 4 output ports:								
RC-125-2	50	1.5-125MHz	64.00	—	67.00	67.00	—	—
TC-125-4	50	1.5-125MHz	67.00	—	61.50	61.50	—	—
Relative Power Dividers, 3, 4 and 9 ports:								
RC-2-30	50	DC-2.0GHz	64.00	—	—	64.00	—	—
RC-3-30	50	DC-800MHz	64.00	—	—	64.00	—	—
RC-5-30	50	DC-800MHz	—	—	—	64.00	—	—
RC-3-75, 4-75	75	DC-800MHz	64.00	—	—	64.00	—	—
Double Balanced Mixers:								
DBM-1000	50	S-1000MHz	61.00	—	71.00	61.00	—	34.00
DBM-500PC	50	2-500MHz	—	—	—	—	—	34.00
RF Fuses, 1/8 Amp. and 1/16 Amp:								
FL-50	50	DC-1.5GHz	12.00	18.00	—	17.00	—	—
FL-75	75	DC-1.5GHz	12.00	18.00	—	17.00	—	—

NOTE: 1) Critical parameters fully tested and guaranteed. Fabricated from Mil. Spec. High-Rel. resistors. Schottky diodes, Mil. Spec. plated parts, and connectors in nickel, silver, and gold. 2) See catalog for complete Model Number. Specify connector type. 3) Calibration marked on label of unit. 4) Price subject to change 1985-A without notice. Shipping \$5.00 Domestic or \$15.00 Foreign on Prepaid Orders. Delivery is stock to 30 days ARO.

Send for Free Catalog on your Letterhead.
Elcom SYSTEMS INC. 305-994-1774
4032 CLINT MOORE ROAD, BOCA RATON, FL 33431

MOS FET POWER From INTECH



COM 1000: 1000W. Av. Power
1.6-30 MHz with PS 248 Dual
Switching AC Power Supply.

Introducing the next generation
of unconditionally stable POWER
MOS FET Linear Amplifiers from
Intech.

Combining the low order distortion
of Class "A" with the high
efficiency of "AB" & "C"

Designs, they can withstand
severe load mismatch conditions
without spurious oscillation or
failure.

They are capable of high speed
on-off switching and are Frequency
Agile over their 1.6-30 MHz
range.

They are ideal for: RFI/EMI
Testing, H.F. Transmitters, Linear
Accelerators, N.M.R. CATSCAN,
plasma equipment and
diathermy.

Power levels — 500 W, 1Kw and
up.

**Please contact Ted Stevenson
Phone: 408-727-0500,
TWX: (910) 338-0254) to
discuss your State-of-the-
Art amplifier requirements
or write him at**

intech

282 Brokaw Rd.
Santa Clara, CA 95050

rf products *Continued*

aging, with a grounding to minimize RFI.
The new, hermetically sealed unit is now
available at any discrete frequency be-

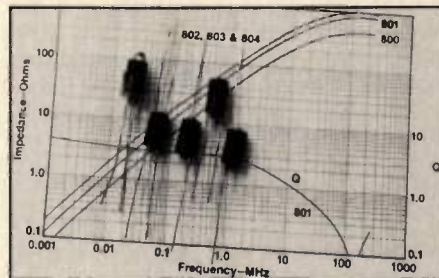


tween 250 kHz and 60 MHz. Models may
be ordered at any of five different frequency
stabilities ($\pm 0.005\%$, $\pm 0.01\%$, $\pm 0.05\%$,
 $\pm 0.1\%$ and $\pm 1\%$) over an operating temperature
range of 0 to $+70^\circ\text{C}$. Designed to
withstand flow soldering without problems,
the XO-43 has a hermetically sealed,
all metal package (nickel plated
base with stainless steel cover) which
resists corrosion and provides maximum
protection against humidity. The new unit
is suitable for dense packaging. It has a
maximum aboveboard seated height of
only .225" with a length of .815" and width
of .515". The XO-43 has a TTL compati-

ble output and will drive fanout of 10 TTL
loads. Input voltage requirements is ± 5
VDC, $\pm 10\%$ at 65 mZ. To minimize RFI,
pin 7 is connected to ground. Dale Elec-
tronics, Inc., Tempe, AZ 85282. Please
circle INFO/CARD #116.

Multi-Hole Ferrite Bead Chokes

Inexpensive multi-hole ferrite bead
chokes that avoid resonance problems in
filtering applications have been intro-
duced. Because low Q and other non-
resonant characteristics are maintained



over a wide range with these chokes,
resonance — common with air core and
other choke types — is not a problem.
With high resistive impedance in the

SUBMINIATURE COAXIAL CONNECTORS



SMA, SMB, SMC

Send for FREE Catalog



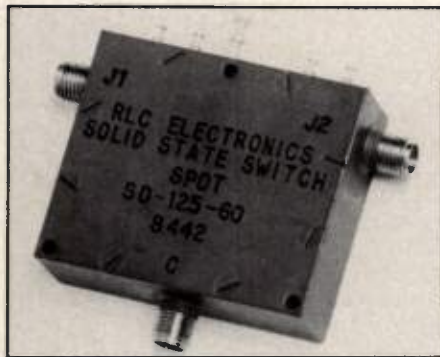
Applied Engineering Products

1475 Whalley Avenue
P.O. Box A-D Amity Station, New Haven, CT 06525
(203) 387-5282 TWX: 710-465-1173

30-300 MHz range, the chokes are effective in eliminating unwanted RF while presenting a low impedance to audio and DC. Unit costs begin at \$0.11 in production quantities. Prototypes are readily available and custom modifications can be provided. **South American Development Corp.**, Hyde Park, NY 12538. Please circle INFO/CARD #115.

Diode Switches

A new line of solid state diode switches which cover a range of .020 to 18 GHz are designed for low power and moderate speed applications. Two independent TTL



drivers are included for maximum versatility. Close tolerance printed circuit techniques and precision bonding of diodes ensure uniform operation under extreme environmental conditions. **RLC Electronics, Inc.**, Mount Kisco, NY 10549. INFO/CARD #114.

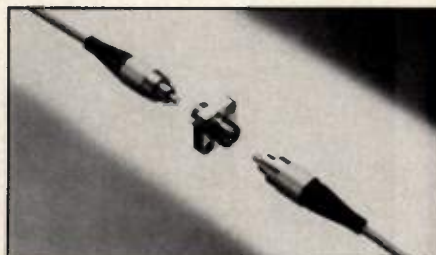
Programmable 1 into 8 Switch

With a frequency range of DC-1000 MHz the programmable 1 into 8 switch has one common input switchable to one of eight outputs and all unused ports are internally 50 ohm terminated. Other options are available, for example 1 into 10 switch. The switching is accomplished by means of TO-5 type relays with a switching speed <6 msec.

This programmable switch is capable of an insertion loss of <2.0 dB at 1000 MHz, VSWR < 1.5:1 at 1000 MHz and Isolation >30 dB at 1000 MHz. It has a standard 12 volt operating voltage but is also available in 5, 6, 9, 18 & 26 volts. These are all at an operating temperature range of -55° to +71°C. **Wavetek Indiana, Inc.**, RF and Microwave Components, Beech Grove, IN 46107. Please circle INFO/CARD #180.

Fiber Optic Connectors

Single and multi-mode fiber optic connectors providing a consistent loss of less than one dB per mated pair, are now available. These connectors are FC-type Nippon Telephone and Telegraph (NTT) compatible.



They are sold without cable attached as well as in pigtails and jumpers. Connector inside diameters are available in six standard sizes ranging from 123 to 128 microns. **Kyocera Industrial Ceramics Division**, San Diego, CA 92123. Please circle INFO/CARD #181.

Toroidal Mixer Series

This series accommodate RF and local oscillator frequencies from 1 MHz to 3 GHz. These devices are designed for 50

**"The Kids
on the Block"
are very
special puppets.
They are
disabled.**

The talent is there. Use it.

President's Committee on Employment of the Handicapped,
Washington, D.C. 20210
Produced by the School of Visual Arts Public Advertising System.



SOLUTIONS TO YOUR RFI/PACKAGING PROBLEMS

- 420 standard configurations off —
the shelf
- Rapid delivery —
- Complete line of gasketing —
& mounting bars
- Interchangeable connectors —
SMA, BNC, TNC & N
- Coaxial accessories: attenuators, —
filters & adapters
- Capable of performing all —
secondary operations to our standard
enclosures from your specs
- Complete customization to your —
specifications from enclosure size
to hole placement

279 Skidmore Road, Deer Park, NY 11729
(516) 667-3933 TWX 510-227-1064

INFO/CARD 68

rf testing minus the if's.

Why mix and match the tools you use for rf testing?

Instead, you can equip your entire test loop with instruments from Amplifier Research that have been thoroughly tested and work well with our high-performance broadband rf amplifiers.

From 1W to 10kW, 10 kHz to 1,000 MHz, in 32 standard models, AR amplifiers give you optimum power, bandwidth, and versatility for your cw, sweep,

and pulse requirements. Each model provides instantly available bandwidth without bandswitching or tuning, is completely immune to load mismatch, and won't shut itself down when you may need it most.

But a high-quality test presumes high-quality test equipment throughout. So we also supply

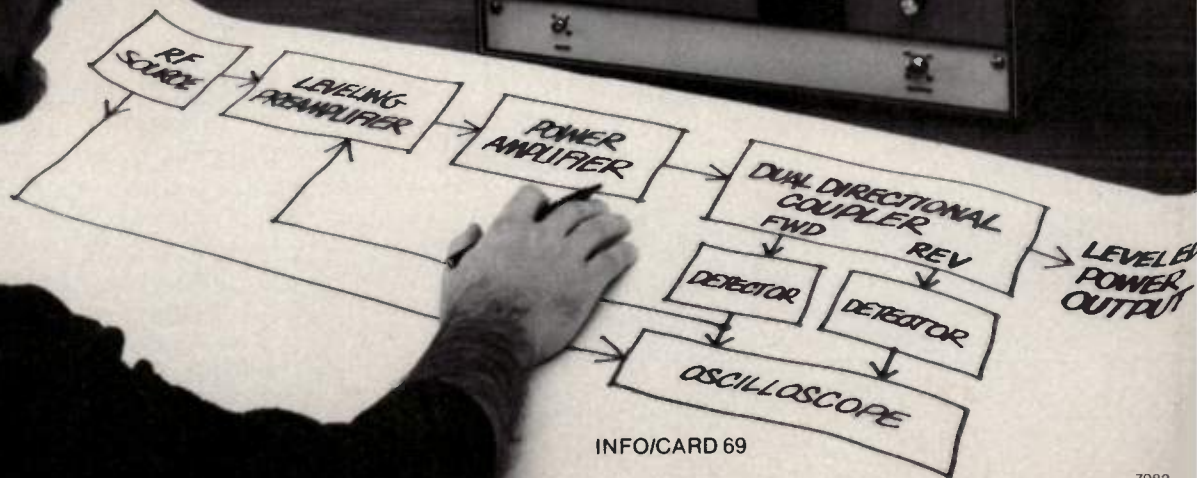
leveling preamplifiers, field sensor systems, fiber-optic telemetry links,

matching transformers, directional couplers, and power combiner/dividers.

With this full-system approach, equipment variables are less likely to show up in your test results. It'll pay you to talk with us about all your rf test requirements.

AR **AMPLIFIER
RESEARCH**

160 School House Road, Souderton, PA 18964-9990 USA
Phone 215-723-8181 • TWX 510-661-6094



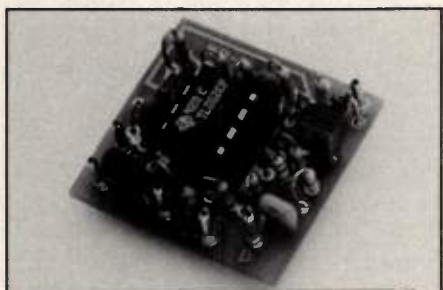
INFO/CARD 69



ohm systems. Typical conversion loss values range from 5.0 dB to 7 dB depending upon the device. Isolation between various ports ranges typically from 30 dB to 50 dB. These devices are designed for operation from -55°C to +100°C. **KDI Electronics, Whippany, NJ 07981. Please circle INFO/CARD #131.**

Reverse Burst Accessory

The RB-1 eliminates the long squelch tail heard with some reed type and other sub-tone decoders. When used in conjunction with decoders that offer squelch tail elimination, the RB-1 will delay



transmitter turn off time and reverse the phase of the encoded tone. This immediately stops the decoder and eliminates the squelch tail. The RB-1 is available from stock and sells for \$14.95. **Communications Specialists, Inc., Orange, CA 92665-4296. INFO/CARD #130.**

Lithium Power Cell

The AL125 high-energy/density Lithium Thionyl Chloride Power Cell features a 1.4 amp-hr. capacity in a flat disk design that is well suited for limited-space requirements. The AL125's compact size, 1.27"x .38"/3.23 cm x .97 cm, makes it a natural choice in printed circuit design where it can be board-mounted to deliver a standard open circuit voltage of 3.6 VDC. The cell additionally features rugged stainless steel construction and a patented ceramic-to-cell seal that assures operation in hazardous environments where temperatures can range from -40°C to +70°C. With a shelf life of more than 10 years, the AL125 is unaffected by spin, altitude or position and meets the most stringent military safety standards

while offering the highest energy density at high discharge rates of any lithium cell available. Nominal capacity of the AL125 is 1.4 A-hr. at the 24-hr. rate, at 20°C, to a 2.5 V cut-off. **Altus Corp., San Jose, CA 95112. INFO/CARD #159.**

EMI/RFI Shielded Instrument Case

These 19-inch EMI/RFI cases are available in heights of 3 to 28 inches and depths of 16, 20 and 24 inches. Case width of 24 inches are available as modified orders. The cases achieve 55dB nominal shielding effectiveness through the use of beryllium copper gasketry. Tests performed at an independent laboratory between 30-1,000 MHz showed attenuation values at varied frequencies ranging up to 77dB. **Scientific-Atlanta, Inc., Atlanta, Georgia 30348, INFO/CARD #186.**

Optical Power Meter

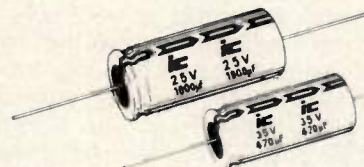
A digital optical power meter for highly accurate direct measurements, designated the ML 93A, is now available. Two optical power sensors cover a wavelength range from 0.38 to 1.8 μ m and provide wide power sensitivity, from -90 to +10 dBm, with overall accuracy of \pm percent. The unit features automatic zeroing, averaging function, GP-IB interface (IEEE 488), digital display, and excellent interchangeability — any of seven optical power sensors can be connected without readjustment. The meter includes sensor include sensor connecting cords and is available in 120 VAC, 240 VAC models. A rechargeable battery pack and charger (optional) provide up to four hours of con-



tinuous operation. A lower cost, analog unit, designated the ML 94A, and a handy, portable, digital unit, designated the ML96A are also offered. The optical power sensors for high levels (MA 97A/98A) use large active area elements for optical power reception so that the optical input can be easily modified. Available are a small active area sensor (MA911A), a slim style sensor (MA 912A) and a moderate power sensor (MA 913A) **Anritsu America, Oakland, NJ 07436. Please circle INFO/CARD #185.**



**THE SOURCE FOR
QUALITY
PERFORMANCE
& DELIVERY**



ic TYPE TTA ELECTROLYTIC CAPACITORS

0.47 Mfd. to 33,000 Mfd.
6.3 WVDC to 500 WVDC
-40°C to +85°C min.
2,000 HOUR OPERATION +85°C rating
TAPE & REEL MOUNTING
EPOXY END SEAL Avail. (TTA-PX)



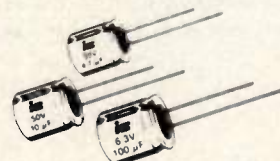
ic TYPE RLR LOW-LEAKAGE ELECTROLYTIC CAPACITORS

0.1 Mfd. To 2,200 Mfd.
6.3 WVDC To 50 WVDC
-40°C To +85°C
Leakage Current: $\leq 0.002CV$ or 0.4 μ A min.
EPOXY END SEAL Optional (RLR-PX)



ic TYPE MSR METALLIZED MYLAR® POLYESTER FILM CAPACITORS

.01 Mfd. to 2.2 Mfd.
250 WVDC to 1000 WVDC
NON-INDUCTIVE WINDINGS
TOLERANCE: $\pm 10\%$, $\pm 5\%$



ic TYPE RSS SUB-SUBMINIATURE ELECTROLYTIC CAPACITORS

0.1 Mfd. To 100 Mfd.
6.3 WVDC To 50 WVDC
Min. Dia. 0.15 in./4.0mm
Max. Length .28 in./7.0mm
-40°C To +85°C Min.

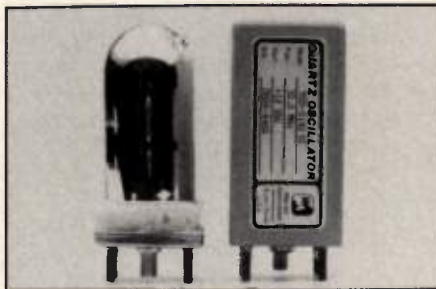
ic NON-POLAR ELECTROLYTICS FILM-FOIL POLYESTER CAPACITORS



3757 W. Touhy
Lincolnwood, IL 60645
(312) 675-1760 Telex: 72-4361

Low Power Oven Oscillator

A miniature low power oven oscillator provides ultra-low phase noise for frequencies in the 3 to 11 MHz range. A vacuum flask insulator allows the "Small Fry" oscillator to consume less than 1 watt at 25°C while maintaining excellent temperature stability of $\pm 5 \times 10^{-9}$ from -25°C to +65°C. SSB phase noise can be specified to -140 dBc (10 Hz) for 5 MHz



oscillators and to -135 dBc for 10 MHz. 1 KHz noise is better than -165 dBc. **Wenzel Associates, Inc., Austin, TX 78759. Please circle INFO/CARD #188.**

Linear Bipolar Chip

The chip, named Samson, provides a 1 A npn darlington output and a 1 A diode with 80 V breakdown voltage, two 200 mA npns, 6 general-purpose npns, three lateral npns, one 5.8 V buried zener, one epi pinch FET, two base-emitter pinch resistors and 24 resistors (total resistance 54 kohms).

Samson replaces hybrids because it carries its own high-power output capability. It thus reduces costs, lowers the parts count and so improves reliability. **Polycore Electronics Inc., Newbury Park, CA 91320. Please circle INFO/CARD #190.**

SSMA to SMA Adapters

The interseries adapters use the WPM-4 (Weinschel Precision Miniature) coaxial connector which incorporates



dielectric support beads at its interface to keep the internal surfaces dirt-free and to provide a rigid support for the center conductor in both male and female versions. Frequency range is from DC to 40 GHz. Maximum VSWR (per mated pair) is 1.20 to 18.0 GHz, 1.30 from 18 to 26 GHz, and 1.40 from 26 to 40 GHz. Insertion loss per mated pair is 1 dB maximum. **Weinschel Engineering, Gaithersburg, MD 20877. Please circle INFO/CARD #191.**

AC/DC Hipot Tester

New Model HC3-AT-AD AC/DC Hipot Tester with Automatic Controls can be operated in Manual, Automatic or Automatic-Remote mode. For operator's safety all high voltage connections are on unit's rear panel allowing use of a simple



NEW



1 GHz Microprocessor-Based Intelligent Counter Offers High Resolution at Low Cost.

Sigmotek Model ITC-3 intelligent counter offers these outstanding features:

- Wide range—0.1 Hz to 200 MHz for nonscaled input, 50 MHz to 1 GHz for prescaled input.
- High resolution over full range—for example, 10 nHz at 1 Hz, 1 Hz at 100 MHz.
- 8 digits, with at least 7 digits displayed in 1 second.
- High sensitivity—10 mV rms typical.
- Self-diagnostics.
- Precision crystal timebase or optional TCXO (≤ 1 ppm, 0° C to 50° C).
- IEEE-488 (GPIB) optional.
- Compact, lightweight design.
- Low price—only \$363.00 for 1 GHz version; \$298.00 for 200 MHz version. TCXO option adds \$60.00. IEEE-488 option adds \$200.00.

Sigmotek International Corporation

4480 Enterprise St. • Fremont, CA • (415) 490-6500

probe for lab use or a variety of optional test fixtures for production line applications. Standard input is 115 V, 50/60 Hz, 100 VA with 220 V also available. Output Voltage is 0-3000 V ac and 0-4000 V dc with a variable rate of rise of 100 to 500 V/sec, current of 5 mA and distortion of less than 5% THD. **Hipotronics, Inc., Brewster, NY 10509. INFO/CARD #192.**

Clock Multiplier

Models WFM 5-1400 and WFM 10-1400 high order frequency multipliers are capable of multiplying 5 or 10 MHz up to 1400 MHz or above. These multipliers are perfectly suited for NAVSTAR Clock Multipliers to multiply 10.23 MHz to 1432.2



MHz. All units are Thick Film Hybrid construction for small size and light weight, and provide a minimum output of +10 dBm with a power consumption of 150 mA at +15 to 32 VDC. Spectral Purity is excellent, with Harmonics and spurs typically >-60 dBc. **Wilmanco, Northridge, CA 91324. INFO/CARD #193.**

Digitally-Tuned UHF Preselector

This device, part number SDTA-200/400-N/N, has a tunable center frequency from 200 MHz to 400 MHz with a 3 dB bandwidth of 0.4%-5.0% and rejection of 18 dB per octave. Insertion loss is dependent on the bandwidth; 2.5 dB maximum at 225 MHz with a 0.4% bandwidth and 1.0 dB maximum at 400 MHz with a 0.8%



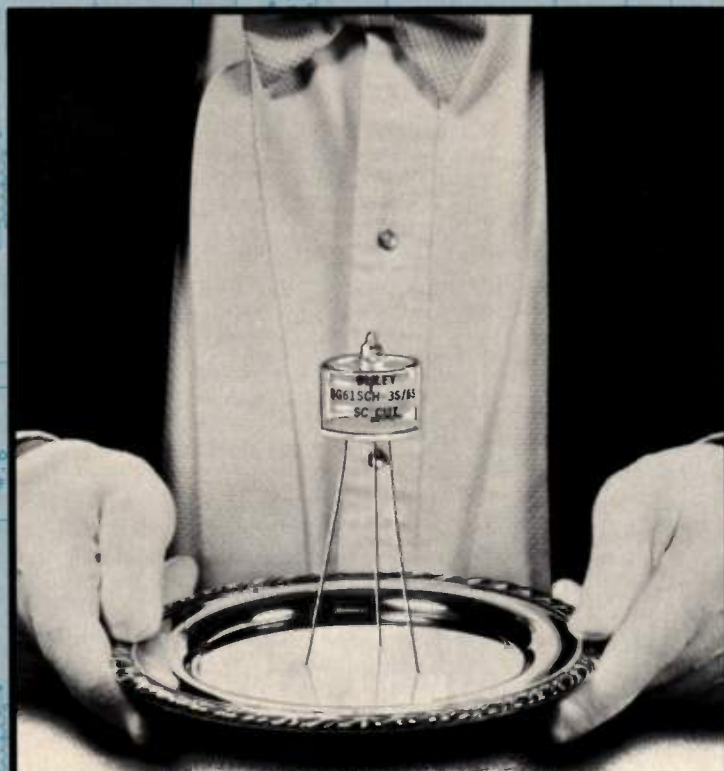
bandwidth. Typical VSWR is 1.5:1 maximum and normal power handling capability is 50 watts. The device has a center

RF Design

frequency accuracy of typically .1%. The control logic interface is available in a serial format, RS-232/300 baud standard, or a parallel format using BCD, Binary, or GPIB (IEEE-488) BUS. Control voltage is 24-28 VDC, though other voltages are optional. Tuning time is typically 3-6 seconds. Standard connectors are type N. **K&L Microwave Inc., Salisbury, MD 21801. INFO/CARD #194.**

0.5 to 30 MHz Gated Amplifier

The Model 515A RF Gated Amplifier features a 500 kHz to 30 MHz frequency range and provides 3 kW RMS pulse power output from 0.5 MHz to 10 MHz, 2.5 kW from 10 to 20 MHz, and 2 kW from 20 to 30 MHz. Producing sequences of coherent, high power RF pulses with stepped or continuously variable width and



The Affordable Luxury.

The specs determine the cost. Let Bliley quote on yours.

• Quartz Crystals • Crystal Oscillators • Free Catalog

Bliley

The First Name in Frequency Control for Your Circuit.

BLILEY ELECTRIC COMPANY

2545 West Grandview Blvd.

P.O. Box 3428, Erie, PA 16508

(814) 838-3571

TWX 510-696-6886

INFO/CARD 73



TELEDYNE MICROWAVE

ISOLATORS

*There when
you need
them!*

Sometimes a need for better isolation is unexpected. A mismatch may occur, or return loss may be greater than anticipated. Teledyne Microwave understands this. That is why we stock broadband isolators from 1 to 26.5 GHz. They are there when you need them!

*Delivered
from Stock*

Isolators—1 to 26.5 GHz

Frequency (GHz)	Isolation (dB)	Loss (dB)	VSWR	Model
1-2	18	0.5	1.25:1	T-1S63T-18
2-4	17	0.5	1.35:1	T-2S63T-6
4-8	17	0.4	1.35:1	T-4S63T-10
7-11	28	0.4	1.10:1	T-7S43T-6
7.6-18	16	0.8	1.50:1	T-7S83T-20
8-12.4	17	0.4	1.35:1	T-8S43T-1A
8-16	17	0.5	1.35:1	T-8S63T-18
10-20	17	0.7	1.35:1	T-10S63T-5
12-18	18	0.5	1.30:1	T-12S43T-8
18-26.5	17	1.0	1.50:1	T-18S33T-7

Small package designs with SMA female connectors are standard.

Call us about your isolator requirements, both standard and custom. We take pride in meeting your needs.

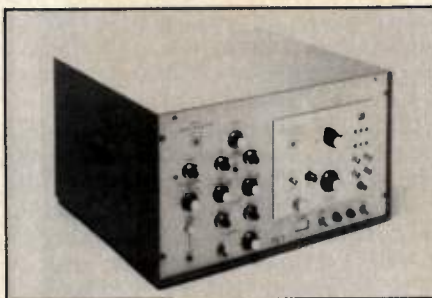
TELEDYNE MICROWAVE

Teledyne Microwave
1290 Terra Bella Avenue
Mountain View, CA 94043
Phone: (415) 968-2211
TWX: 910-379-6939

© Teledyne Microwave, 1984

INFO/CARD 74

rf products *Continued*



separation, it plugs into the firm's Model 5100 Gating Modulator.

Accepting CW input levels from less than 10 mV to over 100 mV with no change in output, the Matec Model 515A RF Gated Amplifier provides an on-off ratio greater than 140 dB and a .002 maximum duty cycle for rated power output. It also accepts external pulse programs for NMR studies. **Matec Instruments, Inc.**, Warwick, RI 02886. Please circle INFO/CARD #202.

EMI Absorber

CHO-SERBS reduce radiated EMI for compliance with FCC and VDE emission limits, while reducing susceptibility to ESD. Unlike cable shields, CHO-SORBS do not require grounding and will not affect the data being transmitted as filters or filter pin connectors often do.

This development in EMI absorbers is made of a sleeve of specially formulated ceramic material providing a minimum of 8 dB of EMI attenuation on data and power cables in the 30-500 MHz frequency range. CHO-SORBS are available in two standard sizes, one for cables up to 1/4" in diameter, and one for cable diameters up to 1/2". By molding a connector boot or cable jacket over the CHO-SORB Absorber, time and assembly costs can be saved. **Chomerics Shielding Technology, Woburn, MA 01888**. INFO/CARD #203.

Ground Plane Cable

The new Series 65 ground plane planar cable features high density and extremely stable, electrical characteristics, making this type of cable ideal for applications in high speed computers, medical instruments, and other equipment that is sensitive to undesirable EMI radiation. Series 65 ground plane cable reduces crosstalk to 1.7% near end and 3.9% far end on a ten-foot sample with 5 ns rise time. The impedance rate is 65 ohms nominal and capacitance is 25pF/foot.

Single or double drain wire option increases the grounding capacity in the cable-to-connector interface. Cable preparation is easy and efficient. A blue tracer on the number one conductor en-

sures positive connector polarization. Precise center-to-center spacing on the 28 AWG cable secures the conductors to the connector with no scoring or nicking.

The Series 65 ground plane cable is available in 10 or 64 conductors and the grey PVC insulation is flame retardant, UL style 2682 recognized. Delivery is four to six weeks. **Midland Ross Corp.**, San Jose, CA 95110. INFO/CARD #204.

Automatic Voltage Regulator

New line of voltage regulators has input voltage range of $\pm 20\%$ for $\pm 1\%$ output accuracy. All standard service line voltages available, single and three phase, at currents ranging from 40 to 1000 amps. Optional features include individual phase control, by-pass switch, and transient suppression. **Hipotronics, Inc.**, Brewster, NY 10509, please circle INFO/CARD #205.

Ultraminiature Double Balanced Mixers

Identified as RHG "DMR" models, the compact "Hermix" series meet high density system requirement and are designed to drop in to integrated MIC assemblies. Removable connectors permit DMR models to be tested without special jigs and fixtures. Mounting centers are consistent with other industry MIC compatible mixer packages.

Model DMR8-12 is priced at \$655. Model DMR2-26 is priced at \$995. Delivery is 90 ARO. **RHG Electronics Laboratory, Inc.**, Deer Park, N.Y. 11729. INFO/CARD #206.

Power Line Disturbance Meter

The Model T1007 is a compact rugged portable instrument designed for field use. It measures the three basic parameters of an AC power line, i.e. voltage, frequency and interference. The T1007 has a built-in 4-digit interference pulse counter, 4 selectable levels of transient pulse voltage threshold (10, 50, 100 and 200 V), 50ns transient pulse capture time, and monitor of either 90-135VAC or 200-260VAC and 35-65 Hz line frequency. **Tactical Electronics Corp.**, Melbourne, FL 32902. INFO/CARD #207.

Miniature RF Chokes

Series 55X-4399 RF chokes are available in either loose piece lots or in tape mounted bandoliers for fast, automatic insertion. These miniature RF chokes offer a space saving advantage over standard molded chokes. The inductance range is from .1 microHenry to 100 microHenrys. The Series 55X-4399 RF

choke is conformally coated and solvent resistant. Solder durability is 260°C in accordance with MIL-STD-810/202 and is flame retardant to UL94V-0. Color coding of these miniature devices is in accordance with MIL-STD-1285. Delivery is stock to twenty weeks. **Midland-Ross Corporation, San Jose, CA 95110. INFO/CARD #195.**

Miniature Power Line Filters

This line includes a total of 18 different series products with current ratings up to 30 amps. Included in the line are a full range of filters ranging from low cost general purpose common mode filters to premium performance multiple section units. Particularly well suited for switching power supply applications, these filters enable equipment to comply with FCC EMI/RFI regulations, along with VDE, CSA and UL safety standards.

Delivery of these products is stock to 6 weeks and they will be available shortly through SFE's franchised distributors. **SFE Technologies, San Fernando Electric Division. INFO/CARD #196.**

Semiconductor Fuse

The 6JX fuse for 600VAC, 0.1A to 30A applications offers a low cost alternative to other semiconductor fuses of the same rating. The 6JX is manufactured to tight specifications and features plated terminals, a ceramic body and pure silver elements. The 6JX is UL listed. The 6JX features low watt loss with fast clearing times. Interrupting capacity is rated at 2,000,000 amps RMS. **Carbone-Ferraz, Inc., Parsippany, N.J. 07054, please circle INFO/CARD #197.**

Shielded Ribbon Cables

A family of extruded shielded ribbon cables for use with SDL connectors has been developed. A precision extrusion system allows tight tolerance control on construction widths from 4 to 24 conductors. Available in 24, 26 & 28 AWG, these cables provide 100% RFI shielding as well as easy stripability for high volume applications. **Phalo Corporation, Westborough, MA 01581, please circle INFO/CARD #198.**

Miniature Oscillator

Less than 0.8 cubic inches in volume, the dielectrically stabilized oscillator operates at a fixed frequency of 5495 \pm MHz. Output power is 10 milliwatts min.; power variation with temperature is 1 dB max.; frequency stability is ± 5 ppm/°C typical and ± 10 ppm/°C max. Load VSWR may be up to 2.5:1 max. (any

phase) and VSWR pulling is ± 1.5 MHz max. Harmonic output is -30 dBc; spurious is >90 dBc; input voltage is -15 VDC and input current is 35 ma, max. Specifications are guaranteed from -54° to $+85^\circ$ C. Size is 1.1 x 9.5 x .68 inches (27.9 x 24.1 x 17.3 mm) nominal, excluding tuning screw, terminals and output cable. RF connectors are SMA. DC connectors are solder pins. **TRAK Microwave Corporation, Tampa, FL 33614. INFO/CARD #199.**

Isolated Power Divider

Model IPD-65 is an economical solution to the problems of using two satellite receivers with no downconverter interaction. The IPD-65 combines a 2-way power divider with ferrite isolators to offer more than 65dB of isolation.

A feature unique to the IPD-65 is an LED indicator that allows verification of power to the LNA. Automatic LNA power switching and DC block circuits are included to simplify downconverter hookup.

Inherent reliability, quality materials, and careful design make the IPD-65 the component of choice for combining two satellite receivers. **Avcom of Virginia, Inc., Richmond, VA 23236, please circle INFO/CARD #200.**

Digitally Compensated Crystal Oscillator

The DT-100 offers frequency vs. temperature stabilities approaching those of ovenized oscillators while consuming only a small fraction of the input power required to operate an oven. The DT-100 is on frequency instantly, eliminating the lengthy wait for an oven to stabilize. The DT-100 can be ordered at any frequency



between 3 MHz and 30 MHz. Over the operating temperature range of -55 to $+85^\circ$ C, the frequency stability is typically $\pm 1 \times 10^{-7}$. ($\pm 3 \times 10^{-7}$ max). The unit requires a power supply of $+15$ VDC $\pm 10\%$ and typically draws 13 mA of input current. (20 mA max.) **Greenray Industries, Inc., Mechanicsburg, PA 17055. Please circle INFO/CARD #201.**



TELEDYNE MICROWAVE

COAXIAL SWITCHES

*Ready when
you are!*

Teledyne Microwave believes your time is valuable. While you've spent hours designing and developing a system, we have been designing coaxial switches to meet your needs. That is why we offer so many different models of coaxial switches from stock. They are ready when you are.

Coaxial Switches DC-18 GHz

*Delivered
from Stock*

Type	Model
SPDT, Failsafe	CS-33S10
SPDT, Latching	CS-33S6C
SP3T, Failsafe	CS-38S13
SP4T, Failsafe	CS-38S14
SP5T, Failsafe	CS-38S15
SP6T, Failsafe	CS-38S16
Transfer, Failsafe	CS-37S10
Transfer, Latching	CS-37S6C

Most models are available from stock with indicators and/or TTL drivers.

If you need reliable coaxial switches and you need them right away, call us. We take pride in meeting your needs.



TELEDYNE MICROWAVE

Teledyne Microwave
1290 Terra Bella Avenue
Mountain View, CA 94043
Phone: (415) 968-2211
TWX: 910-379-6939

© Teledyne Microwave, 1984

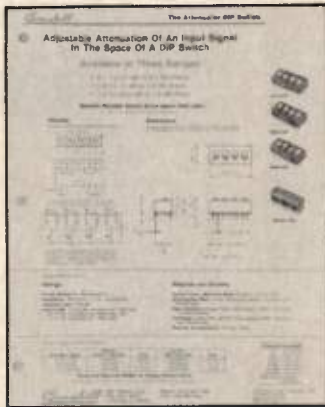
INFO/CARD 75

Test & Measurement Instruments Catalog

A short-form product catalog, featuring test and measurement instrumentation for telecommunications, fiber optics, microwave and general purpose applications is now available. The 8-page catalog provides brief descriptions and general specifications on the most popular instruments in their line. **Anritsu America, Oakland, NJ 07436. INFO/CARD #150.**



Anritsu



Grayhill

Adjustable Attenuator DIP Switch

Adjustable Attenuator DIP Switches, described in new product bulletin No. 361, regulate input signals in the space of an eight position DIP switch. The switches are available in three ranges: 0.1 to 1.5 dB; 1.0 to 15 dB; and 1.5 to 22.5. Bulletin No. 361 pro-

vides complete attenuators DIP switch dimensions, electrical rating information, materials, finishes and prices. **Grayhill, Inc., LaGrange, IL 60525. INFO/CARD #149.**

High-Efficiency Power Amplifiers

This short course brings RF design engineers up to speed on high-efficiency power-amplification techniques. Theory, practical considerations, and design procedures for amplifiers of classes A, B, C, D, E, F, and S are covered thoroughly. Envelope elimination/restoration and other techniques for combining PAs to achieve greater efficiency and/or linearity are included. Nonlinear transistor models and simulation techniques for CAD are presented. The instructor, Dr. F.H. Raab, is coauthor of *Solid State Radio Engineering*. The course is usually conducted at an in-plant location. **Green Mountain Radio Research, Winooski, VT 05404. INFO/CARD #148.**

Stop, Look, Listen

Three new booklets designed to help buyers evaluate and compare low-cost analog and digital multimeters have been published. Titled "STOP Before You Buy Another DMM," "LOOK At the Leaders" and LISTEN To Why BBC is Your Best Choice," the three booklets points out many of the factors to consider when buying a multimeter. **BBC-Metrawatt/Goerz, Broomfield, CO 80020. INFO/CARD #147.**

Chip Capacitors

The *Chip Capacitor Selection Guide* is a 2-page, 4-color brochure describing multilayer ceramic capacitor chips. A center-

PIEZO's Little Wonder.

Superb performance in a plug-in compatible replacement for **HP 10544A/B/C or HP 10811A/B oscillators.**

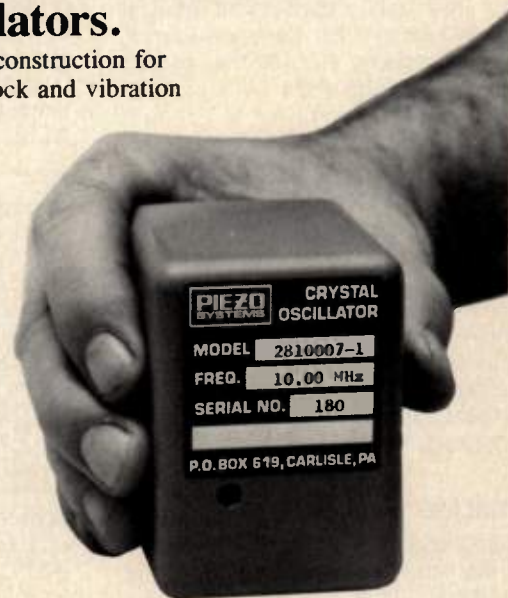
- | | | |
|--|--|--|
| <input type="checkbox"/> High short term stability | <input type="checkbox"/> Low power consumption | <input type="checkbox"/> Rugged construction for |
| <input type="checkbox"/> Low phase noise | <input type="checkbox"/> DRAT* SC cut crystal | extra shock and vibration |
| <input type="checkbox"/> Fast warm up | <input type="checkbox"/> Fast delivery | control |

PIEZO's new Model Number 2810007 Series oscillators are designed for equipment requiring a compact, rugged, precision frequency source. The DRAT (*doubly rotated AT) stress compensated (SC cut) crystal offers the advantages of a longer life and a lower operating cost. This makes the 2810007 an ideal, cost effective oscillator for precision time keeping, instruments, communication and navigation equipment.

The PIEZO standard of quality guarantees you this kind of performance:

- Aging rates: < 5 parts in 10^{10} /day
- Phase noise: Better than 160 dbc at 10 kHz offset
- Warm up: Within 5 parts in 10^9 of

- final frequency in 10 minutes
 - Time domain stability: Better than 5 parts in 10^{12} for a 1 second averaging time
 - Power consumption: Approximately 2 watts after warm up
 - Output frequency: 10 MHz or 10.23 MHz standard
- We offer fast delivery, with limited orders shipped directly from stock. PIEZO Systems is an affiliate of PIEZO Crystal Company, a leader in the production of piezo-electric crystals since 1936. For more information call your nearby PIEZO representative, or write to PIEZO SYSTEMS, P.O. Box 619, Carlisle, PA 17013. Telephone (717) 249-2151.



* Best aging available to date: parts in 10^{12} /day!

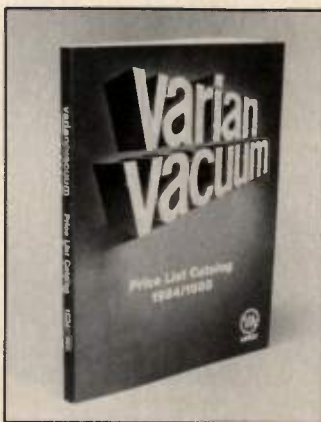


INFO/CARD 76

fold chart allows simplified selection of capacitance VS chip size for 3 different families of Class I and Class II type dielectric materials. It also contains descriptions of the dielectric characteristics for each family. **Johanson Dielectrics, Inc., Burbank, CA 91505. INFO/CARD #146.**



Johanson



Varian

Vacuum Products

The catalog includes the most current pricing information, technical information and dimension drawings for 15 vacuum product categories plus details of training courses and support services. Technical notes for nine of the product lines provide a reliable reference for applications, performance features, operation, and design. Also included is a reference section on general vacuum units and formulas. **Varian, Lexington, MA 02173. Please circle INFO/CARD #145.**

RFI/EMI Organic Coating Effectiveness

A Product Bulletin corresponding to the chemical and physical building blocks of RFI/EMI Conductive Coatings; titled "Particle-Size Compaction." It deals with the conductive pigment types used, particle size achieved, structure and shape of particle, degree of loading and dispersion methods that vary the degree of effectiveness of an applied RFI/EMI organic shielding coatings. **Advanced Coatings & Chemicals, Temple City, CA 91780. Please circle INFO/CARD #143.**

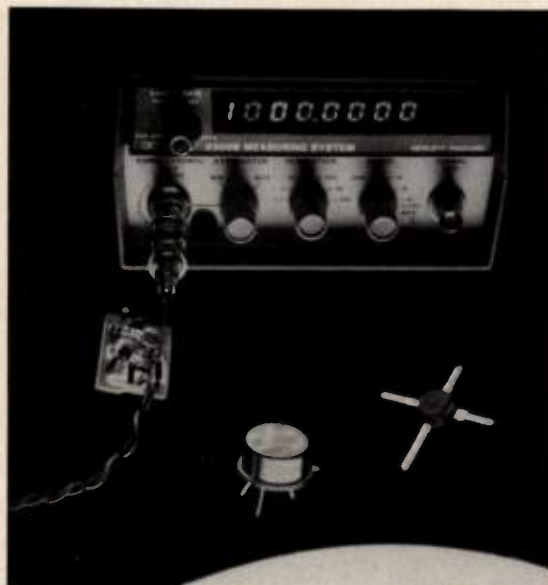
UHF/VHF Ground to Air Radios

This new four-color brochure describes GCA-1000 Series Ground to Air Radios for use in Military ATC Systems, Ground Control Approach systems and air Defense Tactical Communications Systems. Offering 1440 VHF channels in 116 MHz to 151.975 MHz in 25 KHz increments and 7000 useable UHF channels, 225 MHz to 399.975 MHz; coverage is enhanced by permanent memory capacity for 20 channels. Packaged in 19" rack-mount chassis the Series components, depending on mission requirements can be used together, coupled to a single antenna, as a transceiver; or separately. Receiver sensitivity is 10 dB (s+n)/n at 3uV, 30% modulation. Transmitter output power is 25 W (VHF AM carrier) and 20 W (UHF AM carrier). **Aydin Vector Division, Newtown, PA 18940. INFO/CARD #142.**

Ultrasonics and MR Instrumentation

A new catalog that describes a variety of instruments and accessories for performing conducting pulsed ultrasonics and magnetic resonance studies is being offered. The 6-page Short-Form Catalog of Ultrasonics and Magnetic Resonance Instruments describes a module RF gated amplifier system; broadband gated amplifiers and receivers; a modular pulse modulator

1 Transistor 1 Quartz Resonator 1 GHz



For many UHF oscillator applications, nothing can beat the simplicity of the quartz surface acoustic wave resonator.

This fundamental-mode UHF resonator is now being mass produced with resonant frequencies from below 300 MHz to over 1000 MHz.

Surface acoustic wave resonators are used in rf applications from precision instrumentation to high-volume consumer electronics.

For more information on the characteristics and applications of the quartz SAW resonator please contact:



RF Monolithic, Inc.
4441 Sigma Road
Dallas, Texas 75234
(214) 233-2903
TWX: 910-860-5474

A52U UHF RF SWEEP AMPLIFIER



Similar in appearance to the A62 RF Sweep Amplifier pictured, the A52U RF Sweep Amplifier has a frequency range of 1-900 MHz. Flatness is ± 5 dB. Gain is 30 dB nominal. Input VSWR is 1.5:1 max with typical VSWR of 1.2:1. Available in 50 or 75 ohm impedance, the unit is an excellent general purpose lab amplifier amplifying signals for receivers, frequency counters, spectrum analyzers, oscilloscopes, markers and detectors. It is rugged enough for mobile applications. Line filtering and double shielding prevent ambient and power line interference.

Wide Band Engineering Co., Inc.

P.O. Box 21652 1838 East University Dr. Phoenix, AZ 85036 Ph. (602) 254-1570

INFO/CARD 78

EMI PROBLEMS?

Let Eagle Magnetic Control
The Hostile Environment



EAGLE MAGNETIC CO., INC.

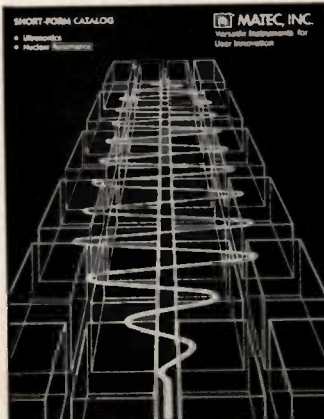
Magnetic Shields (CRT-XTM-PM) Sheet & Foil
317-297-1030

P.O. Box 24283 Indianapolis, Ind. 46224

INFO/CARD 79

rf literature *Continued*

and a receiver with RF pulsed oscillator plug-ins and a variety of other instruments and accessories. **Matec Instruments, Inc.**, Warwick, RI 02886. INFO/CARD #141.



Matec



Polarad

Vector Analyzer

This 16-page brochure describes the Model ZPV Vector Analyzer with 3 new modular plug-in tuners. Frequency coverage is 10 Hz to 2 GHz; previous models provided coverage from .1 MHz to 2 GHz. The Vector Analyzer ZPV implements a completely new, elegant technique for the measurement of complex quantities. The basic unit consists of a dual-channel vector voltmeter measuring according to magnitude and phase and microprocessor-controlled analyzer section, weighting, normalizing and converting the measured voltage vectors into the desired complex quantity. **Polarad Electronics, Inc.**, Lake Success, NY 11042. INFO/CARD #140.

Coils and Inductive Components

This colorful 28-page 8½" x 11" catalog lists primary operational and physical parameters of a wide array of molded, shielded or unshielded coils as well as variable RF coils with inductive values from .022μH to 150,000μH. Also included is a line of toroidal inductors ranging from .10 to 10.0μH. A wide variety of Micro-i (R) miniature inductors with values from .010μH in low profile design for use on thick film H-bond packages are described. High current filter chokes for applications up to 15 amps and other power chokes with inductance values from 1.0 to 15,000 μH are also listed. **Delevan Division, American Precision Industries**, East Aurora, NY 14052-0130. INFO/CARD #139.

Solid State Relays

A new two-page bulletin, "Solid State Relays, Series F-DC Output," is available describing the new Series F Relays which are available SPST (NO) or SPST (NC). The illustrated bulletin has schematic, mechanical arrangement, and inductive load suppression diagrams, as well as charts showing load current versus temperature for both modes. **Douglas Randall, Division of Kid-dee, Inc.**, Pawcatuck, CT 02891-0506. INFO/CARD #138.

Capabilities Brochure

A 16-page full-color brochure describing the capabilities of Varian EIMAC Salt Lake is now available from the company. The division specializes in the design and manufacture of power grid tubes and switch tubes used in communications, broadcast, and defense, and its special-purpose, X-ray generating tubes for medical diagnostics applications. **Varian EIMAC**, Salt Lake City, UT 84104. INFO/CARD #144.

February 1985



LOCAL INTERVIEWS JAN. 22, 23, 24

Systems Research Laboratories, Inc., located in one of the lowest cost-of-living areas of the country, is a 30-year-old R&D company. We're a growing company, and because of our continued expansion we have these professional career opportunities available:

Principal R&M Engineer — Lead the corporate R&M efforts. 5-8 years working knowledge of MIL-SPECS 217, 756, 790, 470 & 472. History of successful R&M program development and implementation is a must.

Managers of Systems Engineering — 10 or more years of experience in logic design, digital systems design and digital signal processing. Current experience in Radar, Avionics, EW, ELINT/SIGINT.

Sr. Electrical Engineers — 5 years diverse experience in such areas as computer interfacing, software, circuit design, electro-optics, displays and video circuitry.

Digital Design Engineers — 3 or more years experience designing digital signal processors, digitally controlled receivers, radar video scan converters, real-time graphic log or digital design.

Scientific Programmers and Scientific Systems Analysts — Multiple opportunities available for individuals with experience in scientific real-time environment. Includes math modeling, simulation and analysis on minicomputers and microprocessors.

Analog/Video Engineers — Experience designing complex systems, flight training simulators, electro-optic systems and high resolution display systems.

Human Factors Research Engineers — Many challenging areas.

Systems Engineer — Multiple opportunities available in developing programs for real-time flight simulation. BS with strong background in math, computer graphics, and RSX/UNIX operating systems, and 3 years experience.

Program Managers/Project Engineers — 2 or more years current management experience at the program or project level. Requires experience in sophisticated electronic systems (displays and/or simulators) with a previous background in a display systems.

Manufacturing Engineers — 3 or more years current experience in the manufacture of sophisticated electronic systems.

Mechanical Engineers — 2 or more years current experience in fluid dynamics, and/or spray diagnostics. MS or Ph.D. required.

Microscopist — Ph.D. and 2 or more years experience. STEM, ETEC probe and SEM.

Avionics Design Engineer — Design interface circuits and wiring for various systems installations on aircraft. BSEE with 3 or more years experience with A/C MODS preferred.

Investigate a high technology career position with us. We offer competitive salaries based on experience, comprehensive benefits, advancement opportunities, and a working atmosphere that encourages personal responsibility in a high technology environment. To schedule a local interview during the RF Technology Expo, phone A.J. Davis at the Anaheim Marriott, Jan. 22, 23, 24, at (714) 750-8000.

E.O.E./M.F.V.H.



SYSTEMS RESEARCH LABORATORIES, INC.
2800 INDIAN RIPPLE RD, DAYTON, OHIO 45440-3696 • (513)426-6000

NATIONAL JOB REGISTRY
RF Design Engineers. Send resume or call for Resume Kit. Fees paid.

T. Murray, P.O. Box 19949 Dept. TM1
Houston, TX 77224 PH. (713) 496-6100



Scientific Placement, Inc.

PROFESSIONALS NEEDED

- Jr. and Sr. Microwave Design Engineers
- Jr. and Sr. RF Circuit Design Engineers

Send resume in confidence to:
Terry Ryder, Sr.

**International
Technical
Services**

**P.O. Box 56037
Phoenix, AZ 85079
602/246-6951**

CLASSIFIED ADVERTISING RATES

(priced by column inch; earned rates available)

ONE TIME RATE: \$110/in.

THREE TIME RATE: \$100/in.

SIX TIME RATE: \$90/in.

Confidential box numbers are available with any ad for \$20.00

Mail inquired to RF Design Magazine
6530 S. Yosemite, Englewood, CO 80111,
or Call Lisa Fontana at (303) 694-1522

We're Sytek, on the San Francisco peninsula . . . expanding our communications network . . . with more than 500 installation sites . . . and over 400 employees. We've accomplished unprecedented achievements in networking technology. We are the suppliers of broadband network communications capability to the IBM-PC family and are servicing an increasing number of Fortune 500 accounts, along with a growing number of small businesses and individual end users. Our network base is branching out . . . Now is your chance to "hook up" with Sytek.

RF Design Engineering Manager

You will have a direct link to Sytek's future as you direct a team of RF Engineers in their development of new integrated RF modems. You should have a thorough knowledge of digital modulation techniques and experience with the integration of RF to silicon. MSEE. A minimum of 5 years experience in RF development with 2 years in a management role.

Senior RF Design Engineers

Be responsible for design and development of LAN related products (modems/headends). You will be involved in engineering and introduction of products in production design, build and test prototypes as well as final products. You will also interface with other departments to write project documentation, product specs and proposals. BS/MSEE with a minimum of 5 years relevant experience in development and engineering RF or communication products and knowledge of RF design techniques, communication circuits for AM, PSK, FSK modulation.

RF Design Engineers

Be involved in the design and implementation of low cost, high volume RF/analog circuits for broadband modems to 500 MHz and RF modem prototype construction and debugging for broadband LANs related RF products. BS/MSEE, 2-3 years related experience with knowledge in RF modem technologies (AM, FM, PSK, modulation/demodulation). PLL and frequency synthesis a plus.

At Sytek, your rewards are exceptional — including an innovative compensation package coupled with industry competitive salaries. For immediate consideration, please send resume with salary history to Peggie Louie, Sytek, Inc., 1225 Charleston Rd., Mt. View, CA 94043, or call Peggie at 415/966-7369. We are an equal opportunity employer.

**Linking today . . .
with tomorrow.**



INFO/CARD 83



Tomorrow is taking shape at a company called TRW.

A four-day work week in the beautiful Rocky Mountains

TRW Electronic Products, Inc. is an industry leader in the manufacture of state-of-the-art military and aerospace communications equipment. Our excellent working conditions, superior benefits package and superb location all add up to make us one of the best in the West. Our current opportunities include:

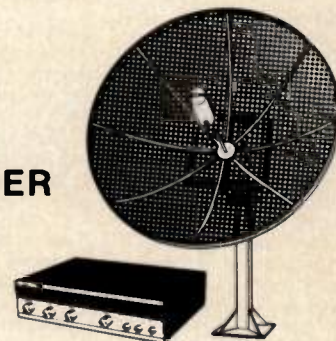
- RF/Digital Engineers
- Component Engineers
- Sr. Manufacturing Engineers
- Reliability Engineers
- Quality Engineers

Send your resume to: TRW Electronic Products, Inc., Employment Dept. KB 200, 3650 N. Nevada Ave., Colorado Springs, CO 80907.

Equal Opportunity Employer.
U.S. Citizenship Required.



RF ENGINEER Colorado



Manufacturer of RF products for TV broadcast, CATV and satellite TVRO needs EE's to design new products. Experience in RF/microwave circuit design required.

Based in Burlington, Iowa and recognized as an industry leader for 30 years, Winegard Company develops new products at its engineering and research division located in a scenic Colorado mountain community within commuting distance of Denver.

Our medium-sized, stable, independent company offers multiple benefits for its professional employees.

Phone or send resume to Jim Kluge, Winegard R&D Lab, P.O. Box 940, Evergreen, CO 80439.

(303) 674-5576

WINEGARD 

At our high technology facility in Rolling Meadows, IL, just northwest of Chicago, Northrop Engineers work on special projects involving the design and development of sophisticated ECM systems. If you have experience in any of the following areas, join the finest minds in engineering at Northrop Defense Systems Division.



The

ENGINEERING

Factor

Electrical Design/Development Engineers

Positions require BSEE or equivalent, and design and development experience in one of the following specialized areas:

POWER SUPPLIES: Develop high/low voltage linear/switching power systems and modulators; magnetics and feedback theory analysis.

MICROWAVE: Active/passive microwave integrated circuit design, familiarity with filter detectors, wave guides, high frequency solid state amplifiers and S-parameters.

RECEIVERS: Conceptual design, fabrication, and test of state-of-the-art receiver systems for ECM/Elint applications. Familiarity with system architecture, signal processing, and channelized, set-on, and micro-scan techniques is desirable.

ANALOG: Specialist in video amplifiers, filters, A/D and D/A conversion; background should include feedback theory analysis and computer-aided circuit analysis.

DIGITAL: Design/develop high speed signal processing and control systems, microprocessor-controlled hardware; D/A - A/D conversion; digital filters; direct memory access utilizing TTL, DTL, ECL, CMOS.

Antenna Design Engineers

BSEE or Physics or equivalent, MS desirable. Requires knowledge of phased arrays, monopulse, D.F. system and millimeter wave techniques.

Automatic Test Equipment Engineers

BSEE/BSCS or equivalent, and related AT hardware experience involving design of automated/semi-automated test equipment systems.

Hardware: Microprocessor/MSI, LSI, analog RF circuits.

Software: Real-time microprocessor control software programming in Assembly, Fortran, PASCAL

Positions available for Engineering Section Manager, Engineering Unit Manager and Project Engineers.

Project Engineer

BSEE, or equivalent; experience in one of the following areas:

- High efficiency broad band solid state power amplifiers having precision linear characteristics. Strong documentation skills required.
- Military receiver HW design for precision phase track receivers to DOA requiring ultra-precision internal phase/amplitude alignment.

TWT Project Design Engineers

BSEE or Physics or equivalent; advanced degree a plus. Will develop TWT design, fabrication, testing procedures with product line design responsibility.

For immediate consideration, call our 24-hour toll free number: 1-800-821-7700
Or send resume with salary requirements to: Supervisor, Staffing.

NORTHROP

Defense Systems Division

600 Hicks Road,
Rolling Meadows, IL 60008

Equal Opportunity Employer M/F/V/H.
U.S. Citizenship Required.

PUT A NEW MARKETING REP ON YOUR TEAM!

USE REPRINTS FROM *RF DESIGN* MAGAZINE



For a cost-efficient way to reach your customers — and potential customers — reprints are the way to go.

WHY REPRINTS?

- Advance consumer & industry awareness
- Focus attention to your products & services
- Explain what your company does
- Positions your company as an industry leader

Order your reprints now. Let a low-cost solution solve a high-cost problem.

For further information on how to order your reprints, call Lisa Fontana at (303) 694-1522.

Advertiser Index

Acrian, Inc.	4	Erbtec Engineering	40	Motorola Components	28
Adams-Russell — Anzac ..	33	Fischer Custom		Motorola Semiconductor	25
AD-Vance Magnetics, Inc. .	75	Communications	55	Piezo Crystal	88
Amperex Hicksville	13	John Fluke Mfg. Co	3	Polarad Electronics	18
Amplifier Research	82	Frequency Sources	50	Programmed Test Sources ..	58
Andersen Laboratories,		General Microwave	12	RF Monolithics	89
Inc.	15	Genisco	45	Racal-Dana	65
Applied Engineering	80	Glasteel	57	Repco-Telemetry	63
Austron, Inc.	76	Hewlett-Packard	49, 73	SRS Industries	52
Avantek, Inc.	35	Illinois Capacitors	83	Sage Laboratories	77
Bliley Electric	85	Instrument Specialties	23	Sawtek	31
Carborundum	14	Intech, Inc.	80	Seiko Instruments	66
CTS Knights	9	JFW Industries	7	Sigmotek International	84
California Eastern Labs, Inc.	17	Janel Laboratories	57	Signature Antenna System ..	79
Cir-Q-Tel	78	Johanson Mfg. Corp.	55	Sokol Crystal	6
Cirtech	48	Kay Elemetrics	30	Stettner	56
Coilcraft	20	Keene Ray Proof	59	Teledyne Microwave	86, 87
Compac	81	Log Tech	53	Telonic Berkeley, Inc.	51
Compact Software	43	M/A-Com MPD	95	Test & Measurement World ..	21
Curtis Industries	11	M/A-Com Land Mobile	77	Texscan	96
Daico Industries	34	Marconi	19	Vectron	69
Eagle Magnetic	90	Matrix Systems	10	Voltronics	67
EEsof	2	Merrimac Industries	74	Weinschel Engineering	72
Elcom Systems	79	Micrometals	78	Wide Band Engineering	90
Electro-Mechanics	60	Microwave Semiconductor ..	42	World Business Corp.	
Electronic Research	41			(WBC)	75

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

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

Space Satellite Amplifiers

- Class A linear or Class C
- Telemetry amplifiers
- "Space-Qualified" transmitters

Satellite Ground Stations

- GaAs FET power amplifiers, up to 20GHz
- 1 and 5 MHz distribution amplifiers, up to 26 outputs

Terrestrial Microwave

- Microwave LOS
- High power troposcatter
- Microwave and UHF radio relay

Avionics

- FAA and MIL TACAN transmitter systems – power amplifiers, modulators, power supplies
- L-band digital transmitters (JTIDS)
- Data link transmitters
- Airborne pulse amplifiers
- MLS power amplifiers

Broadcast

- UHF/VHF color TV transmitters
- Airborne TV visual/sound power amplifiers
- FCC type-accepted driver amplifiers

Missile Systems

- Command/destroy transmitters
- Guided weapon data link amplifiers
- Military drone transmitters

Radar Amplifiers

- L-band transmitters
- S-band pulse drivers for 3-D radar
- Shipboard drivers for AN/SPS-48 radars

Electronic Warfare

- Communication jammers
- Linear AB wideband jammers
- Jamming simulators
- Expendable jammers

Military Communications

- Long pulse data links
- Communication command links
- UHF transceiver amplifiers/modulators
- MIL RF power boosters (ECCM)

Laboratory Instrumentation/Test

- Linear amplifiers
- RF/EMI test amplifiers
- Power meter calibration systems
- Commercial and MIL power supplies



M/A-COM MICROWAVE POWER DEVICES, INC.

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

INFO/CARD 80

ATTENUATORS



The Difference Isn't Always Obvious

At Texscan, we don't believe that you can judge an attenuator by its cover. The point is, all of them look pretty much the same. But, differences lie just below the surface.

Our customers have made it a habit to buy from Texscan because they know we're not just a surface company. Quality construction, reliable performance and customer service are just a few of the underlying reasons to buy Texscan attenuators. And selection is another good reason. Choose from a wide variety of Rotary, Programmable, Fixed, Continuously Variable and Microwave attenuators, all with a choice of connectors in 50 or 75 ohm.

Call Texscan Instruments today. We'll change the way you look at attenuators.

And with features like these:

ROTARY ATTENUATORS

.1, 1 and 10 dB steps
DC to 2 and 4 GHz
Miniature and STD sizes

PROGRAMMABLE ATTENUATORS

.1, 1 and 10 dB steps
DC-2GHz
5V, 12V and 26V control

FIXED PADS

1 to 60 dB
DC-2 GHz
Individual calibration

Texscan
INSTRUMENTS

Texscan Instruments
3169 North Shadeland Ave
Indianapolis, Indiana 46226
(317) 545-4196

INFO/CARD 81